GN32: Energy prediction and post-occupancy evaluation for BREEAM UK New Construction 2018

Contents

Executive summary

The gap between the predicted and actual energy performance of new buildings is acknowledged to be significant. Whilst some of the observed differences in performance between the modelled building design and the 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 handover.
- 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 methodology addresses this by requiring comparable assessments to be made at the design stage and post-construction. 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 evaluation 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 the 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 only measure energy use for the following building services; space heating, cooling, ventilation, lighting, and domestic hot water, referred to as regulated energy use. Standardised equipment loads (unregulated energy uses) and occupancy assumptions are used to determine internal heat gains within the building to provide comparability. These standardised values may underestimate the equipment energy loads and occupancy times, and do not take account of installed building services such as lifts, escalators and security and communication systems or specialist equipment. Therefore, under actual operating conditions the energy use will generally be considerably higher than indicated by energy modelling software that is used to show compliance even when the standardised equipment loads are taken into account. A building that is designed to be efficient under standard operating conditions is unlikely to operate at optimum energy efficiency where actual operating conditions are very different. Compliance modelling also permits the use of simplified modelling of HVAC systems which may not accurately reflect the way the system performs. More detailed modelling which uses customised operating profiles and equipment loads together with more detailed representation of building systems can provide a much more accurate assessment of the actual energy use of the building. More accurate predictions of energy use at early design stages are therefore able to support better design and construction of new buildings.

However, even where energy modelling considers actual occupancy patterns and equipment loads, a significant energy performance gap remains. This can be attributed to a range of 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 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 methodology and post-occupancy evaluation has been devised in accordance with this energy strategy and extends the scope of the BREEAM New Construction Ene 01 (Reduction of energy use and carbon emissions) assessment issue and bridges the gap to the BREEAM In-Use (BIU) assessment scheme generating an initial BIU asset rating.

The energy performance prediction 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 BREEAM UK Refurbishment and Fit-out and the corresponding international schemes in the future. Rating systems such as BREEAM In-Use and NABERS UK Energy for Offices are examples of tools that can be used to measure performance in the operational phase.

3 Overview of the energy prediction methodology in BREEAM

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 and improve operational energy performance in occupation. 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. This enables 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. In all cases energy consumption must be reported for the whole building, but for shell and core developments the target may relate to energy use in common areas and core services provided to tenanted areas. 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 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 consideration was given to the structure and experience of other schemes operating in this area, in particular the Better Buildings Partnership's Landlord Energy Rating scheme[iii] and the Australian NABERS energy rating scheme[iv].

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 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[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 methodology in BREEAM

This section describes how the various elements of the methodology fit within the existing BREEAM UK New Construction scheme.

The energy performance 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.

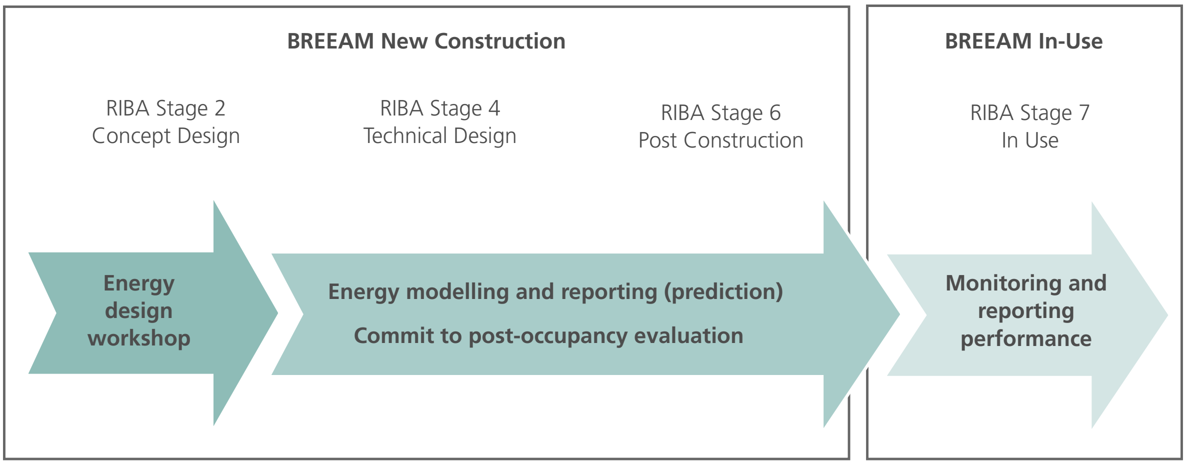

Figure 1: Illustrating how the methodology is implemented by assessment scheme and RIBA stage

The prediction element of the methodology is included within the Ene 01 "Reduction of energy use and carbon emissions" assessment issue within the Energy category of BREEAM UK New Construction 2018.

4.1 Energy modelling and reporting criteria (four credits)

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

Where it can be demonstrated that the operational energy performance of the building has been substantially improved because of the process undertaken to achieve the four 'Prediction of operational energy consumption' credits, the Ene 01 minimum standard for BREEAM Excellent is deemed to have been achieved.

A 'substantial improvement' would be demonstrated where the overall energy performance ratio (EPR_{NC}) achieves 4 credits using the standard Ene 01 2018 calculator based on modelling the actual building and an amended notional building where:

Actual building

- Actual fabric
- Expected actual occupancy
- Actual building servicing systems

Amended 'notional' building

- Notional fabric
- Expected actual occupancy
- Notional building servicing systems

For the energy modelling and reporting criteria the CO_2 metric may be calculated using either the CO_2 and primary energy factors for the version of the Buildings Regulations specified in the BREEAM UK New Construction 2018 manual or using SAP 10 factors[1].

The notional building servicing system may be replaced with a gas boiler as heat generation source.

In instances where the performance improvement over the amended 'notional' building does not equate to 4 credits, the BREEAM excellent standard may still be deemed to have been met if it can be demonstrated that there are constraints that mean that this level of performance improvement is not feasible. 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 line with the metering strategy. In order to reflect seasonal variations, energy consumption estimates must be monthly and distinguish between occupied and unoccupied periods, e.g. weekdays and non-working days.

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.

4.2 Committing to the post-occupancy evaluation within BREEAM New Construction (two credits)

A prerequisite 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 two credits under the Ene 02 Energy monitoring assessment issue, 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 evaluation (POE), the client, or building occupier must commit funds to pay for the assessment and to report on the actual energy consumption compared with the targets set in Ene 01.

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

5 Types of assessment and scope of calculations

The energy prediction 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, building 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. 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. Thus, the assessment scope can align with the definition of the "base building" in the Landlord Energy Rating scheme[iii].

[1] The Government's Standard Assessment Procedure for Energy Rating of Dwellings Version 10.0 available here.

However, the methodology is not applicable to shell only[1] developments where buildings services are not included within the scope of the assessment because it is not possible to make realistic predictions of about building servicing systems and likely occupancy patterns are not available.

6 Detailed methodology

6.1 Energy design workshop focusing on operational energy performance

Relevant members of the design team must hold an energy 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 Prediction of operational energy consumption

6.2.1 Building energy models

The energy modelling should be carried out using a dynamic simulation model with advanced capabilities for HVAC systems and controls.

Table 8.1 of CIBSE AM11 *Building performance modelling*[v] provides a non-exclusive list of computer programmes with extended plant and controls modelling capabilities that would be suitable (see Appendix A).

The 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 these to create a robust energy model for the building as it is predicted to perform in reality.

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

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[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.

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 profiles e.g., standard working days or non-working days.

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.

6.2.2 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 *Evaluating operational energy performance of buildings at the design stage*[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, 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 extended working hours, weekend and holiday operation, cleaning hours, and 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 – These should take account of the intended occupancy densities across the building and how this is expected to vary over time, and 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 Methodology (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.

6.2.3 Management factors

CIBSE TM54[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 (see Appendix B). 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 due to poor management compared to modelled results.

There is an expectation that there will be a positive response to most of the questions for buildings that are undertaking the prediction and occupation stage reporting. Therefore, 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 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.

6.2.4 Weather files

The current 2016 CIBSE TRY (Test Reference Year) weather file may be used to represent "typical" weather[1]. For extreme weather DSY (Design Summer Year) weather files should be used. The current DSY1 weather file is recommended to represent extreme weather outside of London[2], whilst specific DSY data sets reflecting urban, semi-urban, and rural locations are recommended for locations in Greater London[3].

The weather file selected 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[4].

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 can also provide a valuable record for each project to inform future modelling, e.g. the expected occupancy versus actual occupancy.

It is recommended that a risk assessment is 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.

A Central Case energy model must be defined that reflects 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.

In addition to the Central Case energy model, additional scenarios that take account of likely variations in occupancy, management factors and more extreme weather should be modelled. The following scenarios are suggested, but the exact definition and the total number of cases modelled are at the designer's discretion.

1. 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.

2. Poor Management – As for Central Case prediction but with a management factor of 1.1 applied for all servicing systems and equipment.

3. Extreme Weather – As for Central Case prediction but using an extreme weather file.

4. Worst Case – As for Central Case prediction but with a management factor of 1.1 applied for all servicing systems and equipment prediction and using a more extreme weather file.

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[1]The NCM calculation and hence the BREEAM Ene 01 assessment currently uses an earlier CIBSE TRY weather file.
[2]DSY1 is one of three variant design summer year weather files and features a moderately warm summer.
[3]Guidance on using the DSY weather files for London is provided in TM49.
[4]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 heat island effect. (See KBCN1013.)

6.4 Prediction stage reporting

Provide information on the predicted energy consumption for the whole building for the central case for each fuel broken down by servicing system, end use and functional area, in so far as the submetering strategy permits via the BREEAM energy data reporting template which can be accessed via BREEAM Projects in the "BREEAM UK New Construction 2018 Technical Manual and Tools" in the "BREEAM UK NC 2018 Assessment Tools and Calculators" folder.

A report shall be submitted which captures both the modelling assumptions and results in accordance with TM54[vi]. 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.

In addition to submitting detailed evidence on the assumptions used to inform the energy performance target, the Central Case energy performance target for the building must be publicly declared in terms of demand for heating and cooling (MJ/m^2), primary energy consumption (kWh/m^2) and carbon emissions ($kgCO_2eq/m^2$). Where the target does not encompass the whole building, for example in the case of shell and core developments, the end uses included in different areas within the building must be clearly identified e.g. all energy uses in common areas (Xm^2) and heating and cooling only in tenanted areas (Ym^2). The public declaration of other external or internal targets that have been set for the building is encouraged.

6.5 Occupation stage reporting

Information must be provided on the actual energy consumption and adjusted predicted energy consumption for the whole building for each fuel broken down by servicing system, end use and functional area, via the BREEAM energy data reporting template. The actual energy consumption data also generates a provisional BIU operational energy score.

A report must be provided which identifies areas where there are significant discrepancies between the metered energy consumption and the weather adjusted prediction. Remedial actions that have been taken and could be taken to reduce the difference between the two data sets should be identified. Where the remedial actions are not possible, the reasons for any remaining discrepancies must be reported.

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.

References

i Building Performance Evaluation Programme: Findings from non-domestic projects - Getting the best from buildings. Innovate UK, January 2016. assets.publishing.service.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.

iii Landlord Energy Rating: Outline Specification. Verco and Better Buildings Partnership, 2014. www.betterbuildingspartnership.co.uk/landlord-energy-rating-documentation

iv NABERS – National Australian Built Environment Rating System. www.nabers.gov.au

v CIBSE AM11 Building performance modelling. CIBSE, 2015. www.cibse.org/knowledge-research/knowledge-portal/applications-manual-11-building-performance-modelling-2015

vi CIBSE TM54 Evaluating operational energy performance of buildings at the design stage. CIBSE, 2022. www.cibse.org/knowledge-research/knowledge-portal/tm54-evaluating-operational-energy-use-at-the-design-stage-2022

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

Schedule of changes

Version	Release date	Description of change
1.0	Mar 2018	First issue. Launch of BREEAM UK New Construction 2018 (SD5078).
1.1	May 2019	Update to clarify minimum standard for 'Excellent' rating.
1.2	Nov 2021	Fix typo in Appendix A. The developer/vendor of TAS is now correctly listed as EDSL (Environmental Design Solutions Limited).
2.0	Oct 2022	Update following the closure of the separate post-occupancy stage assessment. See KBCN1532.

Find the latest version of this guidance note at: kb.breeam.com/knowledgebase/gn32

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	EDSL (Environmental Design Solutions Limited)	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	A copy of the modelling file for the central case energy scenario must be lodged with BRE together with details of the software version used to generate the model. This is to ensure that the model can be rerun using actual weather data for the occupied stage reporting. The file will be held in confidence and will only be released to the designated modellers at the request of the client.
Climate data	Filename and source of the climate files used. 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. Qualitative description of the expected impact of surroundings on the building.
Glazing	Glazing specifications used throughout the building with additional notes on proportion of each glazing type.
Floor area	A description of modelled floor area identifying the activity areas within the building and their management status (e.g. tenanted areas).
Lighting power density	Actual lighting power density as installed.
Lighting hours	Occupancy
Lighting controls	For example: 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 types	Describe the systems modelled and any differences between the design and the modelled systems.
HVAC hours	Hours of operation for each system.
After hours	Describe any hours of operation of the HVAC plant outside of core working hours.
Plant	Compare the efficiencies of modelled plant to the specified plant.
Zoning	Compare the zoning of modelled plant to specified plant.
Control	Describe the philosophy of the control scheme for the HVAC.
Exclusions	Identify any features or aspects of the building that have not been included in the modelling and the reasoning behind these exclusions.
Reference documents	A list of the documents supplied along with the report, to support the data input.
Occupancy/operation	Whole building: Number of hours occupied. Occupancy timetables. Shell and core: hours per week for which services will be required by tenants. Operation hours and a description of the rationale following the output from the design stage workshop.
Management	Management factors and a description of the rationale following the output from the design stage workshop.

<table>
<tr><th>Element</th><th>Description</th></tr>
<tr><td>Climate</td><td>Location and time period for weather data used.</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>Modelling results</td><td>Modelling results to be provided in BREEAM Energy Reporting Template.

For each energy source:

At least 12 months' modelling results, presented monthly as kWh/m² for:

— Each sub meter*
— Each regulated energy use (heat generation, heat distribution, cooling generation, cooling distribution, mechanical ventilation, domestic hot water and lighting)
— Each HVAC system
— Special loads and equipment (e.g. separable energy uses for DECs and any other significant equipment loads and specialist equipment that is separately sub-metered)
— Other unregulated energy uses by activity zone
— For shell and core buildings, unregulated energy use for each separately tenanted area

*identifying the building's services and equipment within each activity zones (as per the building model) that each sub-meter serves

Half hourly energy consumption profiles for:

— A typical working day in summer
— A typical working day in winter
— A typical non-working day in summer
— A typical non-working day in winter

The typical occupancy profile for a typical working day and a typical non-working day for:

— The whole building, common areas, separately tenanted areas and activity zones where the activity profile is significantly different from that of the building as a whole</td></tr>
<tr><td>Energy performance target</td><td>The scope of the energy performance target that has been set for the building e.g. the activity areas and building services included in the target.

The energy performance target expressed as kWh delivered energy consumption by fuel.

Where the energy performance target is published.</td></tr>
</table>

Appendix D: Occupied stage reporting template

Category	Detail
Overview report	The overview report should: — Provide a breakdown of the energy performance of building servicing systems and how their performance deviates from the weather corrected modelled energy use. — Identify how actual weather, occupancy and management practices in the actual building differ from the predicted energy performance. — Identify what was done to improve energy performance during the commissioning and initial occupation of the building. — For any remaining discrepancies between modelled performance and monitored performance identify potential causes and future remedial actions that could be taken.
Monthly performance data and daily energy use profiles	Energy data to be provided on BREEAM Energy Reporting Template for the weather corrected modelling results and for sub-metered data as follows: For each energy source: — At least 12 months' metering data, presented monthly as kWh/m^2 for: — Each sub-meter — Each HVAC system — Special loads and equipment (e.g. separable energy uses for DECs and any other significant equipment loads and specialist equipment that is separately submetered) — For shell and core buildings, unregulated energy use in each separately tenanted area For weather corrected modelling results only — Each regulated energy use (heat generation, heat distribution, cooling generation, cooling distribution, mechanical ventilation, domestic hot water and lighting) — Other unregulated energy uses by activity zone Half hourly energy consumption data for — A typical working day in summer — A typical working day in winter — A typical non-working day in summer — A typical non-working day in winter The typical occupancy profile for a typical working day and a typical non-working day for: — The whole building, common areas, separately tenanted areas and activity zones where the activity profile is significantly different from that of the building as a whole
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 compared to design expectations and occupancy schedules.
Energy performance target	The scope of the energy performance that is being measured for the building i.e. the activity areas and building services included in the target. The actual energy performance expressed as kWh delivered energy consumption by fuel. Where the actual and target energy performance is published.