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Guidance Note GN32

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# GN32: BREEAM New Construction Guidance Note - Energy Prediction and Post Occupancy Assessment

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## Introduction

The gap between predicted and actual energy performance of new buildings is acknowledged to be significant. Whilst some of the observed difference in performance between the modelled building design and actual building will arise from differences in the occupancy schedules and the installed equipment loads, there are other factors that are known to make a significant contribution to the energy performance gap. These include:

- Differences in the actual performance of building components, including degradation over time.
- Imperfect installation of building systems and control strategies.
- Imperfect commissioning and hand over.
- Poor management and maintenance practices.
- Lack of operational knowledge and conflicting human behaviours

However, there is a lack of detailed data that enables meaningful comparisons to be made between actual and predicted performance. The BREEAM energy prediction and post occupancy assessment methodology addresses this by requiring comparable assessment to be made at the design stage and post occupancy. At the design stage it requires more detailed modelling to be carried out to ensure that the assumptions made about occupancy schedules and equipment loads are carefully considered, and that the effect of the other factors listed above (referred to collectively as management factors) are also taken into consideration.

The aim of the BREEAM energy prediction and post occupancy assessment methodology is to encourage all those involved in the building design, construction, commissioning, facilities management and operation to take steps to close the energy performance gap by:

- Undertaking more comprehensive and accurate modelling of energy use at the design stage, including modelling alternative scenarios.
- Determining energy performance targets based on adequate modelling.
- Measuring actual energy performance on a comparable basis.
- Comparing predicted and actual energy performance at a disaggregated level to identify where the performance gaps lie.
- Identifying specific actions to reduce the gap.
- Providing a basis for continuous monitoring and improvement of energy performance.
- Facilitating a wider uptake of energy performance benchmarking.

Expected outcomes and benefits of implementing the methodology include:

- Improved energy performance of building.
- More realistic modelling through:
  - Better modellers.
  - Better models.
- Improved design decisions.
- Better commissioning.
- Better facilities management.
- Lower running costs.
- More productive occupants.

## 1 Background

The gap between predicted and actual energy performance of new buildings is acknowledged to be significant with recent studies[i,ii], showing that actual energy performance can be up to four times higher than that determined by compliance calculations carried out at the design stage. These studies show that part of the reason for the energy performance gap is that in the UK buildings are generally designed to show compliance with Building Regulations.

Calculations made solely for compliance purposes are subject to standardisations made to help with simplification and comparability and, as a consequence, tend to underestimate the equipment energy loads, often referred to as unregulated energy use, and do not take account of all equipment types for example, lifts and escalators. Under actual operating conditions the energy use will generally be considerably higher than indicated by energy modelling software that is used to show compliance. Also, a building that is designed to be efficient under standard operating conditions is unlike to be optimum where actual operating conditions are very different. Customised modelling can use more appropriate operating profiles and represent building systems with more accuracy than such modelling for compliance can. This should also incentivise better understanding of energy modelling techniques and reward more accurate predictions of energy use at early stages to support better design and construction of new buildings.

However, even where energy modelling takes into account actual occupancy patterns and equipment loads, a significant energy performance gap remains. This can be attributed to a range factors that include:

- Differences in the actual performance of building components, including degradation over time.
- Imperfect installation of building systems and control strategies.
- Imperfect commissioning and handover.
- Poor management and maintenance practices.
- Occupants lacking operational knowledge.

These are collectively referred to as management factors which are caused by either a lack of knowledge, in the case of component performance, or a lack understanding and poor communication between the design team and the construction and building management teams. In particular, design teams don't communicate the intended energy performance for the design from the earliest stages through to the detailed design and into the construction process and to the facilities management team. Feedback to the design team regarding what is, and what is not buildable and crucially about how the building actually performs in practice is also lacking. These problems are exacerbated by the fact that there are rarely any consequences for designers, contractors and suppliers when energy consumption exceeds predictions. Increased use of BIM from the design stage will enable component energy consumptions to be integrated from the design stage which has the potential to facilitate better transfer of information between those responsible for energy performance over the building lifecycle.

Although the reasons for the energy performance gap are understood, there is a lack of detailed data to enable the observed differences to be attributed to specific causes, and hence to effectively tackle the problem.

## 2 Energy Performance Assessment in BREEAM

Energy performance is an important aspect of all BREEAM schemes. BREEAM's energy strategy seeks to create greater alignment between the building level schemes with the ultimate aim of the energy strategy to ensure that the BREEAM energy assessment methodologies are as effective as they can be in driving down energy consumption and carbon emissions associated with the built environment.

BREEAM recognises performance that exceeds standard practice by awarding credits, where the number of credits reflects where the performance sits within the distribution of performance in the building stock. Whilst the definition of standard practice will differ across BREEAM schemes, the metrics that are used must provide a consistent and holistic assessment of the environmental impacts of energy use to enable comparisons to be made over the building lifecycle. Whilst both absolute and relative energy performance metrics are recognised, the main focus is on actual rather than calculated performance wherever possible. Improvements in energy performance over time should also be rewarded.

The BREEAM energy strategy also promotes the use of more frequent (e.g. monthly or real time) and more disaggregated (e.g. end use/building servicing system) measurements of energy performance both to facilitate the generation of more detailed performance benchmarks and to provide feedback on areas where energy performance is poor. The strategy also includes recognition of the positive impacts of building controls and the benefits of on-site and near site low and zero carbon energy sources and other demand side response capabilities such as energy storage. Ultimately BREEAM aims to provide a holistic framework for continuously assessing energy performance across all life stages of the building that also provides feedback to building managers that enables energy use and its environmental impacts to be minimised at each stage.

The BREEAM energy prediction and post occupancy assessment methodology has been devised in accordance with this energy strategy and extends the scope of the Ene 01 energy assessment within New Construction and bridges the gap to the BREEAM In-Use (BIU) assessment scheme generating initial BIU asset and operational energy performance ratings generated during the post occupancy assessment stage.

The energy performance prediction and subsequent post occupancy monitoring methodology described in this document relates specifically to BREEAM UK New Construction 2018. However, it is also intended that the energy performance methodology be extended to UK BREEAM Refurbishment and Fit Out and the corresponding international schemes the future. Integration with any future extension of BREEAM In-Use to incorporate more continuous energy monitoring is also envisaged as part of the broader aim of widening the scope of energy assessment within BREEAM across the whole building lifecycle.

## 3 Overview of BREEAM Energy Prediction and Post Occupancy Assessment Methodology

The broad aims of the BREEAM methodology is to incentivise more detailed energy modelling and reward more accurate predictions of energy use throughout the design process to support better design and construction of new buildings. It incorporates practical steps to promote comparable measurement of energy use both in design and operation, by ensuring that energy predictions and sub metering strategies are consistent. Thus enabling building operators to identify areas where measured energy consumption is higher than expected and to investigate and, where possible, resolve any discrepancy between predicted and actual consumption during the commissioning stage and beyond.

The setting of an overall energy performance target at the design stage and subsequent comparison against measured energy consumption is a key element of the methodology and aims to encourage the use of more realistic energy modelling assumptions. The requirement to publicly declare the target is designed to encourage scheme participants to set challenging, but achievable, targets. It also provides the freedom to align energy performance with whichever existing energy benchmark or energy ratings are most appropriate for a specific building. The post occupancy assessment is a key part of the process and involves collecting detailed energy consumption data for at least a year and comparing this to the predicted energy performance target adjusted to take account of the actual weather during the monitoring period. This stage requires a report to be submitted that compares the predicted and actual performance and identifies reasons for discrepancies between them.

Although achieving actual energy performance which is close to the target will not be a requirement under the current post occupancy assessment scheme, scores will be generated based on how closely the actual performance meets the target set and how stretching the performance target is. In future it is envisaged that minimum performance requirements will be set to achieve the target in order to obtain the post occupancy certificate, which will contain ratings based on performance scores.

The BREEAM methodology has been devised to be consistent with current industry standard methodologies, referring to existing guidance documents wherever possible. However, the approach also allows for some flexibility as is appropriate when using detailed simulation models. It is also compatible with existing energy reporting and energy targeting methodologies. In developing the BREEAM methodology we took into account the structure and experience of other schemes operating in this area, in particular the Better Buildings Partnership's Landlord Energy Rating[iii] scheme and the Australian NABERS[iv] energy rating scheme.

In order to make realistic predictions of energy, detailed assumptions about building servicing systems and likely occupancy patterns are required, therefore this methodology is not appropriate for shell only developments[1]. However, it can be applied shell and core developments where the project scope includes the provision of main building servicing systems to the whole building, including tenanted areas, and where common (shared) areas within the building are fully fitted out[2].

1 Shell only buildings in BREEAM are defined as those where the scope of the construction project covers new build work to the fabric and the sub and superstructure of the building only, including external walls, windows, doors (external), roof, core internal walls, structural floors.

2 This aligns with the definition of the "base building" in the Landlord Energy Rating scheme

## 4 Implementing the Energy Prediction and Post Occupancy Assessment Methodology in BREEAM

This section describes how the various elements of the methodology fit within the existing BREEAM UK New Construction scheme and the new Post Occupancy assessment scheme.

The energy performance and post occupancy methodology begins in the early design stage through to the start of the in use phase. The elements which relate to the design stage and post construction stages are incorporated within BREEAM UK New Construction 2018, whilst additional requirements that extend beyond to the commissioning[3] and in use stages are recognised under a separate BREEAM post occupancy assessment scheme. This is summarised in Figure1.

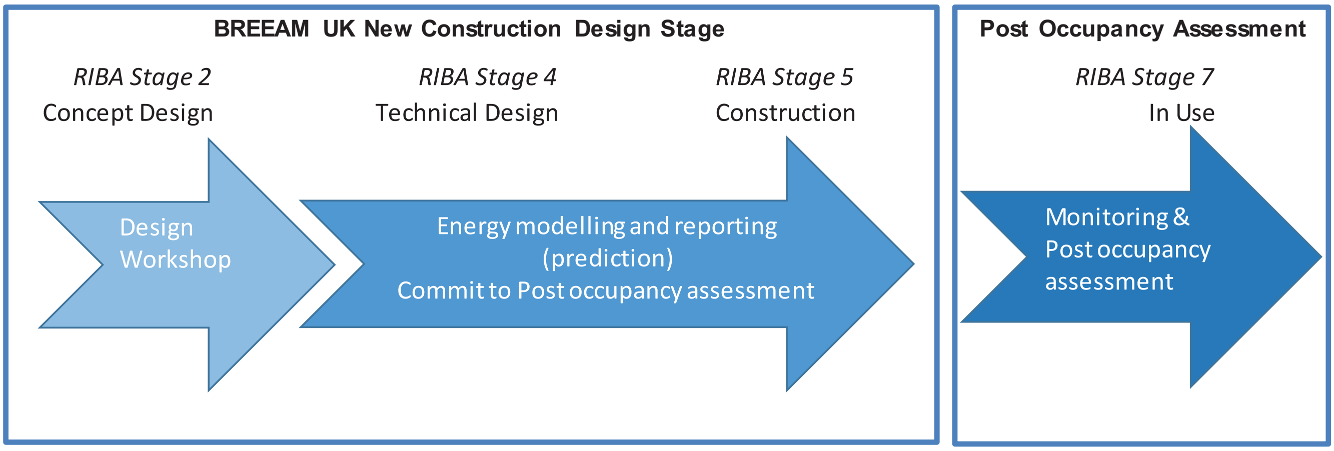


**Figure 1: Illustrating how the methodology is implemented by assessment scheme and RIBA stage**

The prediction element of the methodology and commitment to the post occupancy stage assessment are included within the "Reduction of energy use and carbon emissions" issue (Ene01) within the Energy category of BREEAM UK New Construction 2018.

### 4.1 Energy modelling and reporting criteria (4 credits).

A pre-requisite for these credits is for the design team to hold a preliminary design workshop focusing on design for operational energy performance at the concept design stage. Advanced energy modelling, including scenario modelling, must then be undertaken during the detailed design stage which informs detailed predictions of operational energy consumption and the setting and public reporting of an overall energy consumption target.

The energy consumption predictions must generate disaggregated energy consumption predictions broken down by fuel type, building servicing systems/end categories, areas with different functionality and separately tenanted areas. In order to reflect seasonal variations, energy consumption estimates must be monthly and distinguish between occupied and unoccupied periods, e.g. weekdays and weekends and holidays.

The modelling must be updated at the post construction stage to account for any changes to the building specification, and the consumption target revised accordingly.

A risk assessment must also be carried out at the detailed design stage to highlight any significant design, technical, and process risks that should be monitored and managed throughout the construction and commissioning process. It is recommended that an independent design review is conducted to inform this risk assessment.

3 The post occupancy stage commissioning requirements extend beyond the commissioning and handover requirements of Man04, commissioning and handover within the UK New Construction scheme.

### 4.2 Committing to the post occupancy stage within BREEAM New Construction (2 credits).

A pre requisite for these credits is that the energy metering strategy must be sufficiently detailed to allow comparison between predicted and actual consumption at a disaggregated level. This requires a metering strategy that is in accordance with CIBSE TM39 Building Energy Metering. This requirement would be met by achieving 2 credits under Ene 02 Energy monitoring, or for building types that are only eligible for one credit, the additional requirement for sub metering high energy loads and tenancy areas would need to be met.

This is to assist with commissioning by enabling systems and areas where energy performance is below expectation to be identified and rectified.

To demonstrate commitment to undertake the post occupancy stage, the client, or building occupier, must commit to funds to pay for the assessment and to report on the actual energy consumption compared with the targets set in the criterion.

The energy modelling (comprising the model, input assumptions and outputs) carried out for the prediction stage must be submitted to BRE and also provided to the building owner to ensure that this can be achieved. This is to ensure that the energy predictions and overall energy target can be adjusted to take account of actual weather conditions during the monitoring period.

A more detailed description of various aspects of the methodology are provided in Section 6.

### 4.3 Separate post occupancy stage certification scheme.

This must be carried out over a one year period which must commence within two years of the first occupants entering the building, or when the building reaches 80% occupancy, whichever is sooner. This is to allow adequate time for commissioning to be carried out aided by comparing the disaggregated modelled energy consumption to monitoring data and will enable building managers and operators to identify areas where measured energy consumption is higher than expected and to investigate and, where possible, resolve any discrepancy between predicted and actual consumption during the commissioning stage and beyond.

The requirements for this post occupancy stage are to collect and analyse metered energy data at a disaggregated level to compare predicted and actual performance. A minimum of 12 months monitored data is required in order to assess at this stage. To enable meaningful comparison to be made the modelling results must to be adjusted to take account of actual weather conditions. The outputs from the adjusted central case model shall be compared to the disaggregated metered data

A report must be submitted to BRE which includes the adjusted modelling results and actual metered consumption and identifies any reasons for deviation from predicted energy usage.

However, to encourage buildings to be designed for performance rather than compliance and to provide valuable feedback to help to develop the industry skillset in predicting operational energy use, a provisional scoring system will reward the setting of challenging design performance targets. In future, the post occupancy assessment scheme may also set minimum standards and differentiate performance achievements for these areas.

A provisional performance score will be generated that reflects how stretching the energy performance target is, how close the actual energy performance is compared to the (adjusted) target and achieving good energy performance in practice.

A more detailed description of various aspects of the methodology are provided in Section 6.

## 5 Types of Assessment and Scope of Calculations

The energy prediction and post occupancy methodology can be applied to all building types and sizes. It is appropriate for assessments carried out on fully fitted buildings, where the development includes the building envelope, buildings services and includes internal layout and fixtures and fittings. It can also be applied to shell and core developments where the project scope includes the provision of main building servicing systems to the whole building, including tenanted areas, and where common (shared) areas within the building are fully fitted out. Thus the assessment can be align with the definition of the "base building" in the Landlord Energy Rating scheme[iii].

However, the methodology is not applicable to shell only[4] developments where buildings services are not included within the scope of the assessment because it is not possible to make realistic predictions of energy detailed assumptions about buildings servicing systems and likely occupancy patterns are not available. For shell and core projects the scope of energy consumption should, as a minimum, cover all energy use in common areas plus energy use for all centralised mechanical and electrical plant including heating cooling and ventilation in other areas. If the energy use related to a service cannot be separately identified by metering, it is assumed to be part of the 'core' services.

## 6 Detailed Methodology

### 6.1 Preliminary design workshop focusing on operational energy performance

Prior to completion of the concept design stage (RIBA stage 2), relevant members of the design team hold a preliminary design workshop focusing on operational energy performance.

The workshop should establish the levels of risk pertaining to the operational energy performance of the building. It should consider how the energy performance of the building will be affected by future weather patterns, changes of use and variations in the expected usage of the building and consider the resilience of building systems.

The outcomes of the workshop should be used to inform improvements to the design of the building and to the operational, maintenance and handover strategies. The energy performance risk assessment should inform the scenarios that are to be modelled.

### 6.2 Building energy models

The energy modelling should be carried out using a dynamic simulation model with advanced capabilities for HVAC system and controls. Table 8.1 of CIBSE AM 11 Building Performance Modelling[v] provides a non-exclusive list of computer programmes with extended plant and controls modelling capabilities that would be suitable which is reproduced in Appendix A.

Suggested minimum requirements for the energy model are an ability to:

- Calculate 8,760 hours of building operation to simulate annual energy use.
- Model hourly variations in occupancy, lighting power, miscellaneous equipment power. thermostat set points, and HVAC system operation.
- Model thermal mass effects, part load performance curves for mechanical equipment, capacity and efficiency correction curves for mechanical heating and cooling equipment and air side economisers with integrated control.
- Be able to take account of lighting controls linked to lighting levels from daylight.

However, it is up to the energy modeller to select software tools that are most appropriate for a specific project.

The energy modelling will need to be undertaken by a suitably qualified energy modeller (as defined in the UK New Construction 2018 technical manual) who is responsible for logging the specific assumptions made and all the information provided by the design team and using this create a robust energy model for the building as it is predicted to perform in reality.

The model must be able take into account both regulated and unregulated energy consumption and generate scenarios around central prediction to explore how the building will perform under different operating conditions.

4 Shell only buildings in BREEAM are defined as those where the scope of the construction project covers new build work to the fabric and the sub and superstructure of the building only, including external walls, windows, doors (external), roof, core internal walls, structural floors.

The output required from the model is annual energy consumption in terms of delivered energy on a gross calorific value basis which, as a minimum, must be broken down by:

- Fuel/energy source.
- Building servicing systems and end use groups.
- Functional area and/or separately tenanted and common areas.
- Month.
- Occupancy status e.g., standard working day or weekend/holiday.

The modeller must ensure that the calculated energy consumption data maps directly onto the metered data to allow comparison to be made between predicted and monitored performance at the most detailed level possible.

### 6.2.1 Calculating unregulated energy demand for building systems or processes

Energy consumption by unregulated energy uses must be calculated to provide a comprehensive picture of energy consumption and to better inform the internal heat gains within the building. Unregulated energy use is calculated from the installed equipment loads and hours use. Therefore, the intended usage patterns for different functional areas, the expected equipment densities and usage factors must be determined together with the identification of any special or process equipment.

The principles described in CIBSE TM54: 2013[vi] form the basis for calculating unregulated energy use for each functional area and/or separately tenanted area. However, instead of generating annual consumption for each end use category, the energy consumption must be calculated on an hourly basis.

In accordance with CIBSE TM54[vi] operating hours and occupancy factors and equipment loads should be determined by carrying out structured interviews with intended occupants which take the following into consideration:

- Operating hours - As well as determining core working hours, the likelihood of extending working hours, weekend and holiday operation, cleaning hours, any out of hours operational equipment usage will need to be determined, e.g. lighting for security, IT left running overnight, night set back or night purge for HVAC services.
- Occupancy factors – This should take account of the intended occupancy densities across the building and how this is expected to vary over time, the activity level of the occupants.
- Equipment loads should be based on actual consumption rather than nameplate ratings where they exist.

For speculative developments, i.e. shell and core projects, there will be a greater level of uncertainty regarding equipment loads and usage patterns. In these cases, instead of using standard National Calculation Methdology (NCM)[vii] occupancy assumptions, the project team will need to make the best estimates they can based on available data for similar projects. The use of green tenancy agreements, which specify occupancy hours and maximum equipment loads as a way of reducing the level of uncertainty associated with equipment loads and usage patterns, is encouraged.

#### 6.2.1.1 Management factors

CIBSE TM 54[vi] suggests the generation of a predicted range based on the idealised operation of the building and anticipated operational performance of the building, which includes a margin to account for differences between ideal and actual performance.

This requires that the design team establish how well the building is expected to be managed in practice by carrying out a structured interview with prospective occupants and poses a list of questions (reproduced in Appendix A). This is then used to determine management factors for specific end uses, and/or functional areas where a management factor of 1.1 represents a 10% increase in energy use compared to modelled results due to poor management.

There is an expectation that there will be a positive response to the majority of the questions for buildings that are undertaking the prediction and post occupancy assessment. Therefore, in order to justify the inclusion of a management factor in the central case prediction, the design team must confirm that the action is outside of the control of the client and efforts have been made to engage with prospective occupiers/building managers to ensure these activities will be implemented. The management factors for individual end use and/or function area that are used to determine the central prediction must be justified based on responses to the structured interviews and must not be larger than 1.15.

### 6.3 Scenario modelling

Several alternative scenarios are to be modelled at the design stage and should explicitly consider the possibility of changes to how the building is used, how it is managed, and the effect of the weather, along with any other changes the modeller deems necessary to capture building energy performance. This is also a valuable record for each project to inform future modelling, e.g. the expected occupancy versus actual occupancy.

The scenarios modelled must include the following:

1. Central Case – This is the central case energy model for the expected occupancy and equipment loads with detailed HVAC system modelling, "typical" weather and central case management factors for servicing systems and equipment and uses reference year weather data.
2. Good Management - As for Central Case prediction but with "typical" weather and a management factor of 1.0 applied for all servicing systems and equipment.
3. Poor Management - As for Central Case prediction but with a management factor of 1.15 applied for all servicing systems and equipment.
4. Extreme Weather - As for Central Case prediction but using an extreme weather file.
5. Worst Case - As for Central Case prediction but with a management factor of 1.15 applied for all servicing systems and equipment prediction and using DSY weather file.

In addition the outputs from the NCM calculation for both regulated and unregulated energy consumption based on standardised occupancy profiles must be provided.

The weather files that should be used for "typical" and "extreme" scenarios are specified in Section 6.3.1.

Any number of further scenarios may be modelled according to the designer's discretion.

#### 6.3.1 Weather files

The 2016 CIBSE Test Reference Year (TRY) data and Design Summer Year (DSY) weather files should be used to model the scenarios[viii, 5].

Scenarios 1 to 3 should use the current 2016 CIBSE TRY weather file to represent "typical" weather. For scenarios 4 and 5 the current DSY1 weather file[6] should be used to represent extreme weather outside of London, whilst specific DSY data sets reflecting urban, semi urban and rural locations should be used in London[7, ix].

The weather file should be for the nearest location, except where this does not represent the most appropriate climatic conditions for the actual location, in which case it is permissible to use the weather file from another, nearby location, which more closely matches the climate at the actual location[8].

5 The NCM calculation and hence the BREEAM Ene 01 assessment currently use earlier CIBSE TRY weather files.

6 DSY1 is one of three variant design summer year weather files and features a moderately warm summer.

7 Guidance on using the DSY weather files for London is provided in TM49.

8 This can take account of the climatic influences of height above sea level, a coastal location or other local climate-moderating features such as mountains, woodland, lakes, prevailing wind direction or urban heat island effect. (From KBCN1013).

### 6.4 Prediction stage reporting

Report predicted energy consumption targets by end use, design assumptions and input data (with justifications).

A report shall be submitted which captures both the modelling assumptions and results in accordance with TM546. This report will describe:

- Source of the information for the assumptions and inputs.
- Key assumptions that have been made and the risks of these being wrong.
- Level of accuracy that can be ascribed to the key assumptions and inputs.
- Ranges of possible outcomes.
- Division between the variables that are under the control of the designers and those that are controlled by the occupants.
- Changes to the results as the project progresses from design through construction and to completion.
- Sensitivity of the variables.

These reports should be submitted at the design and as built stages using the report template shown in Appendix B.

In addition to submitting detailed evidence on the energy performance targets, the overall energy performance target must be publically declared in terms of demand for heating and cooling (MJ/$m^2$), primary energy consumption (kWh/$m^2$) and carbon emissions (kg$CO_2$eq/$m^2$). The public declaration of other external or internal targets that have been set for the building are also encouraged.

### 6.5 Post occupancy assessment

This stage must be carried out over a one year period which should commence within two years of the first occupants entering the building, or when the building reaches 80% occupancy, whichever is sooner.

Metered data shall be collected at the most disaggregated level possible and reported on a monthly basis as a minimum to enable the actual energy performance to be compared to predicted performance. A minimum of 12 months monitored data is required in order to assess at this stage.

In order to facilitate comparison of actual performance against the target based on modelled performance, the modelling results need to be adjusted to take account of actual weather. The preferred method is to re-run the central case scenario model using actual weather and to adjust the performance target accordingly.

Where it is not possible to re-run the central case model with actual weather data, an acceptable alternative would be weather corrections using procedures identified in Section 6.5.1.

The outputs from the adjusted central case model must then be compared to the disaggregated metered data so that areas where performance is poorer than expected should be identified (this may relate to particular servicing systems, or where there is higher than expected energy consumption out of hours etc.). Potential causes for any significant discrepancies should be identified and remedial actions suggested and implemented where feasible. Where the remedial actions are not possible, the reasons for any remaining discrepancies must also be reported.

### 6.5.1 Methodology to normalise modelled consumption for actual weather

Where it is not possible to re-run the central case model using actual weather data, it is acceptable to adjust predicted energy performance for weather at the post occupancy stage using inverse modelling to normalise the modelled consumption according to the weather conditions during the monitoring period. This approach uses regression analysis to find a correlation between external temperature and building energy demand for each fuel, which can then be used to calculate what the energy demand would be under different weather conditions.

In order to run this analysis, the following information is needed:

- Weather data files used in the simulation.
- Energy demand (monthly or more frequent) for each fuel calculated by the simulation for each of the weather files.
- Weather data files for the monitoring period.

– Energy demand (meter) data during the monitoring period (monthly or more frequent).

As metered data will be available at a disaggregated level this analysis should be carried out separately for all end uses that are expected to be significantly affected by weather, in particular heating and cooling. It is also recommended that the separate analysis is also undertaken for areas within the building where energy consumption is expected show a different relationship with external temperature, for example areas that are predominantly south facing and subject to higher solar gains.

### 6.6 Post occupancy stage reporting

A report shall be submitted which compares the adjusted modelling results for the central case to the actual metered consumption and whether the actual performance falls within the target range along with any reasons for deviation from predicted energy usage.

### 6.7 Provisional scoring

The first version of the post occupancy assessment scheme will award certificates for completing the post occupancy assessment process and no credits or scoring requirements are included.

However, to encourage buildings to be designed for performance rather than compliance and to provide valuable feedback to help to develop the industry skillset in predicting operational energy use, a provisional scoring system will be implemented. This will reward the setting of challenging design performance targets, accurate modelling, and achieving good energy performance in practice, the latter via initial BIU energy ratings. As for BREEAM New Construction, the performance score will be based on the triple metric approach which rewards low demand for heating and cooling, low primary energy consumption and low carbon emissions. It is expected that future versions of the scheme will award credits to differentiate between credits and may also set minimum standards.

To obtain a good energy rating at the post occupancy stage the project team will need to have anticipated changes in climate, usage and building management at the design stage, and produce a building that is robust with regard to those elements in reality. It will also reward commissioning and remedial actions undertaken to correct any underperforming areas to ensure that actual operational energy use is as close the targets and as low as possible.

## References

i Building Performance Evaluation Programme: Findings from non-domestic projects  Getting the best from buildings January 2016, Innovate UK https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/497761/Non-Domestic_Building_performance_full_report_2016.pdf

ii Closing the gap: Lessons learned on realising the potential of low carbon building design, Carbon Trust, 2011 https://www.carbontrust.com/media/81361/ctg047-closing-the-gap-low-carbon-building-design.pdf

iii Landlord Energy Rating: Outline Specification, Verco and Better Buildings Partnerhip http://www.betterbuildingspartnership.co.uk/landlord-energy-rating-documentation

iv NABERS – National Australian Built Environment Rating System https://nabers.gov.au/public/webpages/home.aspx

v CIBSE AM 11 Building Performance Modelling 2015 https://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008JeYXAA0

vi CIBSE TM54: Evaluating Operational Energy Performance of Buildings the Design Stage - http://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I7f7AAC

vii UK's National Calculation Method for Non Domestic Buildings https://www.uk-ncm.org.uk/

viii CIBSE Weather Data Sets: weather Data – New Sets Released [2016]  https://www.cibse.org/weatherdata

ix CIBSE TM49: Design Summer Years for London 2014 https://www.cibse.org/Knowledge/knowledge-items/detail?id=a0q20000008I6yFAAS

## Appendix A Non exhaustive list of computer programmes with extended plant and controls modelling capabilities

| Name | Developer/vendor | Environment | Plant modelling features |
|---|---|---|---|
| APACHE | Integrated Environmental Solutions (IES), UK | Part of a standalone program | Control laws and simple steady state |
| BECON | Hong Kong Polytechnic University and Cardiff University | Plug-in to HTB2 | 'Catalogue fit' and steady state plant model library |
| CARNOT | Solar Institute, Juelich, Germany | Matlab-Simulink blockset | Dynamic state and stead state components |
| DesignBuilder | DesignBuilder Software Ltd, UK | Front end to EnergyPlus | Limited access to EnergyPlus components |
| DOE-2 | Lawrence Berkeley National Laboratory, USA | Standalone program | Steady state components |
| ESP-r | Strathclyde University, UK | Standalone program | Limited dynamic modelling; embedded renewable components |
| EnergyPlus | Department of Energy, USA | Standalone program | Steady state components |
| HAMLab | Eindhoven University of Technology | Matlab/Simulink/FEMLab | Dynamic-state plant and controls |
| Hevacomp Simulator | Bentley Systems, UK | Front end to EnergyPlus | Limited access to EnergyPlus components |
| HVACSIM+ | NIST, USA | Standalone program | Steady state, and some dynamic state components |
| SIMBAD | CSTB, France | Matlab-Simulink blockset | Steady state and some dynamic state components |
| SPARK | Lawrence Berkeley National Laboratory, USA | Standalone program | Customisable library of HVAC components and systems |
| TAS | Bentley Systems, UK | Standalone program | Control laws and simple steady state components |
| TRNSYS | University of Wisconsin, USA | Standalone program | Moderate steady state component library; mainly solar |

## Appendix B List of questions for determining management factors:

Will the operator be incentivised to reduce energy use?

Will anyone be responsible for employing energy savings measures (e.g., switching off lights during the day or using pool covers at night)?

Will there be a full time engineer or energy manager based on site?

Will the building be maintained regularly through a planned preventative maintenance programme?

Will there be properly commission sub-meters to help to identify where energy is being used?

Will automatic metering reading (AMR) be installed?

Will there be building energy management software provided as part of the BMS to enable the building manager to monitor energy use and target energy savings measures?

Will energy targets be set?

Will there be consequences if energy use reduction targets are not achieved (e.g., director-level scrutiny)?

Will there be a budget to assist with energy efficiency?

If a budget is assigned, then is it reasonable for the measures that need to be undertaken?

Will occupants be made aware of their role in energy efficiency through regular awareness campaigns etc?

Will there be a formal arrangement between landlords and tenants on sharing responsibility for energy efficiency savings and investments (e.g., a Green Lease Agreement)?

## Appendix C Prediction stage reporting template

| Element | Description |
|---|---|
| Model file | Filename of the energy model, and detail of the software to which it applies. |
| Built form | |
| Climate Data | Filename and source of the climate files used.<br>The specific location to which the climate data pertains. |
| Building typology and geometry | A description of how the building has been represented and any relevant simplifications/ assumptions made in modelling it. |
| Building Surroundings | Description of any relevant external shading and surrounding area, expected impact, and how it is modelled in the file.<br>Qualitative description of the expected impact of surroundings on building. |
| Fabric | |
| Glazing | Most typical glazing specification throughout with additional notes on proportion of glazing types. |
| Insulation | Most typical insulation specification. |
| Car parks/External areas? | Where for exclusive use of building occupants, extent of lighting/operation of parking spaces. |
| Floor Area | A description of modelled floor area – is this the same as rated floor area? |
| Unregulated Energy | |
| Lighting Power Density | Actual lighting power density as installed |
| Lighting Hours | Occupancy |
| Lighting Controls | e.g. dimming, automation, timed. |
| Equipment Density | Describe type of equipment |
| Equipment Hours | Describe operations |
| Occupant density | Source of data. |
| Calculations | TM54 calculations pertaining to unregulated energy use and internal heat gains. |
| HVAC | |
| System type | Describe the systems modelled and any differences between the design and the modelled systems. |
| Hours | Hours of operation |
| After hours | Describe any hours of operation of the HVAC plant outside of core working hours |
| Plant | Default efficiencies modelled versus actual |
| Zoning | Zoning of plant in model, variations against actual |

<table>
<tr><td>Control</td><td>Control scheme for HVAC, control philosophy</td></tr>
<tr><td colspan="2">Scope</td></tr>
<tr><td>Energy Coverage</td><td>Whole building/Shell and core/Excluded areas due to lack of metering etc.</td></tr>
<tr><td>Exclusions</td><td>Exclusions from comparison and the reasoning behind it.</td></tr>
<tr><td>Reference Documents</td><td>A list of the documents supplied along with the report, to support the data input.</td></tr>
<tr><td colspan="2">Scenarios Covered</td></tr>
<tr><td>Occupancy/operation</td><td>Whole building: Number of hours occupied. Occupancy timetables.<br>Shell and core: hours per week for which services will be required by tenants<br>Operation hours and a description of the rationale following design stage workshop.</td></tr>
<tr><td>Management</td><td>Management factors and a description of the rationale following design stage workshop.</td></tr>
<tr><td>Climate</td><td>Location for climate data<br>(if modelled) weather years: Current, 2030s, 2050s</td></tr>
<tr><td>Other</td><td>Any other information reflected in the scenarios according to the modeller's discretion e.g. reflecting special usage</td></tr>
<tr><td colspan="2">Modelling Results Format</td></tr>
<tr><td>Modelling Results</td><td>Modelling results to be presented in .csv (comma separated) format.<br>At least 12 months' modelling results, presented monthly and separated into end use and fuel type. The columns will be:
<table>
<tr><td>Monthly plus Typical weekday and weekend profile</td><td>Heating kWh</td><td>Cooling kWh</td><td>Auxiliary kWh</td><td>Lighting kWh</td><td>Equipment kWh</td></tr>
</table>
This is expected to be provided for the whole building but also with enough granularity to be comparable with metered data in an individual meter basis.</td></tr>
<tr><td>Scenarios</td><td>Each as a .csv file, filename clearly labelling the scenario modelled:<br><Projectname>_Central_Case.csv<br><Projectname>_Good_Management.csv<br><Projectname>_Poor_Management.csv<br><Projectname>_Extreme_Weather.csv<br><Projectname>_Worst_Case .csv<br><Projectname>_NCM .csv<br>Any other scenarios may be provided at the modeller's discretion.</td></tr>
</table>

## Appendix D Post occupancy stage reporting template

| Category | Detail |
|---|---|
| Overview Report | The overview report should:<br>Provide a breakdown of the systems and how their performance deviates from as modelled.<br>Breakdown of the effect of: weather, occupancy, and management.<br>Identify what was done to improve score during the period of operation.<br>Identify what will be done to rectify discrepancies between modelled performance and monitored performance. |
| Monthly performance data and daily energy use profiles | Energy consumption (separately for each fuel) and associated time periods. Readings should be monthly or more frequent and should cover an overall time period of at least 12 months |
| Sub metered data | Core services, HVAC, small power, tenant meters, etc. at the lowest level |
| Variation from design stage input | Revised occupancy schedule |
| Faults | Details of any meter faults that could impact the accuracy of the data |
| Plant operation status | |
| Changes to operation | Details of any changes to use of space e.g. office move |