Lighting, cooking, electrical appliances and incidental heat losses in the Home Energy Model: FHS assessment wrapper

A technical explanation of the assumptions

December 2023

Acknowledgements

This methodology has been developed for the Department for Energy Security & Net Zero by a consortium led by the Building Research Establishment (BRE), including AECOM, Sustenic, University of Strathclyde's Energy Systems Research Unit, Kiwa Ltd., Loughborough University Enterprises Limited, Chris Martin and John Tebbit.

Quality assurance has been undertaken by a consortium led by Etude, including Levitt Bernstein, Julie Godefroy Sustainability, and UCL.

Document reference: HEMFHS-TP-04

Document version: v1.0

Issue date: 13/12/23

Home Energy Model version: HEM v0.24

Home Energy Model: FHS assessment version: HEM: FHS v0.18

Contents

Background to the Home Energy Model: Future Homes Standard assessment

What is the Home Energy Model: Future Homes Standard assessment?

The Home Energy Model: Future Homes Standard assessment is a calculation methodology designed to assess compliance with the 2025 Future Homes Standard (FHS).It builds on the government's Home Energy Model, which will replace the government's Standard Assessment Procedure (SAP).

The Home Energy Model: FHS assessment is still under development and its first version will be implemented alongside the FHS in 2025. We are publishing information about the model while it is still at a formative stage to enable industry to participate in the ongoing development process.

Where can I find more information?

This document is part of a wider package of material relating to the Home Energy Model:

Home Energy Model: FHS assessment technical documentation (e.g. this document)

What: This document is one of a suite of technical documents, which go into further detail on the assumptions and the validation exercises that have been carried out. We intend to update and produce further technical documentation throughout the model development process.

Audience: The technical documentation will be of interest to those who want to understand the justifications and evidence base behind the assumptions used in the model.

The Home Energy Model: Future Homes Standard assessment consultation

What: The Home Energy Model: Future Homes Standard (FHS) assessment consultation seeks views on the proposed methodology for demonstrating compliance with the FHS.

Audience: The Home Energy Model: FHS assessment consultation will be of interest to those who want to understand the proposed standardised assumptions around occupancy, energy demand etc. to be used when assessing compliance with the FHS, as well as the methodology for the calculation of the proposed FHS compliance metrics.

The Home Energy Model reference code

What: The full Python source code for the Home Energy Model and the Home Energy Model: FHS assessment has been published as a Git repository. This code is identical to that sitting behind the consultation tool. We are currently considering whether the open-source code could serve as the legal approved methodology for demonstrating whether new homes comply with energy performance standards in the Building Regulations.

Audience: The reference code will be of interest to those who want to understand how the model has been implemented in code, and those wishing to fully clarify their understanding of the new methodology. It will also be of interest to any potential contributors to the Home Energy Model.

Related content

To see how the energy uses described in this document are interpreted by the Home Energy Model core, see HEM-TP-04 Space heating and cooling demand.[1]

To understand how this methodology has been implemented in computer code, please see:

src/wrappers/future_homes_standard/future_homes_standard.py

[1] Note that there is a slight difference of terminology: in the language of HEM-TP-04 Space heating and cooling demand, lighting and cooking, as well as the appliances, each generate an “appliance gains” profile.

Introduction

The Future Homes Standard Assessment wrapper specifies inputs and outputs for the Home Energy Model, for the use of the model in assessing whether a new home complies with the requirements of Part L of the Building Regulations. Among these specified inputs are standardised assumptions about demand for lighting, and energy consumption in cooking and other electrical appliances. A further assumption identifies two ways in which heat is lost from the living space, to evaporation and to inflowing cold water as it comes up to room temperature.

This paper sets out the assumptions and explains how they have been derived. What these factors have in common is that they each affect the energy balance of the dwelling but are only incidentally related to the building fabric or installed systems.

Lighting is one of the regulated uses of energy, which contribute to the regulated energy efficiency and emissions measures for the dwelling, output by the FHS Assessment wrapper. Energy for cooking and electricity for appliances are not regulated but they also provide thermal gains which affect the energy balance of the dwelling and therefore the demands made on the heating or cooling system. These demands can also be supplied by a solar PV system and will affect the proportion of PV electricity generation attributed to self-consumption.

Figure 1 illustrates the gains and losses from these various sources over the course of a day, also including metabolic gains from the occupants themselves as set out in technical paper HEMFHS-TP-01 FHS occupancy assumptions.

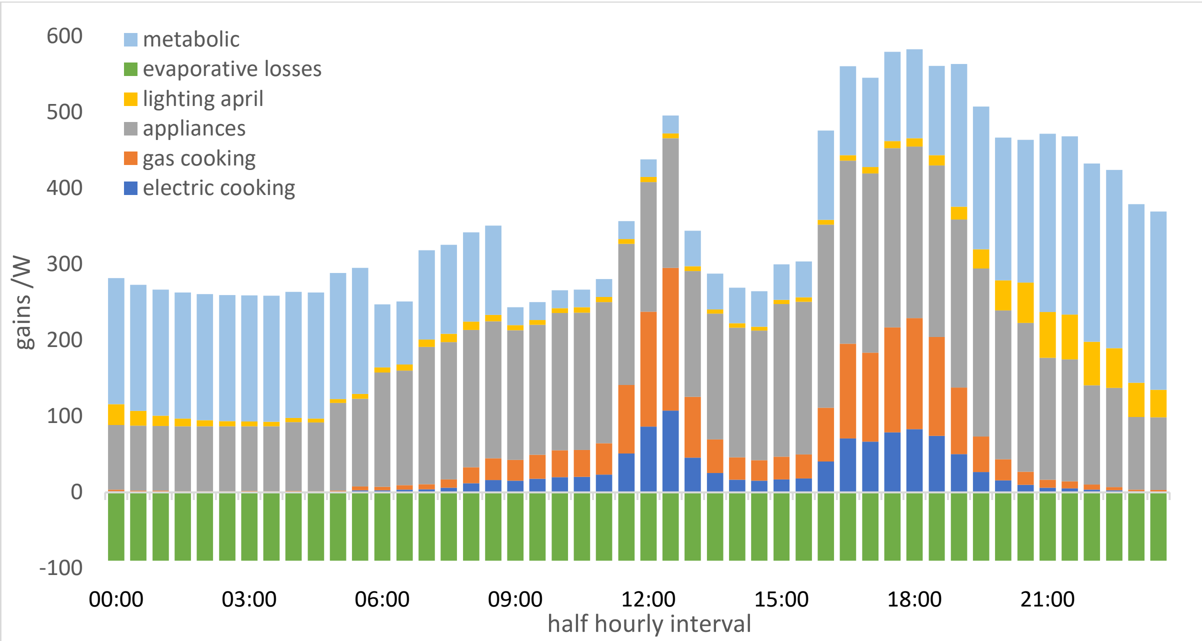

Figure 1 – Example gains produced by FHS assessment wrapper, for a small 2 bedroom household on a weekday in April.

Overview

For each energy use covered this paper presents:

- an estimate of typical consumption, derived from survey evidence;
- the *availability factor* (also *gains fraction)*, the estimated proportion of consumption which becomes a heat gain in the dwelling;
- a time profile for when the gains occur.

Heat loss to incoming cold water and evaporation is assumed to occur at a constant loss rate of 40W per occupant.

Evidence base

Evidence for the consumption of electricity in contemporary dwellings is drawn from case-level data in the Energy Follow Up Survey (EFUS) 2017[2], with data collected in 2017-19. This is assumed to show typical demand.

For allocating EFUS consumption between uses the principal data source is the Household Electricity Survey undertaken in 2011[3].

1. Lighting

1.1 Lighting demand

Evidence for average lighting demand is taken from the Household Electricity Survey, 2012, which reports electricity consumption by use type for 250 households. This survey antedates the general transition away from incandescent bulbs. We estimate the corresponding average demand for the dwellings in the EFUS survey, which have a modern lighting mix. We assume that building-to-building behavioural variation from the average lighting demand is correlated with overall variation in electricity use. Hence we estimate a best-fit curve characterising typical demand for light, in kilolumens per year, as a function of floor area and occupancy.

[2] Energy Follow Up Survey (EFUS) 2017 reports available at Powering_the_Nation_2_260614.pdf (publishing.service.gov.uk)
[3] There are two principal reports:
Powering the Nation 2 report, 2014 Powering_the_Nation_2_260614.pdf (publishing.service.gov.uk)
Zimmerman et al., Household Electricity Survey: A study of domestic electrical product usage, Intertek, May 2012. Powering_the_Nation_2_260614.pdf (publishing.service.gov.uk)

The detailed Household Electricity Survey report[4] shows (at figure 452) the average number of bulbs of each type in a dwelling in the HES survey stock. The EFUS survey records the number of light bulbs of each type for the majority of dwellings, of which 160 are in the reduced sample without electric space heating or domestic hot water. The efficacy of LED lights has improved since the Household Electricity Survey. For analysis of the two data sets we assume the respective efficacies shown in table 1.

SAP 10.2 (for HES analysis)		**EFUS analysis**	
Lamp type	**Efficacy (Lumens/Watt)**	**Lamp type**	**Efficacy (Lumens/Watt)**
Linear fluorescent	80.5	Linear fluorescent	80.5
LEDs, CFLs	66.9	CFL	66.9
Halogen LV	26.1	Halogen	20
Halogen lamps	15.7	LED	100
Incandescent	11.2	Incandescent	11.2

Table 1 – Lamp efficacies

The HES summary report *Powering The Nation 2* reports that lighting takes up 483kWh = 11.8% of all electricity consumption on average.

Using the efficacies assumed in SAP10.2 and the proportions from figure 452, we calculate an average efficacy for lights in the HES stock. From this and the reported average energy used for lighting we get an average demand for lighting measured in kilolumen-hours per year, as shown in Table 2:

	Average household
Lighting requirement kWh/yr	483
Efficacy lm/W	31.7
Lumens klmh/yr	15311

Table 2 – Household Electricity Survey average lighting demand

The arithmetic mean efficacy of lightbulbs in the filtered EFUS stock is 57.3 Lm/W.

In HES, average lighting requirement is 15,311 kLmh/yr. We assume this is also true of the EFUS survey stock. Dividing the energy for this across all bulbs in the stock we get 15,311 / 57.3 = 267kWh/yr of electricity consumed for lighting on average. This is 9.5% of the average electricity consumption across the filtered EFUS sample, which is 2835kWh/yr. We assume it is 9.5% of electricity consumption for every building, apart from what is used for heating.

Fitting a power-law relationship between (floor area × observed occupancy) and 9.5% of the electricity consumption of each dwelling in the filtered stock, converted into lumens at the dwelling's mean efficacy, we get the following relationship shown in figure 3:

[4] Zimmerman et al., Household Electricity Survey: A study of domestic electrical product usage, Intertek, May 2012. https://www.gov.uk/government/publications/household-electricity-survey--2

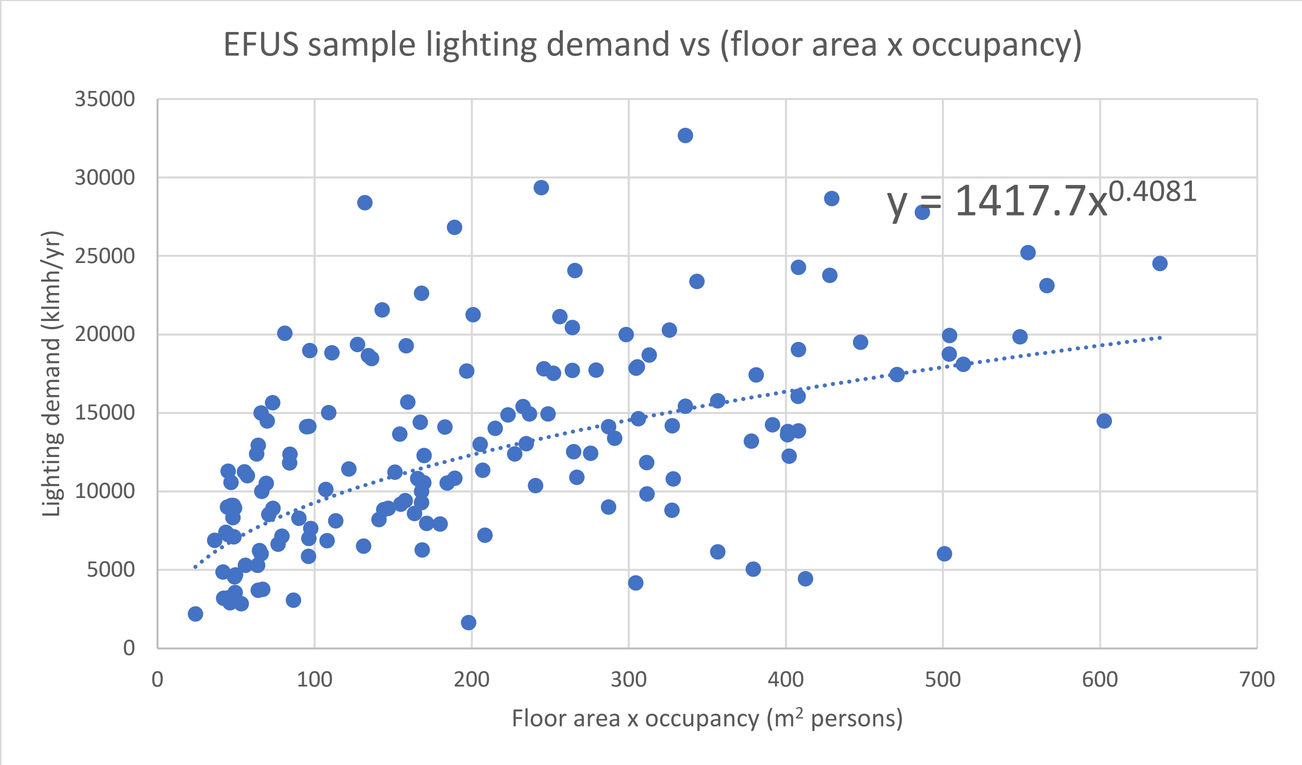

Figure 2 – Relationship between (floor area x occupants) and annual lumens from the EFUS 2017 dataset. Subsample of households without electric heating and electric DHW, and with lighting efficacy data.

This fitted curve is adopted, after numerical rounding, as the FHS standardised lighting demand. For a typical home this is about 5% less than the demand assumed in SAP10.2.

Let E be the average efficacy of lighting in the dwelling, measured in lumens per watt. Then:

$$\text{Demand} = 1418(A \times Occ)^{0.41} \ \text{klmh/yr},$$

$$\text{Consumption} = \frac{1418(A \times Occ)^{0.41}}{E} \ \text{kWh/yr}.$$

1.2 Lighting availability factor

The availability factor for lighting is 85%.

The availability factor is the proportion of the consumed energy which will result as thermal gains in the indoor space. For lighting, this excludes electricity for external lighting, which are assumed to be 15% of all lighting by energy consumed. This assumption is drawn from the SAP 2009 assumptions, where it is documented as derived from (unpublished) Lighting Association research data provided to BRE.

1.3 Lighting time-of-day profile

The evidence for when people light their homes is derived ultimately from survey data gathered by the UK Domestic Lighting Project,1996-7[5]. This is interpreted via an intermediate model by Stokes, M., Rylatt, M. & Lomas, K[6]. A different daily profile is supplied for each month of the year, and the total daily usage varies between months. As the overall demand for lighting in the Future Homes Standard wrapper is calculated separately above, proportional profiles were obtained by dividing the average energy consumption of Electricity Association homes for each half-hourly interval of the day by the annual average daily energy consumption. The rate of electricity use is calculated by multiplying the profiled value, in kWh per half-hour, to get a consumption value in watts.

The profiles are illustrated in the coloured table 3 and figure 3 below.

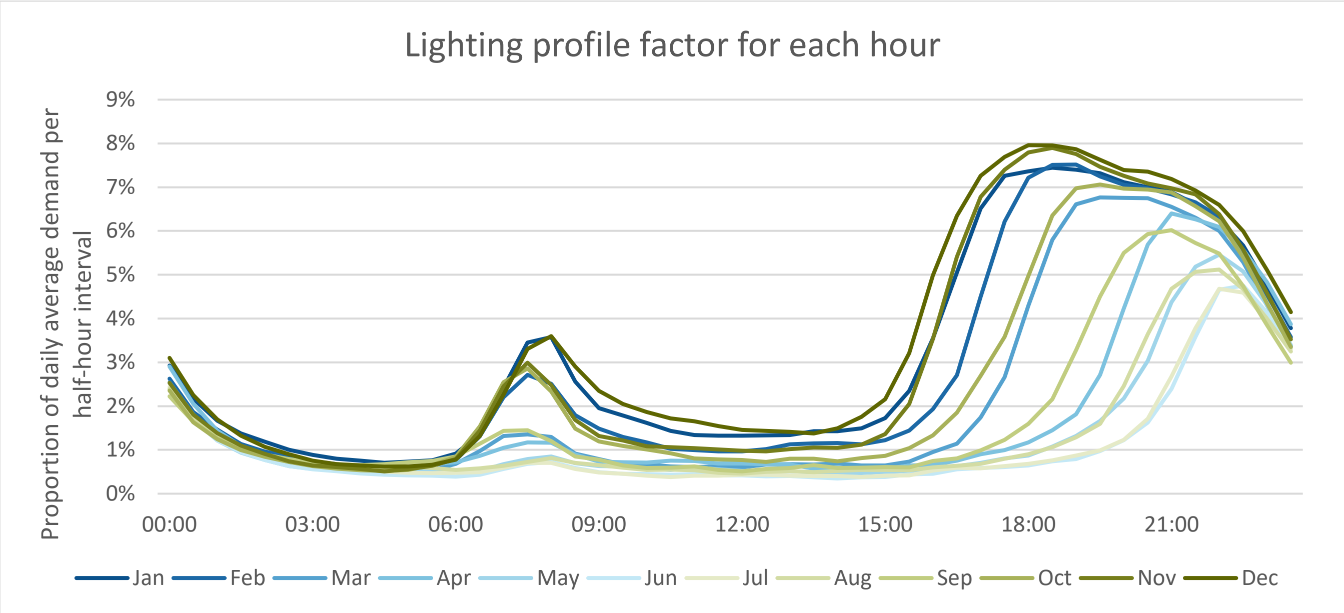

Figure 3 – Lighting profile factor by time of day and month

[5] UK Domestic Lighting Project Preliminary Analysis. Load Research Group, Electricity Association, 1996. Not available online.
[6] A simple model of domestic lighting demand, Stokes, M., Rylatt, M. & Lomas, K. (2004), available at https://www.academia.edu/15531665/A_simple_model_of_domestic_lighting_demand

Lighting demand by time of day and month, proportion of daily average demand per half-hour interval. (%)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00:00	2.92	2.63	2.54	2.90	2.38	2.40	2.44	2.39	2.22	2.36	2.53	3.10
00:30	2.17	1.86	1.82	2.06	1.69	1.69	1.80	1.69	1.64	1.63	1.81	2.25
01:00	1.67	1.46	1.28	1.44	1.22	1.23	1.34	1.29	1.27	1.24	1.38	1.70
01:30	1.37	1.13	0.96	1.08	0.93	0.95	1.05	1.02	1.06	1.00	1.10	1.33
02:00	1.19	0.96	0.79	0.86	0.77	0.77	0.86	0.88	0.89	0.84	0.91	1.07
02:30	1.00	0.86	0.68	0.73	0.63	0.63	0.75	0.77	0.79	0.72	0.74	0.90
03:00	0.88	0.74	0.61	0.68	0.56	0.56	0.66	0.66	0.71	0.63	0.64	0.76
03:30	0.80	0.67	0.55	0.64	0.57	0.51	0.62	0.60	0.68	0.57	0.61	0.67
04:00	0.75	0.61	0.51	0.60	0.55	0.46	0.57	0.60	0.65	0.54	0.56	0.65
04:30	0.71	0.58	0.49	0.57	0.52	0.44	0.51	0.59	0.68	0.52	0.51	0.62
05:00	0.73	0.58	0.48	0.58	0.51	0.42	0.47	0.62	0.72	0.54	0.56	0.62
05:30	0.76	0.64	0.54	0.67	0.54	0.41	0.47	0.59	0.75	0.65	0.64	0.66
06:00	0.92	0.77	0.68	0.72	0.50	0.39	0.48	0.54	0.85	0.84	0.79	0.78
06:30	1.36	1.31	0.97	0.86	0.52	0.43	0.49	0.58	1.14	1.53	1.44	1.31
07:00	2.42	2.20	1.31	1.05	0.68	0.57	0.60	0.64	1.43	2.55	2.45	2.26
07:30	3.45	2.71	1.36	1.17	0.79	0.68	0.70	0.73	1.45	2.86	2.99	3.31
08:00	3.58	2.51	1.29	1.16	0.85	0.73	0.71	0.81	1.20	2.34	2.48	3.60
08:30	2.56	1.79	0.92	0.89	0.70	0.59	0.57	0.70	0.85	1.49	1.69	2.90
09:00	1.95	1.49	0.79	0.73	0.63	0.49	0.48	0.65	0.78	1.19	1.31	2.35
09:30	1.79	1.29	0.67	0.72	0.62	0.45	0.45	0.59	0.64	1.09	1.22	2.05
10:00	1.61	1.17	0.67	0.71	0.58	0.45	0.41	0.54	0.59	1.01	1.09	1.87
10:30	1.43	1.02	0.62	0.75	0.54	0.43	0.38	0.55	0.59	0.93	1.06	1.72
11:00	1.34	0.99	0.61	0.74	0.60	0.45	0.41	0.53	0.62	0.80	1.04	1.65
11:30	1.32	0.97	0.63	0.69	0.56	0.42	0.41	0.48	0.54	0.79	1.01	1.54
12:00	1.33	0.97	0.60	0.69	0.52	0.42	0.44	0.46	0.51	0.77	0.98	1.46
12:30	1.33	1.02	0.67	0.67	0.52	0.39	0.43	0.50	0.57	0.72	0.97	1.43
13:00	1.34	1.13	0.67	0.67	0.52	0.40	0.41	0.52	0.59	0.80	1.01	1.41
13:30	1.43	1.15	0.67	0.57	0.49	0.38	0.40	0.49	0.65	0.80	1.05	1.37
14:00	1.43	1.16	0.69	0.59	0.48	0.35	0.40	0.52	0.59	0.74	1.04	1.49
14:30	1.49	1.13	0.64	0.53	0.47	0.37	0.38	0.54	0.60	0.81	1.12	1.75
15:00	1.73	1.22	0.64	0.57	0.50	0.38	0.41	0.54	0.61	0.86	1.36	2.16
15:30	2.35	1.44	0.74	0.65	0.52	0.44	0.42	0.53	0.60	1.04	2.05	3.21
16:00	3.55	1.93	0.95	0.66	0.57	0.46	0.53	0.60	0.75	1.33	3.53	4.99
16:30	5.06	2.71	1.14	0.75	0.63	0.56	0.60	0.64	0.80	1.85	5.41	6.35
17:00	6.51	4.50	1.74	0.90	0.70	0.59	0.58	0.68	0.99	2.69	6.78	7.26
17:30	7.26	6.21	2.66	1.00	0.80	0.61	0.63	0.79	1.23	3.59	7.40	7.69
18:00	7.36	7.22	4.30	1.17	0.87	0.64	0.68	0.90	1.59	4.97	7.79	7.96
18:30	7.45	7.51	5.80	1.45	1.07	0.74	0.76	1.06	2.16	6.36	7.90	7.95
19:00	7.40	7.52	6.61	1.82	1.32	0.79	0.87	1.29	3.28	6.97	7.75	7.87
19:30	7.32	7.24	6.77	2.71	1.66	0.97	0.99	1.60	4.50	7.06	7.46	7.62
20:00	7.12	7.06	6.76	4.22	2.17	1.22	1.23	2.46	5.50	6.97	7.26	7.39
20:30	7.00	6.98	6.75	5.69	3.04	1.63	1.71	3.64	5.93	6.94	7.09	7.36
21:00	6.89	6.84	6.55	6.40	4.37	2.39	2.68	4.68	6.02	6.88	6.97	7.19
21:30	6.61	6.66	6.30	6.27	5.19	3.59	3.78	5.07	5.73	6.56	6.84	6.92
22:00	6.27	6.32	6.00	6.09	5.46	4.66	4.68	5.12	5.49	6.22	6.38	6.59
22:30	5.66	5.56	5.28	5.58	5.07	4.75	4.59	4.67	4.74	5.40	5.57	6.00
23:00	4.75	4.55	4.31	4.83	4.31	4.14	3.95	4.00	3.85	4.35	4.59	5.11
23:30	3.78	3.57	3.37	3.87	3.39	3.32	3.31	3.25	2.99	3.35	3.52	4.15

Table 3 – Proportional consumption of lighting by time of day and month.

1.4 Lighting: future development

The method of average efficacy adopted here uses the arithmetic mean of efficacies for each light fitting in the sample, and each fitting in the modelled dwelling. Implicitly this assumes that each watt of input electricity is divided equally between fittings, so 2W divided between one fitting at 100lm/W and one at 12lm/W will produce 112lm. Arguably this is unrealistic, as an 8W LED fitting substitutes for a 60W bulb, and if they are hung in two rooms the division will be such that output lumens are divided equally between them. This would be modelled by applying a harmonic mean to the efficacies (or an arithmetic mean to the reciprocal of efficacy). This reinterpretation of the evidence would reduce the assumed efficacy in the HES sample and lead to a smaller estimated consumption of energy for lighting.

The assumption that the trend value for lighting demand is a constant proportion of all electricity consumption (other than that used for space and water heating), as floor area and occupancy vary, needs justification. Direct survey evidence of lighting demand in modern households (meaning in this case, since the widespread adoption of LED lighting) should be sought.

More recent evidence for the proportion of lighting used outdoors should be sought.

This methodology takes no account of lighting provided for free by sunlight. The reduced gains calculation in SAP, used when assessing the dwelling against the fabric energy efficiency standard (FEE), makes an allowance dependent on window area[7]. Consideration should be given to a similar adjustment in the FHS assessment wrapper. Times when there are appreciable solar gains into the space could be assumed not to require artificial light.

2. Cooking

The FHS assessment wrapper models three choices for the cooking fuel used for the hob and oven: electric, non-electric (for which the evidence is based on gas cooking) and “mixed” when one, but not both of hob and oven is non-electric. The presence of additional electric cooking devices like kettle, instant boiling water tap or microwave is not modelled, and their electricity consumption is aggregated into appliances (as treated in section 3 below).

2.1 Cooking demand

Evidence for cooking demand is taken from the EFUS 2017 survey and derived from the difference in electricity consumption between households using electric and non-electric cooking. Having estimated the typical consumption for electric cooking, we assume that building-to-building behavioural variation from the average cooking demand is correlated with overall variation in electricity use. In effect that means imputing a fixed proportion of electricity consumption, after space and water heating, to cooking.

We then model the standardised consumption for cooking as a linear function of occupancy (so that each additional household member, after the first, is assumed to need the same additional amount of fuel to cook for). Non-electric fuel can meet the same demand with a lower efficiency.

[7] Calculated in section L1 of Appendix L to SAP. There is a typographical error in all recent editions of the SAP document: in equation (L2b), the value of $C_{daylight}$ for $G_L > 0.095$ should be 0.66, not 0.96 as printed.

2.1.1 Electric cooking

The EFUS 2017 survey records the presence of ovens and hobs, and the type of fuel they use. Figure 4.11 of the Lights & Appliances report[8] plots the median excess electricity consumption over a typical day for a household with any electric cooking appliance over one without. Electric cooking is associated with higher consumption at all hours of the day, even outside cooking hours. The difference is approximately 566kWh/year, of which 175kWh/year can be attributed to a baseline (extrapolating from 1am-5am consumption) and 391kWh/year of cooking demand.

For the present analysis we compare a filtered sample of those (gas-heated) homes with both electric oven and hob to those with both a gas oven and hob, as in table 4.

	Mean total consumption, kWh/yr	Difference attributed to cooking, kWh/yr	Proportion of total consumption, %
Electric cooking	3360	430	12.8%
Gas cooking	2930	-	-

Mean across 47 electric- and 29 gas-cooking homes.

Table 4 – EFUS 2017 electricity consumption for cooking

The attributed typical consumption of 430kWh/yr and 12.8% of consumption compares well with 391kWh/yr attributed from the EFUS published analysis and with 10.9% and 448kWh reported in *Powering the Nation 2.*

To account for behavioural variation we assume that 12.8% is a typical proportion of the household's electricity consumption to use for cooking and fit the linear relationship shown in Figure 4.

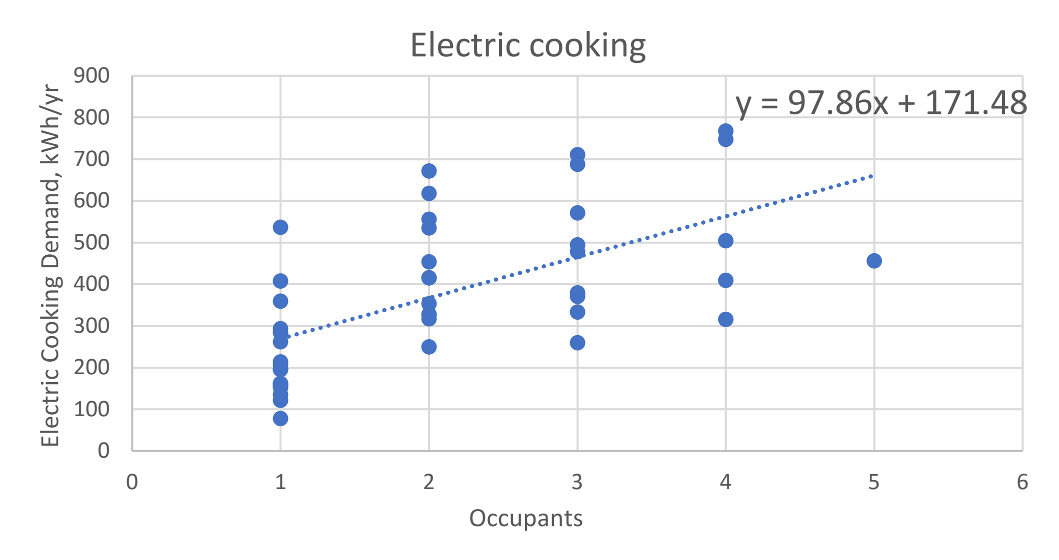

Figure 4 – Relationship between occupancy and electricity consumption attributed to cooking,

[8] *Lights, appliances and smart technologies Final report*, BEIS 2021. https://www.gov.uk/government/publications/energy-follow-up-survey-efus-2017-reports

2.1.2 Gas cooking

Gas cookers release more heat into the space than electric cooking does. In the absence of newer evidence we adopt the relative efficiency of gas and electric cooking from the BREDEM 2012 energy model[9]. For estimating gains it is assumed that cooking with gas uses 175% of the equivalent electrical consumption.

Again in the absence of more precise evidence we assume that half of all cooking energy demand is on the hob, and accordingly that homes with a gas hob and electric oven have a fuel consumption midway between purely electric and purely gas cooking.

$$\text{Consumption} = \begin{cases} 171 + 98 \times Occ & \text{kWh/yr,} \quad \text{electric cooking.} \\ 236 + 135 \times Occ & \text{kWh/yr,} \quad \text{mixed cooking, of which:} \\ & \begin{cases} 86 + 49 \times Occ \text{ kWh}/yr & \text{is electricity} \\ 150 + 86 \times Occ \text{ kWh/yr} & \text{is non-electric} \end{cases} \\ 299 + 171 \times Occ & \text{kWh/yr,} \quad \text{non-electric cooking.} \end{cases}$$

The fitted relationship is adopted as the FHS energy consumption for cooking, for the appropriate fuel mix. For a typical household of 2.37 occupants and electric cooking the assumed demand (403kWh/year) almost exactly matches the consumption assumed by SAP10.2 (405kWh/year).

2.2 Cooking availability factor

The availability factor of 0.5, for both electric and non-electric fuel is taken from the Passivhaus Planning Package model[10]. This has been preferred to the factor of 0.9 for electricity and 0.75 for gas assumed in BREDEM 1993 and models deriving from it.

The factor reflects energy removed from the space by tipping away boiling water, etc, and by occupants increasing ventilation in the cooking space to remove water vapour (from heating water and from the combustion of gas). No quantitative evidence was identified but the BREDEM factor is described as accounting only for purge ventilation and not for other factors[11].

[9] BREDEM 2012, A technical description of the BRE Domestic Energy Model version 1.1, BRE, 2015. https://www.bre.co.uk/filelibrary/bredem/BREDEM-2012-specification.pdf
[10] Passive House Institute, Passive House Planning Package (PHPP). https://passivehouse.com/04_phpp/04_phpp.htm
[11] STP 09/AUX 01 Review of auxiliary energy use and the internal gains assumptions in SAP, BRE 2009. https://www.bre.co.uk/filelibrary/SAP/2012/STP09-AUX01_Auxiliary_energy__use_and_internal__gains.pdf

2.3 Cooking time-of-day profile

The daily profile for cooking energy use is also derived from data provided from (unpublished) Electricity Association research[12] using half hourly electricity consumption for the period 01/04/1999 to 31/03/2000. This is applied to the average daily cooking demand to generate a daily profile. The same profile, shown in figure 5 and table 5, is used for each day of the year.

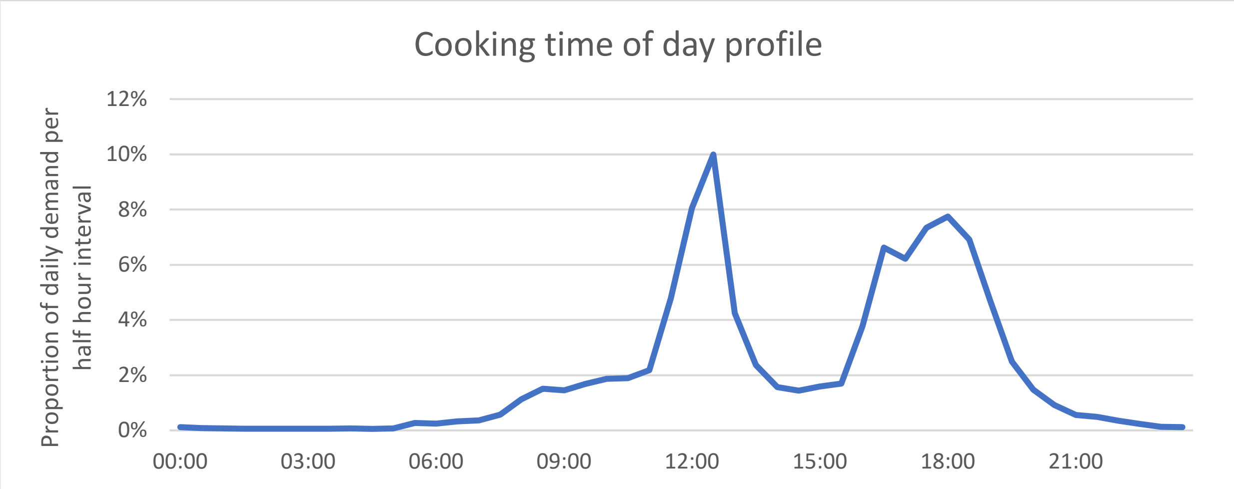

Figure 5 – Proportional energy use for cooking by time of day

Time-of-day factors for cooking, half-hourly proportion of daily total (%)

00:00	00:30	01:00	01:30	02:00	02:30	03:00	03:30	04:00	04:30	05:00	05:30
0.12	0.08	0.07	0.06	0.06	0.06	0.06	0.06	0.07	0.05	0.07	0.26
06:00	**06:30**	**07:00**	**07:30**	**08:00**	**08:30**	**09:00**	**09:30**	**10:00**	**10:30**	**11:00**	**11:30**
0.24	0.33	0.36	0.57	1.13	1.51	1.45	1.68	1.87	1.89	2.19	4.78
12:00	**12:30**	**13:00**	**13:30**	**14:00**	**14:30**	**15:00**	**15:30**	**16:00**	**16:30**	**17:00**	**17:30**
8.05	9.99	4.25	2.36	1.57	1.43	1.60	1.69	3.77	6.62	6.22	7.34
18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30
7.75	6.91	4.67	2.49	1.48	0.92	0.56	0.49	0.35	0.24	0.13	0.11

Table 5 – Proportional energy use for cooking by time of day

2.4 Cooking: future development

There is scope to make better use of the available data to give more assurance to the assumptions. The relation between occupancy and cooking demand is based on very few households. The assumption that the trend demand for cooking is a constant proportion of the total consumption of electricity (apart from what is used for space and water heating) needs justification.

[12] Held confidentially by BRE. Further work is intended to replace this assumption.

The assumed relative efficiency of gas and electric cooking needs better evidence which may be available from analysis of gas consumption data either in EFUS or the National Energy Efficiency Data Framework (NEED).

The time-of-day profile for cooking will be updated with data from the ONS study Time Use in the UK[13], reflecting contemporary time use patterns and separating weekday and weekend data.

3. Appliances

The Future Homes Standard wrapper includes all non-regulated electricity consumption under the category of “appliances”, with the exception of lighting and cooking. This definition includes all of what might ordinarily be thought of as household appliances (fridges, dishwashers, washing machines) as well as televisions and IT devices, irons and hairdryers. The EFUS survey identifies a list of the less usual energy intensive appliances found in their sample: aquariums, vivariums, greenhouse heaters, workshop machinery, hot tubs/jacuzzis, patio heaters, swimming pools, kilns, and saunas.

Most wet white goods now heat hot water internally rather than having a hot water feed, so energy use for hot water demand from appliances is also included in this category.

3.1 Appliance demand

To establish a typical value we model appliance use as the residual of EFUS electricity consumption in buildings without electric space or hot water heating, after subtracting:

(1) the modelled typical consumption for lighting (9.5%);
(2) the modelled typical consumption for cooking (10.8% for electric cooking, 5.4% for mixed fuels);
(3) 250kWh, to account for auxiliary electricity used by heating system fans, pumps and control systems.

The value of 250kWh for auxiliary consumption is approximately the median figure for condensing boilers found in an Energy Saving Trust study.[14]

[13] Time Use In The UK: March 2023, Office for National Statistics, https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/bulletins/timeuseintheuk/march2023

[14] In situ monitoring of efficiencies of condensing boilers and use of secondary heating, Energy Saving Trust 2009 (page 43) https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/180950/In-situ_monitoring_of_condensing_boilers_final_report.pdf

The EFUS sample of residual electricity use is skewed by some dwellings with a very high consumption. We assume these outliers represent homes with atypical appliances which are not present in the standardised household, and trim them from the data set. Removing 9 cases from the sample (of 190, initially) aligns the mean and median residual consumption of the remaining sample at 2020kWh/yr. The distribution is shown in figure 6.

Both the size of the household and of the home itself affect the residual electricity consumption. Fitting a power-law relationship to (occupancy x floor area) captures more of the variance in the sample than fitting to occupancy or floor area alone. (The non-linear fit to the product has R^2 = 36% as against 26% for occupancy or 25% for floor area). We do not attempt to model appliance use as a function of the two variables independently, to avoid over-fitting.

The fitted relationship is shown in Figure 7 and this is the demand for electric appliances assumed in the Future Homes Standard wrapper:

$$\text{Consumption} = 145.04(A \times Occ)^{0.4856}\ \text{kWh/yr.}$$

For most households this assumption is about 75% of the appliance demand assumed in SAP10.2.

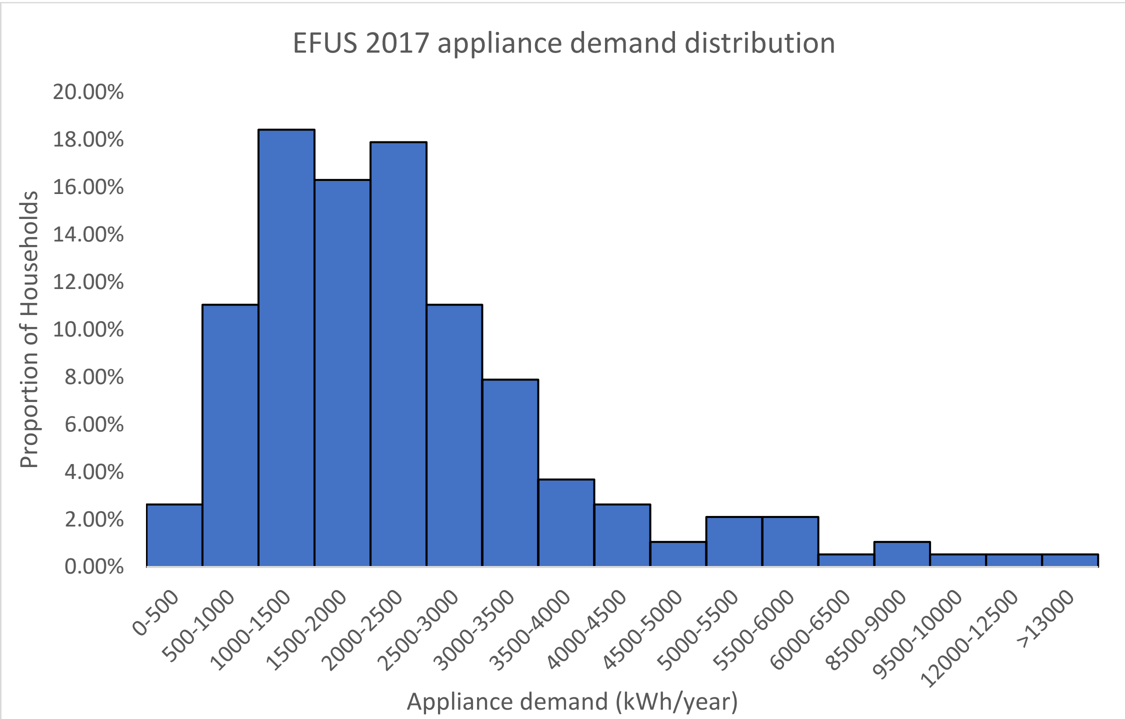

Figure 6 – EFUS 2017 Residual electric consumption distribution, households with no electric space or water heating

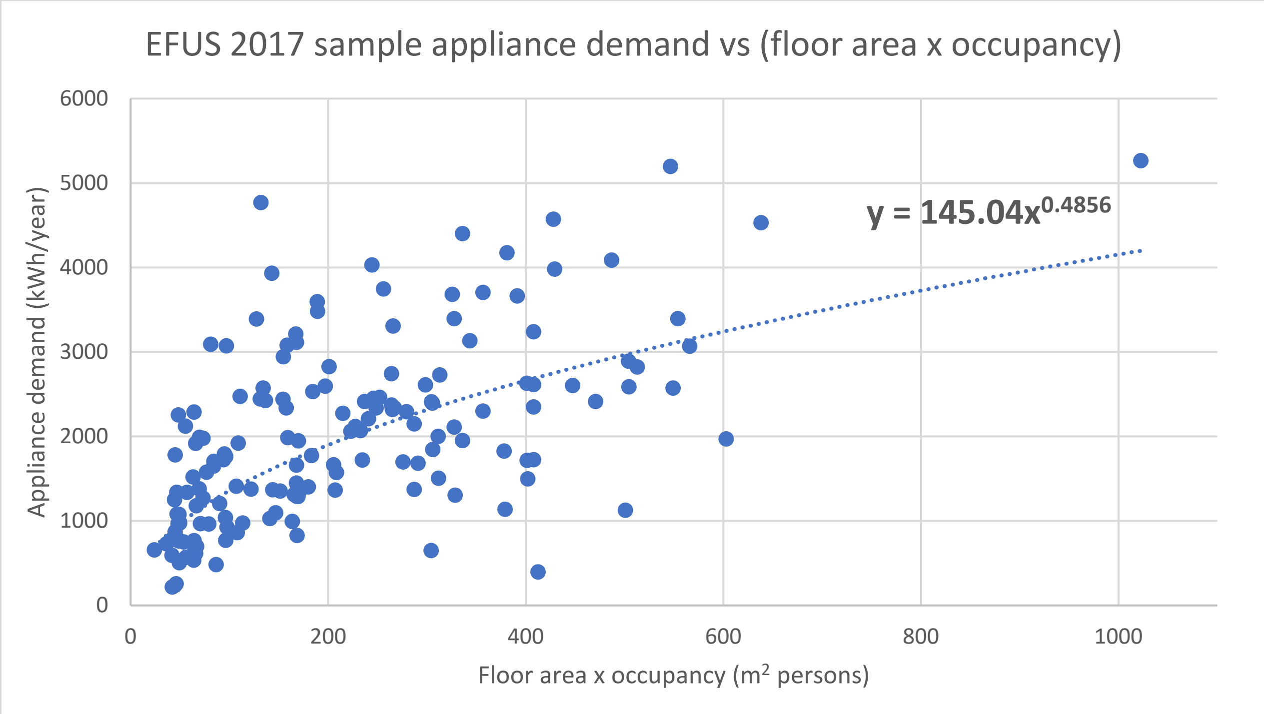

Figure 7 – Relationship between (floor area x occupants) and energy consumed by electrical appliances.

3.2 Appliance availability factor

The appliance availability factor is derived by weighting factors for various appliance types by the mix of consumption found in the Household Electricity Survey[15].

Washing and drying appliances in the home drain hot water and vent hot air out of the space. In the Passivhaus methodology they are assumed to have an average availability factor of 0.3, and other appliances are assigned an availability of 100%. For the Future Homes Standard modelling a further 10% reduction is proposed to allow for an unknown proportion of households in the survey with their cold appliances and washing / drying outside the thermal envelope (in unheated garages or basements). A 50% reduction applied to the “other” and “not known” categories which include exterior devices such as pond pumps and patio heaters[16]. These factors are not supported by substantial evidence, however.

[15] Zimmerman et al., as above, table 2 on page 28

[16] Note however that “other” appliances also include dehumidifiers which may have an availability factor exceeding 100%.

	Proportion of appliance consumption	Availability factor *Passivhaus*	Availability factor Proposed
Cold appliances	25%	*100%*	90%
Audiovisual	23%	*100%*	100%
ICT	10%	*100%*	100%
Washing/Drying	21%	*30%*	27%
Other	6%	*100%*	50%
Not known	15%	*100%*	50%
Total	100%	***85%***	**71%**

Table 6 – appliance availability factor from HES breakdown

Reflecting the uncertainty in this analysis the appliance availability factor in the FHS Assessment wrapper is the rounded value of 70%.

3.3 Appliance time-of-day profile

Appliances use hourly profiles based on EFUS 2017 appliance use data, as reported in the EFUS *Lights, appliances and smart technologies* figure 6.4. Metered consumption data was collated by month and time of day for all dwellings in the sample without electric heating, and the proportion of annual consumption for each hour was derived.

This contrasts with the method used for lighting and cooking, where the profile is based on older half-hourly data. Appliances make up 70-75% of consumption for the (no-electric-heating) subsample and the EFUS profile for all electricity consumption has been attributed to appliances, without attempting to adjust for the remaining 25-30%. The general shape of the profile, with a wide evening peak and a higher demand in winter months is consistent with the lighting time-of-day profile so adjusting for this would not make a substantial difference.

The profiles are illustrated in the coloured table 7 and figure 8 below.

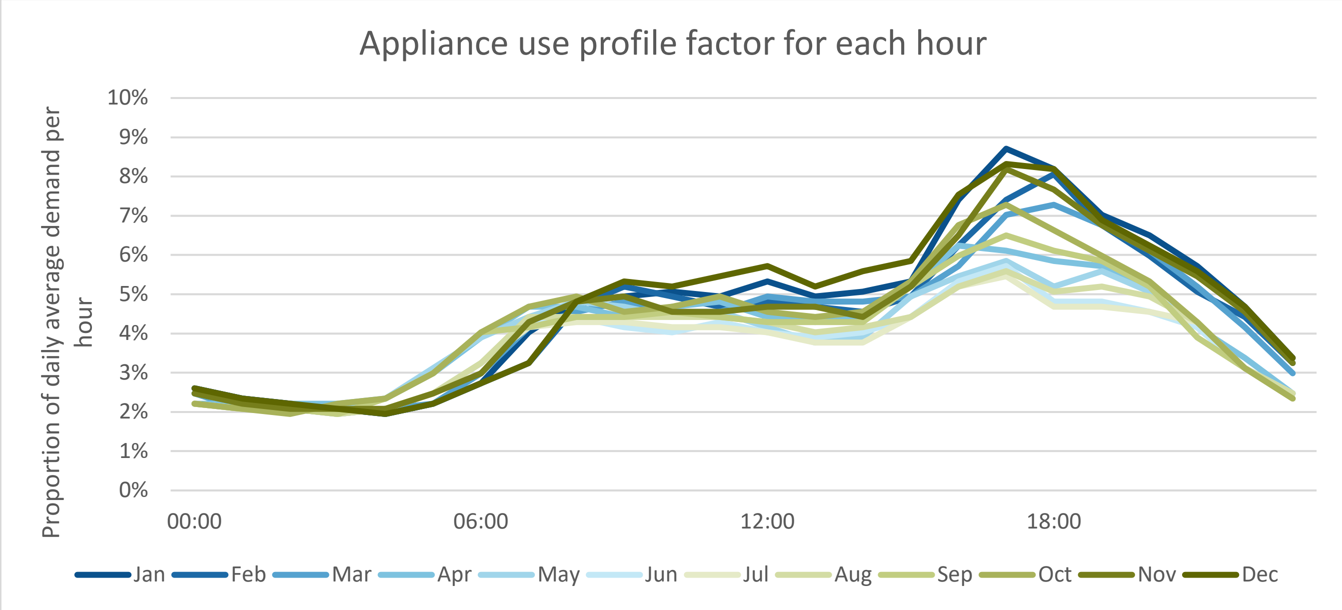

Figure 8 – Proportional electricity use for appliances by month and time of day

Time-of-day factors for appliances, proportion of average daily total per hour (%)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00:00	2.60	2.60	2.47	2.21	2.47	2.21	2.21	2.21	2.21	2.21	2.47	2.60
01:00	2.34	2.34	2.08	2.21	2.21	2.08	2.08	2.08	2.08	2.08	2.21	2.34
02:00	2.21	2.21	2.08	2.21	2.08	2.08	2.08	2.08	2.08	1.95	2.08	2.21
03:00	2.08	2.08	1.95	2.21	2.08	1.95	1.95	1.95	1.95	2.21	2.08	2.08
04:00	1.95	1.95	2.08	2.34	2.34	2.08	2.08	2.08	2.34	2.34	2.08	1.95
05:00	2.21	2.21	2.21	2.99	3.12	2.47	2.47	2.47	2.99	2.99	2.47	2.21
06:00	2.73	2.73	2.99	3.90	3.90	3.25	3.25	3.25	4.03	4.03	2.99	2.73
07:00	4.03	3.25	4.16	4.68	4.42	4.29	4.16	4.42	4.16	4.68	4.29	3.25
08:00	4.81	4.68	4.55	4.68	4.81	4.42	4.29	4.42	4.42	4.94	4.81	4.81
09:00	4.94	5.20	4.81	4.42	4.68	4.16	4.29	4.42	4.42	4.55	4.94	5.33
10:00	5.07	4.94	4.55	4.68	4.42	4.03	4.16	4.42	4.55	4.68	4.55	5.20
11:00	4.94	4.68	4.55	4.81	4.55	4.29	4.16	4.42	4.42	4.94	4.55	5.46
12:00	5.33	4.81	4.94	4.42	4.16	4.03	4.03	4.29	4.29	4.55	4.68	5.72
13:00	4.94	4.68	4.81	4.29	3.77	3.90	3.77	4.03	4.29	4.42	4.68	5.20
14:00	5.07	4.55	4.81	4.42	3.90	4.03	3.77	4.16	4.29	4.55	4.42	5.59
15:00	5.33	4.94	4.94	5.20	4.94	4.42	4.42	4.42	5.20	5.33	5.20	5.85
16:00	7.41	6.24	5.72	6.24	5.46	5.33	5.20	5.20	5.98	6.76	6.50	7.54
17:00	8.71	7.41	7.02	6.11	5.85	5.72	5.46	5.59	6.50	7.28	8.19	8.32
18:00	8.19	8.06	7.28	5.85	5.20	4.81	4.68	5.07	6.11	6.63	7.67	8.19
19:00	7.02	6.76	6.76	5.72	5.59	4.81	4.68	5.20	5.85	5.98	6.76	6.89
20:00	6.50	5.98	6.11	5.07	5.07	4.55	4.55	4.94	5.20	5.33	6.11	6.24
21:00	5.72	5.07	5.20	4.16	4.16	4.16	4.29	4.29	3.90	4.29	5.46	5.59
22:00	4.68	4.42	4.16	3.38	3.12	3.12	3.12	3.12	3.12	3.12	4.55	4.68
23:00	3.38	3.25	2.99	2.47	2.47	2.47	2.47	2.47	2.34	2.34	3.25	3.38

Table 7 – Proportional electricity use for appliances by month and time of day

3.4 Appliances: future development

The approach taken here for modelling appliance demand is top-down, in the sense of taking observed overall electricity consumption and attributing it at the time resolution of the monitoring data. This produces the smooth time-of-day curves in figure 8 above. This is acceptable for modelling space heating demand but a realistic demand schedule would be spiky, as individual appliances turn on and off. This has a significant impact on modelling self-consumption factors for solar PV generation. The PV may often not be able to supply the spikes in demand which are concealed by taking hourly averages.

We intend to replace the current approach with a bottom-up model similar to the approach taken for the hot water event schedule in HEMFHS-TP-03 FHS domestic hot water assumptions. This will also permit the model to take the energy efficiency of individual appliances into account. This analysis will use Household Electricity Survey raw data or smart meter evidence.

A principled view should be taken of which appliances are in scope for standardised consumption, and exceptional cases found in the data (vivariums, for example) should be filtered out.

4. Cold water and evaporative losses

4.1 Cold water and evaporative loss rate

Energy is lost from the space in the dwelling to incoming cold water and evaporation. The Home Energy Model takes the inflow temperature into account when supplying hot water to the dwelling and delivering it as mixed water to taps, showers and baths; but the model is not aware of cold water used on its own. Cold water used in the toilet cistern, for example, typically warms to room temperature before being flushed.

Sources of evaporation in the home typically include damp towels after bathing, laundry dried indoors, washing-up, hair-drying and respiration by house-plants.

The Home Energy Model does not simulate humidity within the dwelling. It treats the latent heat of evaporation as heat removed from the space, and ultimately vented. Evaporation during cooking is accounted for in the availability factor for cooking. Evaporation from occupants themselves is accounted for within metabolic gains.

There is little evidence about the likely total of these effects, a wide possible range of behavioural factors affecting them and some risk of double-counting with the appliance availability factor, as we do not treat wet and dry appliances separately.

The Future Homes Standard assumes a constant rate of cold water and evaporative loss of 40W per occupant. This is adopted from the SAP 10.2 assumptions and is equivalent to, roughly, warming 45 litres/person of cold water to room temperature together with 0.9 litres/person of evaporation. For comparison, version 9 of the Passivhaus Planning Package (PHPP 9) assumes an average background evaporative loss of 25W per occupant, with approximately a further 10W/person for indoor clothes drying when that is the technology used in the dwelling, and losses to incoming cold water between 17W/person in winter and 20W/person in summer[17].

4.2 Cold water and evaporative losses: future development

Consideration should be given to using a time-dependent profile, The rate of evaporation is likely to be driven both by occupant behaviour and temperature, and the difference between incoming cold water and room temperature varies seasonally.

[17] Passipedia, Internal heat gains in relation to living area (version as at 2022/04/26), https://passipedia.org/planning/calculating_energy_efficiency/phpp_-_the_passive_house_planning_package/internal_heat_gains_in_relation_to_living_area

This publication is available from: https://www.gov.uk/government/publications/home-energy-model-future-homes-standard-assessment-technical-documentation