University of Reading Energy and Environmental Engineering Research Group and Energy Demand Research Centre's joint response to DESNZ consultation on:

The Home Energy Model – Future Homes Standard assessment

About UoR E&EERG and EDRC

UoR E&EERG (the University of Reading Energy and Environmental Engineering Research Group) brings together a group of researchers based at the School of the Built Environment, which is internationally renowned for its research and education relating to the design, construction and operation of the buildings within which we live, work and play. Research interests across E&EERG encompass Building and urban environmental quality, Urban green infrastructure, Energy system behaviours as related to building-level energy demands, Power networks operation, Future energy technology portfolios, Demand-side management, and the Urban climate-energy environmental system nexus.

EDRC (the Energy Demand Research Centre) aims to inform and inspire energy demand reductions that support an affordable, comfortable and secure Net Zero society. Collaborating with partners across policy, industry, civil society and academia, EDRC will deliver a world-leading transformative and interdisciplinary research programme that identifies and shapes evidence-based energy demand solutions for a sustainable and more equitable future. The Energy Demand Research Centre is supported by the Engineering and Physical Sciences Research Council and the Economic and Social Research Council [grant number EP/Y010078/1].

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Background and General Comments

UoR E&EERG and EDRC welcome and support wholeheartedly DESNZ' initiative to develop enhanced frameworks for the energy rating of dwellings that are fit for the challenges associated with the Net Zero agenda.

The new Home Energy Model has the potential to become a very valuable resource for the assessment of energy performance across the UK housing stock, and one that is more in line with the decarbonisation ambitions for the residential sector.

Based on the consultation document, as well as the various technical annexes and consultation tool provided, it is evident that a lot of effort has already been put towards this initiative.

As with any model, however, there is always room for improvement, on the one hand, and a risk of pushing the scope further than what is useful or justified by the data underpinning such a model.

In what follows, we provide a series of observations as well as recommendations with a view to hopefully contribute to the improvement of what we think is being done well already, but also to raise a number of issues on what we think could lead to undesirable consequences.

Some of the views expressed in this response draw on recent work that aims to fill the gaps in the energy policy space around the quantification of energy demand flexibility at the building level. Given the substantial overlaps between buildings' energy performance assessment and the quantification of their demand flexibility potential, as well as the intention to use the Future Homes Standards framework to increase the number of homes that are 'flexibility ready' and 'new-technology ready', we believe you might find our report on Demand Flexibility Certificates interesting, if not useful.

We look forward to continuing to engage with you on any further consultations on the Home Energy Model, and its applications for assessing dwellings' compliance with the Future Homes Standards.

Questions

Ch 2: The Future Home Standard assessment: a wrapper for the Home Energy Model

Q1 - What are your views on the choice of inputs that have been standardised vs left open as user inputs (as in the consultation tool)?

From a general point of view, the balance between the inputs that have been standardised and those that have been left open would seem to be adequate.
However, when it comes to the approach to the standardisation of the selected inputs, namely the typical occupancy, and associated energy demands from Space heating and cooling, Domestic hot water, and other lighting, cooking and appliances, there is a risk of pushing the generalisation assumptions further than what is useful and appropriately informative for the purpose of accurately assessing a dwelling's compliance with the FHS.

For instance, in the case of occupancy assumptions, we acknowledge that a great improvement has been made by taking into account the number of bedrooms as opposed to bulk floor area figures when it comes to estimating the likely occupancy characteristics of said dwelling.
However, a case could be made against the use of deterministic 'occupancy curves' instead of alternative methods that take into account the probabilistic relationship between some of the variables considered (e.g. floor area and number of bedrooms) which would also yield much more sensible results, i.e. integer numbers of occupants as opposed to statements along the lines of "For one-bedroom dwellings the sigmoid curve is significant and standardised occupancy takes a value between 1.2 and 1.44".

On the topic of inputs required to assess dwellings' compliance with the FHS, it is worth noting that for the first time, home standards come with an expectation for homes to be 'flexibility ready' and more generally 'new-technology ready'.

Flexibility potential is closely linked with energy performance. However, SAP methodologies are unsuitable for assessing such flexibility potential.

In recognition of such a problem, we have proposed a Demand Flexibility Certification framework [1] which we believe could provide some useful inputs and metrics that could be integrated into the new Home Energy Model's assessment procedures.

For instance, standardized inputs could include demand flexibility metrics, such as Building Cool-Down Profile and Temperature Recovery Rate, capturing the Basal Flexibility component which is entirely dependent on the building fabric's energy performance.

[1] Ramirez-Mendiola et al. (2023) Demand Flexibility Certificates: Increasing the Visibility of Demand Flexibility through Certification, Energy Demand Research Centre, https://zenodo.org/doi/10.5281/zenodo.10640357

Q2 - What are your views on the ease of populating or sourcing data for those user inputs?

Setting aside any considerations around the challenges of a large-scale survey to collect the necessary input data, the data gathering itself on a per-dwelling basis is straightforward enough, and the inputs that have been left open can only be populated on a per-dwelling basis.

It is assumed that the set of open inputs listed in the consultation tool examples are merely intended for illustrative purposes and that perhaps a more comprehensive data gathering effort would take place in a 'real life' scenario. If this is not the case, however, the potential negative consequences should be carefully considered.

Further, given the tendency for assessors to make input errors in the use of the RdSAP-based data entry[2], it would be sensible for the model to feedback whether the values being entered fall within 2 standard deviations from mean values (or some other measure of accuracy), so that the assessor is aware of atypical inputs.

Ch 3: Occupancy and energy demand

Q3 - What are your views on the proposed standard occupancy assumption?

We wholeheartedly support the use of Time Use Survey data to inform the simulations of active home occupancy.

However, when it comes to 'converting' active home occupancy into overall demand for energy, or that associated with particular energy end-uses, especial care should be taken in order to mitigate the negative impacts of over-simplifying assumptions such as: "increasing occupancy levels raises the modelled demand for hot water, cooking, lighting, and electric appliances."

From an intuitive point of view, taking the Level of occupancy as indicator of the likely demand for energy (services) make sense. However, the evidence suggests that while this intuitive assumption does in fact hold in some cases, that is not always the case; see for instance Ramirez-Mendiola et al. (2017). As a practical example, in the case of cooking activities, whether a larger number of people living in a given dwelling results in higher demand for energy depends on whether the dwelling is occupied by a single-family unit, or a multi-family or other form of shared household, and not only the total number of occupants. A similar argument could be made for lighting, as well as most appliances, not to mention space heating or cooling demands.

In summary, occupancy and demand are far from following a linear relationship.

[2] A. Hardy, D. Glew, An analysis of errors in the Energy Performance certificate database, Energy Policy, Volume 129, 2019, Pages 1168-1178, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2019.03.022

Q4 - What are your views on the assumptions for metabolic gains?

Metabolic gains are indeed an important consideration to make when it comes to the simulation of energy demand.
The use of the referenced ISO standards to inform the simulations appears to be adequate.

However, as with the assumptions around the relationship between occupancy and demand for energy, care should be taken in order to avoid any potential negative impacts of over-simplifying assumptions.

Q5 - Do you think the FHS assessment wrapper should keep two thermal zones for all dwellings?

As the consultation briefing document itself puts it, “in practice, in UK homes there is often not a specific setpoint temperature in non-living rooms with supply of heat to other rooms being determined by the living room thermostat”. Therefore, on this basis, there appears to be no real justification for applying this ‘two thermal zones’ assumption to *all* dwellings.

Out of the three alternatives being considered, the most preferrable one would be to keep the two zones model but add the so-called ‘inter-zone heat transfer’ component, and only apply this *selectively*. That is, only use the differed thermal zones model when differed temperature control regimes actually exist, or where the size of the dwelling is such that the use of a single temperature control unit leads to the emergence of ‘thermal zones’ within the dwelling by virtue of the natural thermal imbalances bound to be found, which the ‘inter-zone heat transfer’ component intends to address. In any case, the number of cases in which this level of complexity would be justified is likely to be minimal, therefore rendering this alternative as overkill, and leaving the ‘single zone’ alternative as the most generic.

Q6 - If the FHS assessment wrapper keeps two thermal zones, do you think we should introduce inter-zone heat transfer?

The potential trade-offs of adding this ‘inter-zone heat transfer’ component should be carefully considered, as this is likely to greatly increase the complexity of the simulations.

In practice, the advantages to doing this are likely to be marginal for the intended use of this model.

Moreover, as the evidence would appear to indicate, the cases in which a two-thermal zone version of the model would be required are rather limited relative to the most commonly found scenario in ‘real-life’ UK homes.

Q7 - What are your views on heating setpoints for (a) one zone; (b) two zones without inter-zone heat transfer (i.e. the current assumptions given above); and (c) two zones with inter-zone heat transfer?

The justification for set-point of 21˚ C is weak. This has been based on capturing feedback of some interviewees in the EHS as not achieving desired temperature, yet it is not clear on the influence of building type, household or setpoint temperatures at which dissatisfaction occurs. Whilst 21˚ C might lead to more efficient design, it might also preclude sufficient designs with 'other advantages'. A 20 ˚ C setpoint would be adequate. Using the same logic of a degree difference in setpoint, we would, therefore go with 19˚ C in zone two. We do not think option (c) is necessary.

Q8 - What are your views on the assumptions for space heating hours?

In order to capture effects associated with system hysteresis, we would recommend shifting on/off times back one hour in all instances. For the non-living areas of zone-2 of the model, we would also suggest a reduced morning heating period by one hour (i.e., having period of heating to 21˚ C from 06:00-07:30). It is important to highlight that the assumptions of space heating hours seem to be based on a particular heating system and heat source technology. There is evidence to suggest that heating approach is informed by heating technology. For example, heat pumps would require different 'warm-up' periods than gas boilers. It would, therefore, be appropriate to introduce different profiles for different heat-source technology and heat delivery systems.

Q9 - What are your views on the ability to specify a control scheme (e.g. setback temperatures and "advanced start" periods) that works for the system being installed?

Considering that the internal thermal mass of the building is part of the model inputs, a setback temperature should not result in 'a shock' to the model temperature profile (i.e., should not create seesaw control) and, therefore, a setback temperature would be a reasonable modelling approach.

Q10 - What are your views on the treatment of the heating season vs non-heating season (months where the heating is assumed to be off regardless of the temperature)?

The fixed on/off assumption made as part of the SAP methodology is clearly too simplistic, and the new Home Energy Model would most certainly benefit from taking a more nuanced approach.

In particular, it is important that shoulder seasons are fully captured in the transitions between heating/cooling seasons.

A weather-dependent, as opposed to date-dependent simulation of heating/cooling demands is much more likely to represent the scenarios observed in real-life situations.

In addition, as we pointed out in our Flexibility Certificates report, a dwelling's flexibility potential will vary considerably depending on the season, primarily driven by the discrepancy between the use of systems like central heating/cooling throughout the year.

Q11 - What are your views on the proposed assumptions for the use of space cooling systems?

Setpoint temperatures seem reasonable. However, as with the heating profiles, we would shift these back by one hour to be more aligned with occupancy profiles derived from empirical activity data.

It should also be noted that, given the scarcity of data around energy demand and usage of cooling systems, the 'two-thermal zone' approach is likely to push any assumption derived from any existing data further than the data might be able to support.

Moreover, any assumptions around the cooling/heating systems' set points are bound to affect the dwelling's demand flexibility potential, as both the Basal flexibility and the Heating/Cooling flexibility dimensions are a function of the range between which temperatures are to be maintained to achieve adequate levels of thermal comfort. For a more detailed discussion, see here.

Q12 - What are your views on the assumptions for the volume of hot water demand?

An approach based on the explicit use of occupancy and household size for estimating demand for hot water is certainly more appropriate.

We would, however, caution on the influence cylinder size will have on demand. If sized incorrectly, this could lead to unaccounted wasted energy in the model. How water cylinders, in their role as heat storage devices, will also have an impact on a home's potential for engaging inflexibility service provision for demand-response programmes. It is therefore important to have a much clearer picture of the extent to which typical demand for hot water is likely to affect a dwelling's overall flexibility potential.

Q13 - What are your views on the pseudo-randomly generated hot water use schedule, including the algorithm generating it?

We disagree with a randomisation approach to this demand as the intention of the model is to offer consistency in performance evaluations. We would be in favour of fixed household profiles of domestic hot water demand to be more consistent with the approach applied to other demands.

Q14 - What are your views on the proposed hot water / mixed water temperature assumptions?

Hot water temperature delivered to the tap is too low considering the temperature of the water in the cylinder. We would expect this to be about 4 ˚C higher (i.e., from 52 ˚C to 56 ˚C). However, the temperature of the mixed water (41/42 ˚C) is reasonable.

Q15 - What are your views on the assumptions for water heating hours?

It is worth further consideration as to whether the approach to dealing with risk of legionella (modelled in HEM) is reflected in practice.

Q16 - What are your views on the cold water feed temperature assumptions?

Current assumptions seem appropriate, and the intention to further develop the model to account for regional differences is welcome.

Q17 - What are your views on the proposed assumptions for lighting demand, time of use, and thermal gains availability?

There are a number of considerations we would like to draw your attention to.
While the estimated increases in demand for lighting derived from the 2017 EFUS are recent enough to warrant their use over the short term, the use of 1990 survey data for estimating changes in time of use might not be appropriate. There is certainly scope for reusing datasets that are already being considered for the development of the new Home Energy Model, such as the time-use survey, which allow for the extraction of active occupancy profiles and provide a much more recent picture of the variation in time of use profiles.

While it is established in the consultation document that the assumptions around the availability factor for lighting is inherited from the SAP methodology, it is not clear whether there are any changes to the methodology for estimating the actual heat gains.
Moreover, it is also unclear whether and how technology changes are being addressed as part of these calculations. That is, whether penetration rates of different types of artificial lighting sources (e.g. fluorescent vs LED) are considered, etc.

Q18 - What are your views on the proposed assumptions for cooking energy demand, time of use, and thermal gains availability?

Again, when it comes to the estimation of the intra-day variability of energy demand associated with particular activities, be it cooking or otherwise, there is scope for updating these time-of-day profiles based on more recent data stemming from the series of time-use surveys that have been carried out in more recent years.
These data would also allow for taking the substantial differences in energy consumption behaviours between weekdays and weekends, which seems to be ignored in the proposed methodology.

It is mentioned that there is an intention to develop the same random approach for proposing the time of use for cooking as that for DHWS. We disagree with a randomisation approach to this demand as the intention of the model is to offer consistency in performance evaluations.

In terms of thermal gain reducing the availability factor to 50% underestimates the heat gain associated with the cooking process.

Q19 - What are your views on the assumptions for appliance energy demand, time of use, and thermal gains availability?

The assumption that appliance demand is dependent on occupancy is adequate, as substantial evidence backs this up[3,4,5]

[3] Yamaguchi, Y., Torriti, J. and Shimoda, Y. (2023) Modeling of occupant behavior considering spatial variation: geostatistical analysis and application based on American time use survey data. Energy and Buildings, 281. DOI: https://doi.org/10.1016/j.enbuild.2022.112754

[4] Kleinebrahm, M., Torriti, J., McKenna, R., Ardone, A. and Fichtner, W. (2021) Using neural networks to model long-term dependencies in occupancy behavior. Energy and Buildings, 240. 110879. ISSN 0378-7788. DOI: https://doi.org/10.1016/j.enbuild.2021.110879

[5] Anderson, B. and Torriti, J. (2018) Explaining shifts in UK electricity demand using time use data from 1974 to 2014. Energy Policy, 123. pp. 544-557. ISSN 0301-4215. DOI: https://doi.org/10.1016/j.enpol.2018.09.025

On the other hand, the assumption that appliance demand is dependent on floor area needs a much deeper level of scrutiny. SAP's approach to the standardisation of metrics is largely based on a 'per square meter' basis, which may apply to some dimensions of energy demand, but does not necessarily in most other cases.

In terms of the adjustment to the availability factor used to produce thermal gain estimates, it is not entirely clear whether this approach is preferable to, say, estimating overall thermal losses *after* all thermal gains have been factored into the simulation. We believe this is something worth considering.

Q20 - What are your views on the assumptions for cold water and evaporative losses?

While we acknowledge that there are indeed thermal losses associated with cold water ingress to the dwelling's thermal system, we are not convinced that the same could be said for the so-called 'evaporative losses'.

From the point of view of the HEM, the thermal system in question takes into account the total amount of heat in the dwelling. As long as any potential evaporation from towels, etc. remains in the dwelling, the total heat inside the dwelling remains unchanged.

Ch 4: Weather assumptions

Q21 - What are your views on the use of climate projections rather than historical averages for the weather assumptions within the model?

The intention to provide assessment using weather 'representative' over a building's lifetime would certainly give better insight into the development of heating and cooling demands of the building. However, large uncertainties would be carried in this approach when considering the scenario and time-period on which projections are chosen. It is also recognised, that such a full analysis is not being proposed here – simplifying to 'typical' representations of climate. Heating and cooling energy requirements are two competing issues at play with this choice, with historical and future projected climate averages holding different uncertainties for both. The addition of large uncertainties associated with climate projections seem unnecessary for the purposes of HEM simulations.

Moreover, using climate projections can raise the concern over ability of the weather data to represent the peak periods that are better reflected in the historic data.

Based on this, we would advise against this approach. Instead, we would advocate the use of climate zones over single UK representation.

Ch 5: FHS compliance metrics

Q22 - What are your views on the additional metrics produced by the FHS assessment wrapper (i.e. metrics produced in addition to the FHS compliance metrics)?

The list of additional outputs from the Home Energy Model listed in section 5.1.4 would be very informative for the purpose of assessing the buildings' energy performance.
More importantly, it would allow for the compilation of large-scale datasets at the local, regional and national levels, which could prove quite valuable for other applications.

However, as mentioned in answers to previous questions, the approach to the standardisation of these metrics based on total floor area might not be the most appropriate as it has the potential to introduce unintended biases into the data.

Q23 - What are your suggestions for additional metrics (i.e. metrics produced in addition to the FHS compliance metrics) not currently produced by the FHS assessment wrapper?

Given that the new Home Energy Model has the advantage of drawing on more time-resolved data for the estimation of demands for energy and thermal performance, it would only make sense to try and take advantage of this fact by considering metrics that assess these same factors as a function of time.

As of yet, the only metric considered that appears to make an allusion to the time-dependence of demand for energy is the Peak half-hour electricity draw.

In addition to this, the use of metrics that pay closer attention to the changes in energy demand and performance over time would unleash a number of opportunities to further explore the demand flexibility potential at the dwelling level.

Examples of the metrics that could be used include:

- Active-to-passive demand ratios – this refers to the differences between demand loads between periods of active occupancy (i.e. occupants are awake and making use of appliances) and passive occupancy (i.e. people are mostly resting or fully asleep).
- Heat loss curves – this refers to the quantification of the amount of heat that escapes the dwelling over a given period of time.
- Temperature restoration rates – this refers to the rate at which a given dwelling's temperature can be increased/decreased through active use of heating/cooling systems present within the dwelling.
- Heating/Cooling on-to-off hourly demand ratios – this refers to the difference between periods where heating/cooling systems are on or off, in terms of total hourly demand for energy.

Q24 - What are your views on the methodological approach to define the emission factors and primary energy factors used within the Home Energy Model: FHS assessment?

It is difficult to follow the methodology in the “Fuel factors within the Home Energy Model” document and the rationale behind the factors proposed in appendix A.

Electricity - Given that that a primary concern around previous versions of SAP has been the use of static electricity grid emissions factors, their continued use seems bound to create poor estimates of carbon impacts of electricity. Appreciating that the 2010s were a period of dramatic change in the grid, even still we can expect continued change over the 2025-2029 timeframe. Using a static emissions factor, especially amidst the expected electrification of heat and mobility, is likely to distort any estimates of carbon/environmental performance. Why not simply provide a list of emissions factor estimates for each year in the compliance period for the user to select from (or automatically populate this based on the date of submission).

Q25 - What are your views on the proposed emission and primary energy factors for electricity?

The proposed emission factor for electricity seems low. We propose the use of something such as a rolling weighted average for mains electricity using historic data and sufficient time-window to provide short-term stability.

The primary energy factor calculation method seems sensible, however the resultant value in the appendix (1.969) seems high, representing a low system efficiency of 43%. Given the increasing prevalence of renewables in the grid, this strikes as high. It does lead one to question whether renewables were considered in this estimate. Our crude estimate using the data provided in the appendix suggests 1.7 for 2022 (using a gas conversion efficiency of CCGT of 49%, per DUKES 5.10.C), however the values for 2025-29 would be lower still.

Further, the thermal conversion efficiency of nuclear fuel (36%) is dragging boosting the energy factor unnecessarily; the reason we would consider the conversion efficiency in the first place is that we might be able to use that energy more efficiently in some other application/process, but this is not practical for nuclear fuel.

Finally, the primary fuel factor used for imports is far too high; the UK imports predominantly from France, Norway, Belgium and the Netherlands, which would include high proportions of nuclear and renewables, suggesting that a value of 2.833 (exclusively thermal fossil) would be far too conservative. A more sensible, yet conservative, assumption would be in the range of the UK’s mix.

Q26 - What are your views on the penalisation of energy shortfall and the energy shortfall factors?

The penalisation of energy shortfall and the energy shortfall factors are not clearly outlined in the document. Further clarification on how this measure discourages under-sizing is needed. Better system sizing could be achieved by stipulating a requirement for the simulations to meet temperature set-points as a minimum, or to demonstrate that additional performance metrics such as thermal comfort are met in parallel. This assessment of sizing does raise a further question of appropriate weather representation.

Ch 6: Validating the assumptions used in the FHS assessment wrapper

Q27 - What are your views on the inter-model validation work that has been carried out (i.e. against SAP 10.2, PHPP and ESP-r)?

It is great to validate the model with other tools but considering the expected extent of use for this model, the results of this model should be assessed against real-world case studies. This is because other models used for inter-validation come with a broad range of assumptions.

Section 6.2 points out that some such validation exercises against real-world case studies have been carried out already. However, these studies need to be as comprehensive as possible, and cover a range of different building types, of different vintages, etc. in order to achieve a robust enough model validation.

Q28 - What are your views on the monitoring data case study validation work that has been carried out?

The presented results of this model against the real case studies are promising. But providing the details of assumptions used in the model would have been very informative to better understand the validation process. The detail of measurements needs to be given to provide confidence in this model assessment.

Q29 - What suggestions do you have for further validation exercises that could be undertaken to refine the Home Energy Model: FHS assessment?

Expand the real-world case studies efforts to carry out a more thorough assessments of the model's strengths and weaknesses. These studies need to be as comprehensive as possible, and cover a range of different building types, of different vintages, etc. in order to achieve a robust enough model validation.

Further, the outputs produced under the new Home Energy Model would no longer be consistent with the RdSAP data provided in the publicly-available EPC database. This database has been an invaluable resource for commercial, academic, and government applications. Finding a way to continue providing comparable/compatible outputs with the pre-HEM datasets (or providing some adjustment to existing data in the EPC database based on the new HEM) would be essential for the continuity/cohesion of the data pre-and post HEM.

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