RISE | Retrofit information, support & expertise

British Standard 40101 – Building Performance Evaluation of Occupied and Operational Buildings

Quick guide

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Contents

Introduction

British Standard 40101 (BS 40101) is one of several British Standards that support quality and good practice in construction and retrofit. It focuses on using robust building performance evaluation (BPE) methodologies to measure and monitor the overall performance (including energy for space heating, indoor air quality, moisture handling qualities etc.) of occupied and operational buildings. When published in 2022, BS 40101 was designed to provide a consistent approach to the performance evaluation of all types and ages of buildings, whatever the reason for the evaluation. In domestic retrofit, BS 40101 provides a framework for carrying out the performance monitoring and evaluation requirements of PAS 2035, providing greater insight into the actual improvement in energy performance (and related parameters) of a building.

BS 40101 can be used alongside PAS 2035, to provide an enhanced approach to gathering data from monitoring and evaluation activities. This means that performance evaluation data from these assessments could be stored in the TrustMark data warehouse for future reference, as well as for aggregated analysis and knowledge generation.

Other standards in this suite of Building Standards are available as follows:

- BS 40102 - health and wellbeing and indoor environmental quality in buildings, which is in development.
- BS 40104 - assessment of dwellings for retrofit, which will be available soon.

The British Standards Institute's Technical Committee on Retrofit Energy Efficiency Measures oversees the panels that take forward each standard. We spoke to chair of the panel and co-author (with Dr Zack Gill) of BS 40101, Dr Kerry Mashford OBE, about why the standard is important, how it works, and what RISE users could do to take forward its use.

As a mechanical engineer working in construction since 2000, Kerry has a background in building performance evaluation. Through her leadership of Innovate UK's Building Performance Evaluation programme, Kerry worked with BPE experts to put together a toolkit to enable more consistent building performance evaluation. It established tools that would work in the field (rather than lab conditions) and supported building professionals to use them.

Why is BS 40101 important?

It is acknowledged that the UK's buildings are among the oldest and coldest in Europe, and that over 20% of the country's carbon emissions come from heating buildings (Commons Library 2024). This means we must improve the energy

efficiency performance of our buildings, so that their occupants can maintain them at a comfortable temperature using less energy. The improved domestic efficiency required for the UK to reach net zero by 2050 is a key motivation for ongoing investment in social homes and those occupied by fuel vulnerable people. Better living standards afforded by more energy efficient homes, through lower energy costs and healthier conditions, are other important reasons.

Therefore, the case for more energy efficient homes is clear. There is also a general understanding of how to achieve this - installing measures to improve the building's performance such as insulation, high-performance glazing, airtightness and complementary ventilation, coupled with low carbon energy sources. However, the practical implementation of this is hindered by two things. Firstly, in certain circumstances some measures can lead to unintended consequences, such as damp, which can deter housing providers and homeowners from installing them. Secondly, there is a lack of detailed data about the real time performance of existing homes (both before and after retrofit) to alleviate concerns about risk by evidencing the potential benefits of retrofit.

PAS 2035 seeks to address both issues. It supports the management of risk by establishing a series of project roles that ensure retrofit measures are designed appropriately and installation meets specifications. Where interacting measures are considered a risk, PAS 2035 requires specific design details to be completed. Similarly, where certain projects have heightened risks because they involve specific building types, the people undertaking certain project roles must have specific qualifications or accreditations. There is also provision for monitoring and evaluating the building's performance, but this doesn't currently contain the same level of specificity.

This is where BS 40101 is useful: it suggests methodologies by which users can collect and analyse data consistently, thereby contributing to the body of evidence about how individual buildings and collections of buildings perform. It is referred to in PAS 2035 guidance and can be used alongside it to comply with and go beyond the requirements for monitoring and evaluation.

How does it work?

The origins of BS 40101 in industry has helped ensure the advice and processes it establishes are practically achievable. As such, it can:

- Be applied to all types and uses of buildings
- Be used on individual buildings, cohorts of buildings and base buildings (buildings providing some shared spaces and services where individual dwellings or units within them are separately metered and operated)
- Be used at any point(s) in the 'in-use' phase of a building life
- Be based on actual 'in-use' data

- Enable evaluation against context-relevant comparator cases (design specification, industry benchmarks, target performance, pre-upgrade performance, contractual and regulatory requirements)

BS 40101 does not set performance targets. Instead, it provides a structured process to ensure datasets are consistent and performance parameters (such as space heat demand or airtightness measurements) can be evaluated individually and collectively:

- **Define comparators:** For the key performance parameters carefully (points of reference to compare the performance of your building(s)
- **Type or depth of evaluation:** Preliminary/light/standard/investigative (see figures 1 and 2)
- **Data compatibility:** Ensuring data held in different organisations and collected at different times is compatible and comparable
- **'In the round' interpretations:** E.g., is local condensation (and potentially mould) due to inadequate ventilation, or cold bridges because insulation is not fitted well?

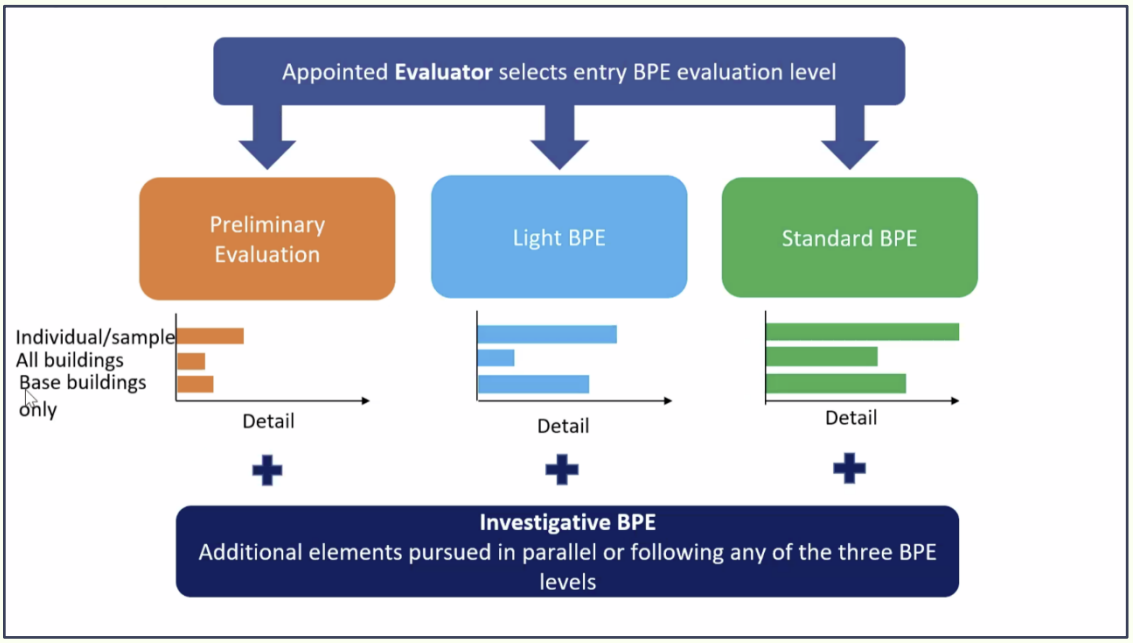

Figure 1 shows the types of building performance evaluation (BPE) established in BS 40101. Source: BS 40101.

Characteristic	All buildings (100% in cohort)	Sample (10%) or individual buildings	Base building only
Building parameters	X	X	X
Occupant/user experience	X	X	X
Post construction review		X	X
Energy use and generation		X	X
Water use		X	X
Internal conditions monitoring (e.g., temperature and relative humidity)		X	
External conditions monitoring (e.g., temperature and relative humidity)		X	X

Figure 2 shows the characteristic of a light building performance evaluation

The standard includes illustrative examples of its use in several situations. It also contains a useful report structure to enable readers to easily process and analyse multiple reports, which could cover multiple buildings or the same buildings over an extended timeframe (figure 3).

Eventually, it is possible that the data collected under BS 40101 building performance evaluation can be stored in TrustMark's data warehouse. This will allow the body of evidence about how buildings perform to be expanded, helping us to improve domestic energy efficiency and reach net zero faster and more effectively.

Section	Contents
a	Project title
b	Unique building/premises identifier (multiple in the case of cohort studies)
c	Period of study
d	Evaluator identity
e	Evaluator contact details and credentials *NOTE: Where the study relies heavily on additional specialists (e.g. scientists specializing in the fabric behaviour related to moisture content) such specialists can also be named in the study. However, responsibility for conformity to this British Standard, including custody of raw data rests with the evaluator.*

Section	Contents
f	Objectives or purpose of the study and its place in any larger project, such as if included in a project following the RIBA plan of works [4], Soft Landings Framework 2 or BS 8536. In the case of Investigative BPE, the report shall describe any specific hypothesis being tested.
g	Reference to previous studies on the target building or cohort, where relevant.
h	Reference to, or inclusion of, the BPE project plan and any departures from the plan, including reasons, implications for the data and information gathered and the quality and reliability of the conclusions reached.
i	The BPE study elements in the project, including, as a minimum, all the elements listed in this British Standard as necessary for the level of study being carried out, e.g. Preliminary Evaluation, Light BPE or Standard BPE, specific to the building type and use.
j	Any additional study elements that the evaluator and client have agreed, specific to the purpose or objectives of the study (including elements from the Investigative BPE toolbox) or to map to parameters available for the chosen comparator(s) and notable omissions and reasons for not including, e.g. if acoustics were not part of the study scope but known to be significant in similar contexts.
k	Qualitative and quantitative performance parameters for all evaluation study elements *NOTE: For time-series data, only the total or averages (over useful periods) and/or derived parameter values should be included explicitly in the BPE report, with full raw data files held separately and referenced in the report. Other numerical values such as peak can also be reported, as appropriate.*
l	Comparator descriptions and comparator parameter values used in the course of the evaluation of the building(s)'s performance, including the design specification, where available, and any regulatory limits. *NOTE: These comparators should already have been set out as part of the BPE plan but are explicitly included in the BPE report as they are crucial to understanding the interpretation made by the evaluator.*
m	Side by side comparison of gathered and comparator performance parameter data. *NOTE: Comparator data can be normalized, if required, to enable like for like comparison with study building data.*

Section	Contents
n	Interpretation of data and conclusions, referring to noted points, such as building plant failure, low occupancy, during the evaluation period. Where BPE studies include incomplete or atypical data at some stage during the required minimum 12-month data collection period, this shall be explained clearly in the evaluation report, including the evaluator's assessment of any impact on the confidence in the findings.
o	Further study recommended to enable the originally stated project objectives to be met, or to investigate matters arising from the reported study.
p	The type of conformity claimed, which shall be one of the following: 1. Level of BPE study conducted: Preliminary Evaluation, Light BPE, or Standard BPE and/or any Investigative BPE (where this is included within, or separately following, a PE, Light or Standard Evaluation); and 2. Type of study conducted, i.e. individual building or premises, cohort of buildings or premises, and/or a full building or base-building study.

Figure 3 shows a suggested structure and list of contents for a BPE report. Source: BS 40101.

Can you share any success stories or testimonials about its usage?

In 2024, the Chartered Institute of Building Service Engineers (CIBSE) published Retrofit Revisit. The research was led by co-author of BS 40101, Dr Zachary Gill, and adapted its processes to evaluate the retrofit works to 10 homes 10 years after completion. Works to the case study buildings were originally funded by the Technology Strategy Board's (now Innovate UK's) Retrofit for the Future programme, which meant that suitable attention had been given to both the retrofit design and works. This is important because it meant that any unexpected findings were unlikely to be the result of designs not being implemented flawlessly during installation.

The BPE itself intended to compare the buildings' current performance to the performance immediately after retrofit, to understand whether there had been any degradation. The BPE methods adopted therefore reflect this, while also being based on those established in BS 40101. They include:

- A core package of BPE tools that draws on those suggested in BS 40101's preliminary and standard levels (figure 4). Tools in this package were applied to all 10 case study buildings.
- A detailed package of BPE tools, which fall within the BS's investigative level (figure 4). Tools in this package were applied to up to 6 homes in the study.

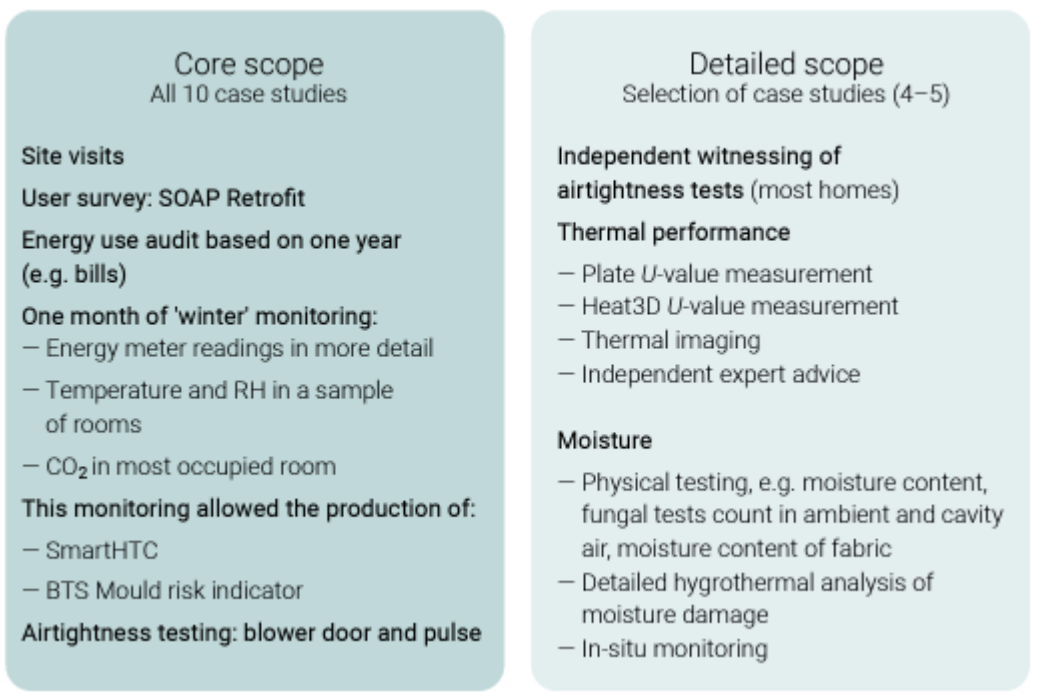

Figure 4 shows the scope of the core and detailed evaluation methods used in Retrofit Revisit. Of the seven characteristics in figure 2, only water use was not assessed at all (some were assessed in part only). Source: Retrofit Revisit.

The above BPE approaches gave the researchers a useful range of factors to measure, allowing two useful sets of conclusions to be drawn:

1. The findings on retrofit are very positive:

- Few major building performance changes have been observed since the original retrofit
- The retrofit has delivered long-term benefits, with energy use still lower than average
- Most occupants are satisfied with their energy bills
- Space heating estimates are in line with best practice retrofit standards and significantly lower than the national average

2. The findings on the use of BPE techniques (including BS 40101) were also positive:

- The flexibility within BS 40101 means it works for defining an end-to-end BPE. The Retrofit Revisit team used the framework where relevant; there were good reasons why it did not use certain aspects. This means that the study could still claim conformity with the BS.

- Lessons learnt about conducting BPE included:
  - Individual measurements of BPE characteristic within each building are important
  - Comparators are essential but hard to find
  - Assessors should be experienced enough to understand the buildings and how they work, notice things that aren't working, and interpret findings from individual measurements in the round. Codifying this is not possible but guidance on finding experienced specialist assessors may be explored by the Building Performance Network
  - Guidelines and pro-formas for conducting the BPE measurements are required
  - Lots of the investigative methods could be done very cost effectively
- The study also provided information about the data that should be gathered as part of BPE:
  - Summer data is as important as winter data
  - Monitoring data every 30 minutes for a whole year (as recommended in BS 40101) is very challenging and perhaps excessive. This level of information may be needed where energy use stands out as different, to help interrogate why
  - The one month of winter energy was really useful
  - Ventilation rate is easy to measure and most of the time is not operating as it should be. It is definitely worth interrogating.

Conclusion

The *Retrofit Revisit* study is one of several that demonstrates the usefulness of BPE to making the case for retrofit works. The benefits to energy performance and occupant experience that it highlights are a positive counter to much of the concern about retrofit risks, which sometimes as a deterrent to installing retrofit measures, as described above. The process it sets out can be used both before and after retrofit, with before findings determining a key comparator case and the after findings evaluating the performance as built.

Anyone interested in developing the evidence base for retrofit, as part of engaging people in it and scaling up its delivery more quickly, should seek to make use of BPE and BS 40101. Its use will be particularly powerful when findings from independent studies are held together in TrustMark's data warehouse, as following its processes will make data comparable. Over time, this will optimise the analysis of data from more and more projects, helping to build the evidence base the sector needs.

Where should people go for more information?

- CIBSE (2024). *Retrofit Revisit: 10 Case studies.* Available at https://www.cibse.org/knowledge-research/knowledge-portal/retrofit-revisit-2024/
- BSI (2022). *Building performance evaluation of occupied and operational buildings (using data gathered from tests, measurements, observation and user experience) – specification.* BSI: London