Resource Hub

Building Performance Evaluation: What, why and the benefits that it brings

BPN training module 1

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Resource Hub Series

These training documents are to help anyone involved in a building project to understand what Building Performance Evaluation is, who will undertake what and when. We present the benefits of these efforts, which include occupant satisfaction, lower environmental impact, and reducing risk. We want the user of this series to have the confidence and information to be able to get the evaluation programme they need to achieve their goals for their project.

There are 5 modules. A fuller description of all of these in provided in the main body of this module.

Module 1 - BPE: What, why and the benefits that it brings

Module 2 - Planning a BPE: Where to start and common techniques

Module 3 - Undertaking dwelling BPE

Module 4 - Data interpretation, reporting and taking action

Module 5 - The performance golden thread: BPE and robust QA

Modules will all be freely available from the BPN Resource Hub.

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01 Introduction

Globally the world is living in a climate emergency. Every country will be affected, and every sector has a role to play. In the UK, the Government has a legally binding commitment to achieve net zero by 2050. We are also experiencing serious energy security issues and a cost-of-living crisis. The necessity for energy, resource and cost-efficient homes is becoming ever more apparent.

The UK housing stock is diverse, with many different types across the country. The UK has the oldest housing stock in Europe, with around 80% of our homes having been built before 1990. It also has some of the least energy-efficient homes in Europe, exposing occupants to rising heating bills as well as accounting for around 20% of the UK's carbon emissions. To address these challenges, it is imperative that we understand our homes, their performance and importantly what we can do to make them better places to live.

There are many factors that play a role in achieving sustainable homes – materials, technologies, finance, skills and interactions with people – all impact how a home performs. The tool we use to understand a home and its systems is building performance evaluation (BPE). If we are to succeed in reducing the carbon footprint of our homes, we need to ensure they perform as intended.

Ecology Building Society is a mission-led financial institution, focussed on combatting climate change through our sustainable mortgage lending, funding the construction, renovation, retrofit and conversion of homes and community buildings that are better for people and planet. We are therefore delighted to support the work of the Building Performance Network to understand and close the 'performance gap' between modelled and actual performance.

This learning module is the first in a series of 5. It provides an overview of what BPE is, the activities that can be undertaken, the data that can be collected, and the benefits of BPE. The module is aimed at those who are new to BPE and want to understand how to avoid building inefficient homes. Whether you are self-building a single home, a small developer who strives to build very high-quality properties, or a landlord that really wants to keep their residents satisfied by getting specific feedback on what is and isn't working, this guide shows the importance of carrying out BPE. In turn this knowledge will allow you to make more informed decisions about your current and future projects.

Gareth Griffiths, CEO

Ecology Building Society

02 BPN training modules

There are 5 modules in this series, each consisting of a report and an associated online training course. The series covers:

Module 1 - BPE: What, why and the benefits that it brings

- What is building performance evaluation (BPE) and why is it needed?
- Overview of common BPE techniques
- Differences between BPE for different housing types
- Benefits and outcomes of BPE

Module 2 - Planning a BPE: Where to start and common techniques

- Engaging project participants
- BPE at different project stages
- More detail on the common BPE techniques and their purpose
- Timing of BPE

Module 3 - Undertaking dwelling BPE

- From in-use screening through to investigative BPE
- Delivery of the techniques and approaches
- Risks and down-sides and how to address them
- The human factor

Module 4 - Data interpretation, reporting and taking action

- What do you do with the data you have?
- How do you take action?
- Embedding lessons learnt

Module 5 - The performance golden thread: BPE and robust QA

- How to maintain the performance golden thread through the design, build, commissioning and in-use stages
- How BPE supports a robust QA process
- In-use and performance verification

Who will find this series useful?

BPE enables a better understanding of a building's fabric, its systems in use, the consumption of energy and water, the quality of the indoor environment, and the impact of occupants and their interaction with controls. It is, therefore, useful to anyone wanting to optimise the experience and efficiency of that building, or to learn from one project in order to improve the process of designing, building and commissioning other buildings.

This series of modules will be useful to anyone who wants to implement a BPE programme to fulfil those goals including clients and design teams. However, we are here focussed on an audience of:

In private housing:

- Self-builders, small builders, retrofitters and their contractors
- Small-scale property developers
- Medium-large scale property developers
- Landlords

And in social housing:

- Contractors
- Small-scale property developers
- Medium-large scale property developers
- Landlords

Though the audience for BPE findings may vary, the process is unchanged.

What you will learn from Module 1

Module 1 will give you an introductory understanding of what BPE is, the benefits it can bring to your project or practice, and what carrying out BPE will entail including differences for particular housing types (new build/retrofit, social/private, owned/rented).

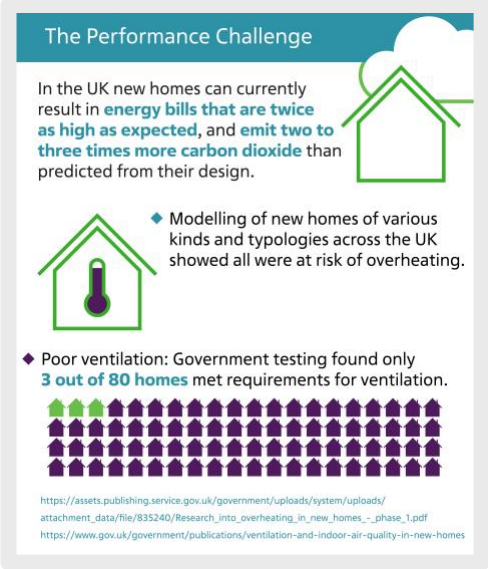
This information will help you decide if you want to carry out a BPE programme. The further Modules will give you more details, enabling you to get what you need from BPE.

03 What is Building Performance Evaluation?

In this section, we set out the main challenge that BPE seeks to overcome: that we usually do not know how well our buildings perform and that when we do measure this, we often find that the performance does not meet expectation. We then explain how BPE will help with this and other challenges.

What is the performance gap?

Many existing, new and refurbished buildings exhibit large gaps between how they are expected to perform (design aspirations and predictions) and how they actually perform when people are occupying them (in-use performance). The difference between the levels of efficiency, comfort and usability that modern buildings are designed to attain and what they actually attain is known commonly as a '**performance gap**'.



Evaluating the performance gap

Performance gaps in buildings can appear at many points within a project. Gaps can be introduced as early as the design stage and continue to appear, or be exacerbated, through construction to the completion, commissioning and use of the building (see Section 04 of this guide). Performance gaps are never intentional, but without a process for reviewing and learning from decisions made throughout all the stages of a building project, opportunities for correction and improvement can be missed. This can lead to errors occurring and recurring.

The good news is there is an established ongoing review and learning process known as **building performance evaluation** (BPE). BPE covers a whole range of tools, techniques and engagement approaches that help determine how well a building performs in relation to the design aspirations and predictions. Importantly, BPE can help you identify and resolve problems when performance falls short of expectations and is intrinsic to ensuring delivery of a building from design to happy occupants.

There is a common understanding that performance means energy use and CO_2 emissions. However, BPE covers much more: all issues that impact technical performance *and* occupant satisfaction. This means the potential inclusion within the evaluation of a range of factors including construction quality, operating efficiency and costs, environmental impact, usability, internal conditions and importantly the perception of the occupants.

Building performance evaluation

"Gathering of a building's (or premises') quantitative and qualitative performance parameter data and the interpretation of these data against comparators to draw conclusions regarding specific aspects of performance and the overall performance of the building (or premises)" (*reference: BS40101:2022, Building performance evaluation of occupied and operational buildings (using data gathered from tests, measurements, observation and user experience) — Specification*)

Why do Building Performance Evaluation?

Informing action

Information is key to understanding whether we are making the right choices throughout the lifecycle of the building. You can use the information gained from BPE to understand better how a building is working and how it is being used then to act to improve its performance. This can enable you to take necessary remedial action promptly and effectively, whether that be improvement to the fabric, recommissioning of building services or delivering more guidance to the occupant.

On-going performance

There are benefits of BPE to ongoing performance of homes. For occupants these might include reduced utility bills, increased comfort and improved satisfaction with their homes. For builders, retrofitters and contractors the benefits can also include reduced snagging costs and improved understanding of how to achieve good performance in a cost-effective way.

In some cases, with ongoing monitoring, maintenance can also be made easier and more efficient. For example, monitoring relative humidity could reveal an issue with ventilation, the resolution of which could pre-empt damage to the property, appearance of mould and threat to the health of the occupants.

Improving working practice

Perhaps most importantly for those responsible for building homes, BPE plays an important role in continual improvement (see IMAGE 1). This guide is the first of a series of 5 modules designed to bridge the information void to enable delivery of embedded and consistent BPE as part of your daily business, leading to a continual cycle of improvement over subsequent projects.

IMAGE 1: BPE is central to a process of improvement in the development of a building.

How does the performance gap arise?

The performance gap is the difference between expectations for a building and the reality once that building is in-use. Here we look at how the expectations are quantified and the reasons why they are not met through the building (or refurbishment) process and then when occupants are using the building.

How do we quantify our expectations of building performance?

There are a number of software tools which can help to estimate the amount of energy that may be used in a new build home, or a retrofit / refurbishment after the works. These include:

- SAP (Standard Assessment Procedure) – used for new build homes, and makes various standardised assumptions in calculations e.g. for the purposes of assessing Building Regulations Part L compliance,
- RdSAP (Reduced Data Standard Assessment Procedure) – used for existing homes, requires less data than SAP, utilising more default assumptions in calculations. This can lead to a greater margin of error in the expectation of building performance.

- PHPP (PassivHaus Planning Package) - requires a greater amount of detailed data on a building and is known for its high level of accuracy. It can be used for new or existing homes.

Any software tool relies on the accuracy of its input and assumptions and there will inevitably be some gaps between real in-use performance and modelling predictions. BPE can help to reduce these gaps through picking up on input errors/changes made during the project process, and by feeding in learning gained from BPE into modelling assumptions.

Realisation of the design

There is often insufficient attention given to the design of certain details of the building and this can have significant impacts on the overall performance. Thermal bridges, for example, can cause dramatic heat loss through only small areas of the building fabric, such that they can substantially reduce the performance of the building. Other small details can reduce the effectiveness of insulation – for example using dot-and-dab adhesive instead of a continuous bead around the perimeter of an insulation board. Buildability may also not have been considered enough at the design stage, leading for example to installation issues for fabric or services or clashes between the two which negatively affect performance (e.g. services compromising the airtightness barrier). Changes may also be made to the design without considering the full implications of these – for example one product being substituted for another. Poor commissioning can also lead to services performing much less efficiently than anticipated. Issues such as these can add up to create a significant performance gap.

Human interaction with the built home

Occupants of a home add an additional level of complexity and uncertainty, which can sometimes be difficult to account for accurately in design calculations. For example, CIBSE Guidelines for dwellings assumes internal operative temperature in winter be between 20-23 degrees Celsius for living rooms and 17-19 degrees Celsius for bedrooms. However these are not necessarily the temperatures employed by residents. (*reference Guide A Environmental design (2015)* table 1.5).

Usage patterns also vary significantly from home to home. For example, some people only heat their homes in sporadic patterns, others leave the heating on most of the day in one or two rooms, all winter, and others may indeed struggle to control their heating at all (see POP-OUT 1 Design of user controls).

POP-OUT 1 Design of user controls

Photo by Arthur Lambillotte on Unsplash

A study done on domestic thermostats *(N.Combe et.al)* compared the usability of different industry standard interfaces, using two different user groups: elderly residents versus younger engineers. The study found that three of the major industry leading interfaces were so confounding that 80% for the younger people couldn't accurately programme the thermostat, and 100% of the older users failed in the same task of inputting a weekly heating schedule.

This study helped advance the design of heating controllers to be more intelligent and linked to smart phones – requiring less complex user interaction, more machine learning, and more intelligence behind optimising heating schedules and setpoints. Smart thermostats and smart controls, a variety of which are now widely available to consumers, have helped overcome the complexity of programming thermostats to include occupancy detection based on when smart phones are connected to Wi-Fi networks, and allow for more intuitive graphic-based heating scheduling.

04 BPE through the stages of delivering a building

The most widely accepted 'map' of the process of designing, constructing and operating building projects is the RIBA Plan of Work. The outline below sets out how BPE fits into that plan. How and when various aspects and techniques of BPE are used are explained in more detail, in Module 2.

Strategic Definition and Preparation and Briefing (RIBA Stages 0-1)

Setting measurable targets that will carry through the project. These performance criteria guide the design and execution of the project. Criteria can be influenced by learning from other BPE projects and may involve a commitment to BPE itself – ideally this should be planned from the earliest stage.

Concept Design and Developed Design (RIBA Stages 2-3)

Intended outcomes should be reflected in chosen strategies, e.g. airtightness and ventilation. Building-integrated monitoring might be included. Budget should be allocated for monitoring and evaluation.

Technical Design (RIBA Stage 4)

Technical decisions about specification and design will be made now which back-up the higher-level strategy, including details such as the size and efficiency of heating system. This includes specifying monitoring and evaluation equipment which will help in validating the intended project outcomes.

Manufacturing and Construction (RIBA Stage 5)

Focus should be on ensuring the design is executed as planned, including any integrated monitoring and evaluation equipment. Certain BPE methods can be integrated into the construction phase to help to identify any defects before they are hidden, e.g., thermal imaging or pressure testing to find failures in the insulation or airtightness strategy, or additional on-site checks. (e.g., service commissioning)

Handover (RIBA Stage 6)

The monitoring and evaluation process must be fully explained to the occupants of the homes, and they must be made aware of how to use any controls or monitoring equipment which might better enable them to use their homes effectively and efficiently.

In Use (RIBA Stage 7)

At this stage occupant feedback and in-use monitoring data is gathered, allowing analysis of the performance of the home as it's being used. After this, lessons learnt from all stages of BPE should be fed back into each of the stages set out here.

05 Levels of BPE

How much data do you need?

During the design and construction process, BPE activities should be recurring, though the nature of the tests will vary, as set out in Section 04, and in further detail in Module 2. By doing this, the project can be kept on track, ensuring it will reach the targets set out at the start, taking remedial action if necessary and before performance gaps become irreparable.

Once the dwelling is occupied, there are some key first principles of undertaking BPE on homes – and one of the most important is to start small and simple. Collecting data is important, but large amounts of data can be unwieldy to store and analyse. The process should also not distract from identifying and rectifying concerns that the occupants experience through living in the building. Therefore, it is useful to be clear about the granularity of the data required to achieve the building performance evaluation.

To assist with this, the British Standard for In-use Building Performance Evaluation (BS 40101:2022) specifies three levels of BPE for in-use evaluations: Preliminary Evaluation, Light BPE and Standard BPE. Any of these may lead to a more investigative approach should the results indicate this is necessary in order to understand a problem with the building's performance.

Preliminary Evaluation is based largely on occupant feedback and the evaluator's observations, with some coarse energy use data. It is not intended to enable you to draw definitive conclusions as to the performance of the building, but rather to gather a broad perspective of whether the building is generally meeting its objectives or if there are major, obvious shortfalls. This should be achievable on nearly every home, with the occupants' consent and participation.

Light BPE includes the elements of the preliminary evaluation combined with additional internal monitoring data on environmental conditions. It is intended to partially verify performance or screen a cohort of homes, to flag significant performance anomalies and guide more targeted investigations, if necessary.

Standard BPE requires more granular data across a larger number of building performance parameters to provide a robust performance verification and gain comprehensive insight into the

performance of a home. It is also intended to look at the building 'in the round' by considering the cross-impact of factors affecting performance (for example, how temperatures and occupancy affect energy consumption, etc).

In addition to the entry levels above, **Investigative BPE** may be undertaken following findings from the first BPE or in parallel, depending on intentions and focus. For example, if indoor environmental quality is of particular concern, monitoring of VOCs and particulate matter may be undertaken.

Ideally, the BPE should be arranged to minimise any time requirements on the occupants, or disruption to their daily living and to the property itself. If the initial stage of the evaluation reveals shortcomings in performance, including dissatisfied occupants, then further, Investigative BPE is recommended. Depending on the nature of the potential shortcoming this could include testing of the building fabric and ongoing monitoring of internal or external conditions.

The techniques for different levels of BPE are introduced in Section 06 below.

Data Protection considerations

Use of personal data for BPE must be compliant with the General Data Protection Regulations (GDPR). This requires, amongst other key principles, that only the data needed for a specified purpose is collected, and the purpose must be clear from the start. Collecting temperature and energy data with loggers when a home is occupied can be intrusive and could inadvertently reveal sensitive information about a household, including times when the property is regularly vacant, when residents are often in the bath or shower, or when the homeowner is usually asleep. This information is rarely necessary in establishing if the home is broadly working correctly, but it can be helpful in fault finding. Thus, this data should only be collected if there is a fault which needs investigation, or a technology needs further data to verify its performance.

It is therefore recommended in most cases to begin with Preliminary Evaluation to catch rectifiable issues and scan for red flags of potential performance problems which require further investigation. If more in-depth investigation is required, then data loggers and the more technical (and expensive) techniques can be deployed.

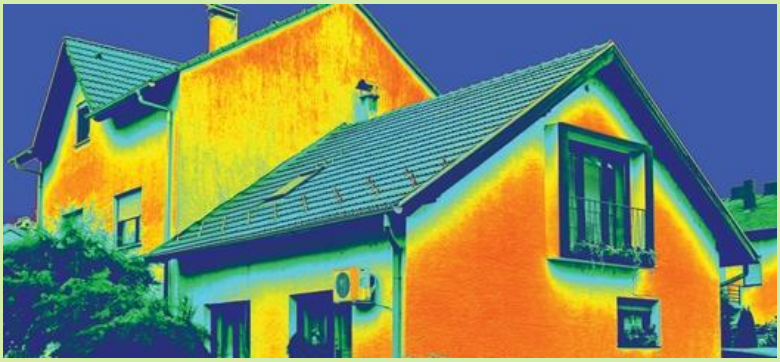
06 What are BPE techniques?

Different techniques will give you different data and information. Some are appropriate to all evaluation projects, and some are not required for the Preliminary or Light BPE. All are described in more detail in *Module 2 – Planning a BPE*: *where to start and common techniques*. Some of the most commonly used techniques are summarised below:

- Reviews of Construction:
  - Design review – including review of key building parameters, performance targets and predictions
  - Construction review – including building walk-through, additional on-site checks
  - Procurement review
  - Commissioning review
  - User control review
  - Handover and induction review
  - Air permeability tests
  - Fabric tests (e.g. measurements of whole fabric heat loss)
  - Thermal imaging survey
- Occupant feedback:
  - Occupant comfort, satisfaction, wellbeing, needs and usability
- In-use monitoring (usually for 12 months) and review:
  - Energy use and generation
  - Water use
  - Internal conditions, such as temperature, humidity and CO_2
  - External conditions, such as temperature, humidity, exposure.

Much of BPE is gathering and assessing relevant information and evidence of the building's construction and overall quality. Findings from each technique should not be viewed in isolation. The various elements and techniques each take a specific aspect of performance and help add to the overall picture of whether the building is meeting its intended level of performance.

POP-OUT 2 Pictorial representation.
The use of thermal imaging surveys produces pictorial representations that can be very effective at demonstrating where issues may be arising to various audiences, including those needing to take remedial action – especially if coupled with the results of occupant feedback.



07 Variations on BPE

BPE in new homes vs BPE for retrofit projects

The investigations for both new-build and homes receiving retrofit energy efficiency improvement works will cover broadly the same technical and performance aspects in the evaluations: construction execution, operating efficiency and costs (e.g. energy and water use), environmental impact, usability, internal conditions and occupant comfort.

New-build BPE is focused on assessing the home in meeting the needs of occupants and getting overall feedback on the performance, quality and usability of a new home. It will look specifically at how the home is meeting design expectations and performance targets. Where relevant, BPE can help assess the overall development as well as performance of an individual or individual homes.

In retrofit cases, similar questions are asked, but in the context of whether the home has been *improved* as a result of the works, with additional feedback typically sought on the process and results of the retrofit, from the occupants' perspective. Evaluators may also be able to compare before and after data if pre-retrofit data is available. Thus, retrofit BPEs tend to be comparative.

There may also be differences in the expectations of the occupant – this is discussed in Module 2.

Are there differences between tenures?

BPE for social housing may require slightly different considerations to private housing. Social housing, for example, may be more likely to have pre-payment meters, which can be more difficult to get energy data from. On the other hand, social housing providers may already be gathering data that can be used or may be able to help coordinate data access. Housing Liaison Officers (or similar) can often help bridge any language or inclusivity gaps to help gather data, including assisting tenants with online surveys and offering onsite support. Their valuable assistance should be agreed early on with the social housing provider so that their time can be allocated and they can be suitably informed and supported.

In private homes, the individual homeowners or tenants need to be engaged and willing to participate where BPE takes place post-occupation. There may be little motivation for a tenant to participate, and some may see it as a risk to their tenancy. It is good practice to assure residents of anonymity and that personal, sensitive information will not be shared.

Simple rewards, such as a prize-draw for vouchers, can help motivate occupants of either tenure to participate in surveys and share data.

08 When BPE has been carried out

The outcomes of carrying out BPE

As discussed in Section 03, there are many benefits to carrying out BPE. It will help you to flag serious failures in performance, to guide timely remedial action and to keep occupants happy with their homes. When implemented well and across different stages of the project process, it will prevent failures in fabric or services being hidden and developing into more serious and expensive issues. It will lead to more efficient, better performing homes overall, with lower running and maintenance costs, better environmental impact and improved levels of comfort. For self-builders or those investing in retrofit in their homes, it will be reassurance that targets have been met. It can also help to futureproof homes for climate adaptation and resource scarcity.

All of this has the associated benefit of helping to manage reputational risks. Stories of very disappointed homeowners do sometimes become public, from both new-build and retrofit projects, where occupants feel they've been short-changed and left with a home that is for example expensive to heat and/or has significant defects. The reputational damage of such publicity can be catastrophic to a small developer. Instead, BPE can be used to build an evidence base of how satisfied occupants are with their homes.

Importantly, BPE can also be part of a continuous improvement process; it helps to inform effective ways of delivering high quality homes by getting specific feedback on what is and is not delivering its intended performance, what techniques, systems and details do and do not work effectively, and allowing you and your clients to learn lessons and make more informed decisions about your projects in the future.

How do we share lessons learned?

Having used the data collected to take remedial action and improve the experience of the occupant (see POP-OUT 4), there are a variety of ways you might want to share learning, both internally to your organisation, and to a wider audience which may include suppliers and contractors. Where you may be working on different projects, the feedback from one development should help inform another even where different personnel are involved.

The UK suffers from a disjointed BPE sector, where data is inaccessible, study methods are not always clear or shared, and decisions are often made on poor or limited information. Sharing data and findings can improve widespread practice by those involved throughout the different stages of a project. In the case of low-energy retrofit, it may be wise to pass some strategic lessons-learned back to TrustMark or to the Retrofit Coordinator who can share learning more widely amongst a professional audience. In the case of new build, feeding learning back to architects or designers can likewise help to improve future homes. Organisations like the Building Performance Network (BPN), Association for Environment Conscious Building (AECB), Good Homes Alliance (GHA), PassivHaus Trust, and Sustainable Traditional Buildings Alliance (STBA) regularly have events where learning is shared about building performance. The most important part of integrating feedback into any organisation, however, is that it's done constructively and with an effort to avoid blame. BPE should always be about improving practice.

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