Resource Hub

Undertaking Dwelling BPE

BPN Training Module 3

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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 Module 1.

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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Contents

01 Introduction

Module 1 explained what Building Performance Evaluation (BPE) is and why we need it. Module 2 built on Module 1 to guide you through how to begin a BPE programme, providing more detail on how to implement it and when.

Module 3 builds on Modules 1 and 2 to set out how to undertake BPE, what aspects you may wish to monitor, and a basic introduction to how monitoring is conducted. This is not a technical guide for BPE professionals and so does not provide in-depth technical guidance on each technique, but rather is intended to help the self-builder, developer or contractor understand the basics of how various element of building performance can be monitored, what's involved, and any practical considerations to be aware of so that you can engage knowledgably with your BPE practitioner and build team on the subject.

Why do BPE?

To give context for this module, it's useful to remember the reasons why you may want to conduct BPE. These are covered in detail in Module 1, but to summarise: many existing, new and refurbished buildings exhibit large discrepancies between how they are expected to perform (that is, the design aspirations) and how they actually perform when people are occupying them (that is, the in-use performance). This is commonly referred to as the 'performance gap'.

The self-builder and their contractors or the developer, whether large or small, can use the information gleaned from BPE to better understand how their building is working and how it is being used, then act to improve its performance and potentially improve ongoing maintenance, too.

For self-builders and occupants, BPE can help ensure the level of energy efficiency, building comfort and usability expected. For developers and contractors, BPE can help demonstrate that the expected building performance has been delivered in practice. BPE also plays an important role in continual improvement for developers and build teams looking to close the gap between design and performance across their portfolio, which is particularly important in the context of the current energy and sustainability crises. Understanding what you want to achieve through BPE is key to a

successful BPE programme. This is covered in this module, along with what aspects to monitor and evaluate in order to fulfil your aims.

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: BS 40101:2022, Building performance evaluation of occupied and operational buildings (using data gathered from tests, measurements, observation and user experience) — Specification)

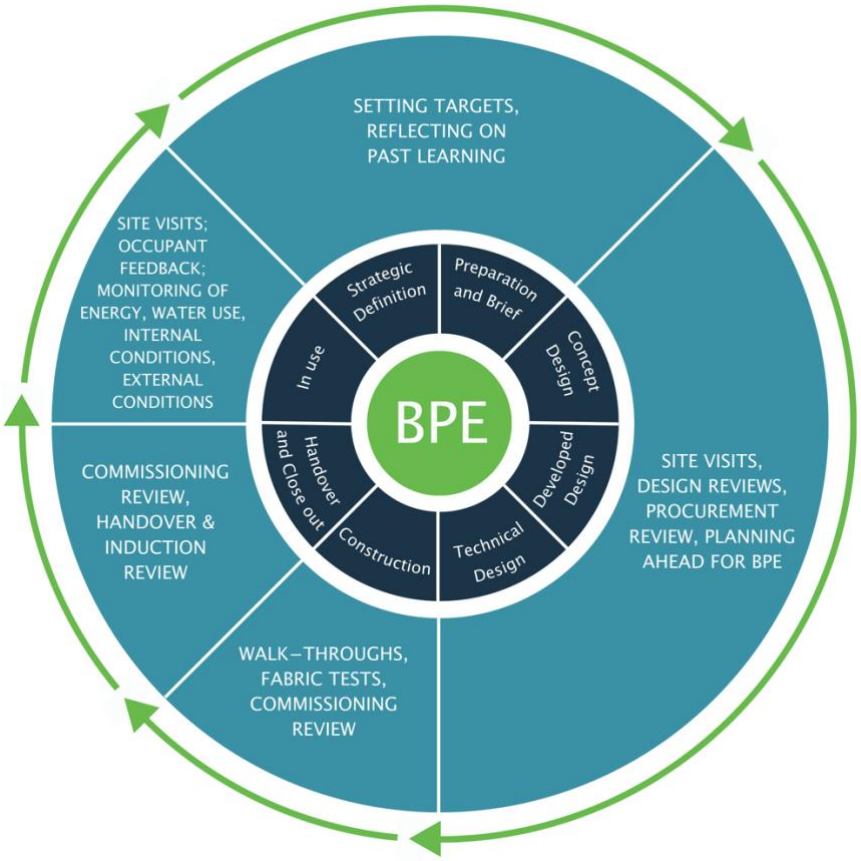
02 Commencing evaluation

Undertaking BPE – What to do at each stage of the project

Ideally, the need for BPE should be taken into account from the earliest stages of construction or refurbishment. You should set out clearly that the building performance in-use will be evaluated, both in relation to the design or refurbishment aspirations and in relation to appropriate comparators. This should be made explicit as early as possible, and communicated to key stakeholders.

Considering BPE at each stage of the build or refurbishment process will help ensure that everything is in place to make evaluation efficient and effective. The diagram below shows what BPE considerations are required at what stage of the design, construction and operation. Module 2 details the BPE requirements at each project stage, and these are summarised in Figure 1 below.

Figure 1. BPE requirements at each stage of the project.



Scoping Considerations

What type of BPE are you undertaking?

At the beginning of the project, you will have determined what type of BPE you are undertaking. The British Standard BS 40101 sets out four levels of BPE:

- **Preliminary**: Initial assessment to inform further investigation - the lightest "entry level" evaluation using readily available data and information plus occupant feedback.
- **Light**: Basic BPE study. The lightest level to take account of internal environmental monitoring.
- **Standard**: All-round study based on more granular data (as specified in the standard). Intended to form a strong basis for decision-making and further performance investigations.
- **Investigative**: Additional study pursuing particular elements requiring further investigation. Can be pursued in parallel or following any of the three levels listed above.

Usually, it is sensible to undertake an initial investigation to help "hot-spot" the areas for further investigation. Where a dwelling is pre-existing, investigative BPE may be used to delve into particular problems or concerns that have been noted.

What do you want to evaluate?

An important key to successful building performance evaluation is being clear about what you want to evaluate and why. For the self-builder, it may be that you want to create a home that gives certain levels of comfort and energy efficiency or ensure your home meets a particular standard (such as Passivhaus). For a developer, it may be that you want to demonstrate new build dwelling(s) meet a certain performance specification or that a refurbishment has delivered improvements in particular aspects (for example, heat loss or occupant comfort).

EXPERT INSIGHT

"Being clear about what aspects of building performance you want to look at and why will really help you get the programme off on the right foot. It provides clarity so you can focus time, energy and budget on what matters most."

Zack Gill, BPE specialist, SOAP Retrofit.

It can be useful to consider what aspects of building performance are most important. Commonly called "hot-spotting", determining what is most important will help you "pick your battles" and target your BPE to where it is most valuable for you. Referring back to the original specification or brief prepared for the new build or upgrade is a great way to do hot-spotting. It will help draw out those attributes that were considered as most important, either from the self-builder's own perspective or, in the case of a small developer, those attributes that they are looking to in order to differentiate their home from the competition. When undertaking preliminary or standard BPE, considering the priorities and potential issues can help focus your BPE and indicate the level of data collection and monitoring that will be appropriate. A very simple preliminary BPE includes little data collection as the norm, so hot-spotting will usefully identify additional focus areas where data does need to be collected. When conducting investigative BPE, the issues that have been flagged for investigation will likely indicate the hot-spots for further evaluation.

What will you compare against?

Once you have decided what you want to evaluate, it is important to consider what you will compare performance against. This may vary depending on your requirements and aspirations. It may also differ depending on the end user(s) and whether the build is speculative or commissioned with a specific occupant(s) in mind. Common comparators include:

- **The design brief and specification**: Does performance in-use meet the design aspirations and specification?
- **Industry standards**: Does performance in-use meet a particular industry standard, such as Passivhaus certification, the RIBA 2030 Challenge (both summarised in the WoodKnowledge Wales Building Performance Evaluation Guide) or EnerPHit?
- **Other similar buildings**: Does performance in-use match that of other similar buildings? Does it equal that of other high-performing buildings of the scale and type?

Photo courtesy Energiesprong

CASE STUDY: ENERGIESPRONG - Guaranteeing in-use performance will meet design targets Energiesprong is a new approach to domestic energy retrofit that has been piloted in nine schemes across the UK, with more to follow in 2022/23. In the design brief, targets are set for aspects such as space heating; hot water; net energy consumption; tenant energy costs and internal temperature. The Energiesprong standard sets these targets based on a net-zero energy aim and ensuring the cost of retrofit can be covered through energy and maintenance savings.

The contractor signs a performance guarantee, ensuring that the in-use energy use and generation are in line with the design brief. The metrics are closely monitored after the project is complete to ensure performance meets the targeted levels. Assured performance means tenants and landlords or social housing providers can have confidence energy costs will stay low and occupant comfort high.

Who will manage and conduct the work?

Various professionals can help plan and implement your BPE programme, alongside planning the building work. These include architects, retrofit coordinators, building performance evaluators, as well as specialist building performance testers. Some aspects of BPE (such as air tightness and heat loss testing) will likely require specialists and their specialist equipment.

You may choose to project manage the BPE programme yourself or engage a BPE practitioner, depending on the complexity and budget of the project. Where possible, it can often be beneficial to engage a BPE practitioner from the early stages of the project to supervise and coordinate the evaluation, as well as giving expert advice.

Procuring BPE assistance

Whichever route you choose, there are some procurement considerations that will make engaging with your BPE practitioner and associated professionals easier. When briefing or engaging your BPE practitioner clearly set out the objectives you wish to achieve. Be clear about

- what you want to know,
- why you are measuring that project,
- any specific issues or aims.

This will help the BPE professional to tailor their proposals to meet your needs. Where possible, it is best to engage the BPE practitioner early, especially given that several aspects of BPE often require long-term monitoring and forward-planning. For example, by involving your BPE practitioner at design stage, if possible, they will be able to highlight any sensors or monitors that should be installed and operational from handover. Our handy checklist (Appendix 1) can form the basis for an early discussion with your BPE practitioner during selection and procurement.

Likewise, giving other stakeholders involved in the project (such as built environment professionals, contractors and occupants) a clear brief on what BPE will be undertaken, what comparators will be used, and any timing implications can help ensure expectations are aligned from the outset of the project. Module 2 provides further guidance on engagement.

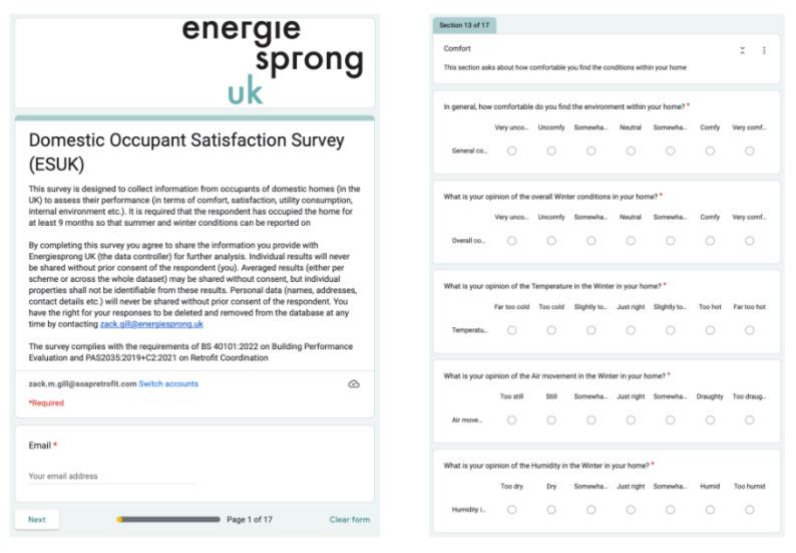
Working with occupants

It is important to remember good performance of the dwelling in-use, with and for the occupants living in it, is the ultimate basis for BPE. This means that it is important to:

- **Understand what occupants want from the building**: for example, they may be most concerned about having appropriate levels of heating, being able to afford to run their home, and/or many other factors that may be unearthed in an initial occupant survey or client brief
- **Work with occupants to understand any issues currently being experienced**: an occupant survey can form a basis for BPE, but continued engagement and dialogue may

be required to truly understand any issues occupants are experiencing (see Module 2 for more on engagement).

Figure 2 Example occupant survey



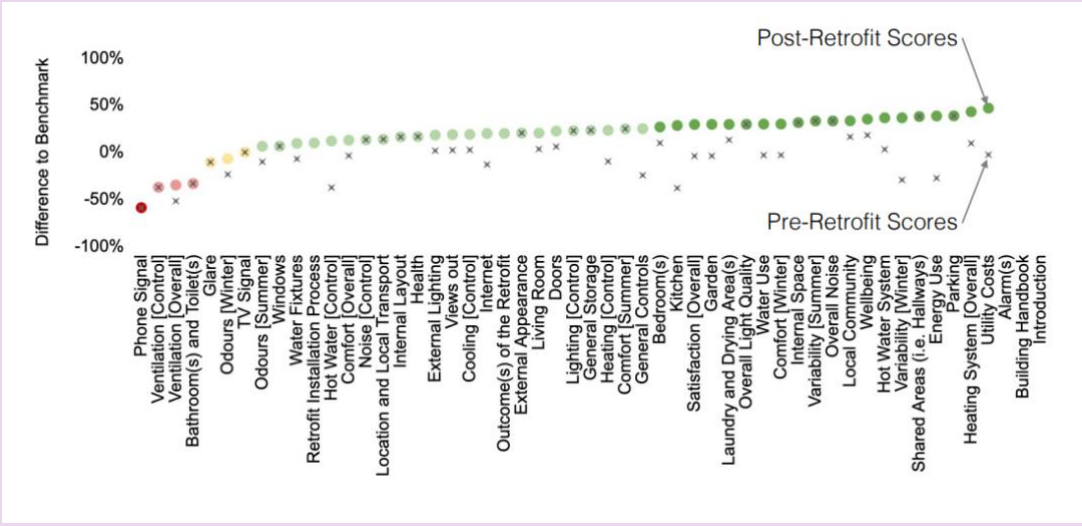
An occupant survey is a useful way to understand what occupants want from the building and issues they are experiencing.

This example provides the context and GDPR requirements, along with contact details for further information. As shown in the sample question page, qualitative feedback is requested in a check-box format.

Courtesy of SOAP retrofit

- **Minimise disruption to occupants during BPE and associated mitigation works**: by setting out the monitoring schedule and any access requirements, and working with participants to find mutually suitable arrangements, the perceived disruption can be greatly reduced. In the RIBA publication *Housing Fit for Purpose*, Professor Fionn Stevenson sets out some guiding principles for working with occupants (see below).
- **Maintain an on-going feedback loop with occupants so that you understand how the building performs long-term**: so that you understand whether any interventions have been effective and if any additional BPE or mitigation measures are required.

Figure 3 Aggregated occupant survey results can show trends and help hotspot issues



Courtesy of SOAP retrofit

EXPERT INSIGHT: Principles for engaging occupants:

- **No purposeful harm**
- **Honestly and integrity**
- **No coercion**
- **Informed consent, including a right to withdraw**
- **A requirement to confidentiality**
- **Equality and diversity**
- **Data protection should at a minimum meet requirements set out by General Data Protection Regulations (GDPR) including that only necessary data be collected and stored, with a specified and explicit purpose, and treated fairly, lawfully and transparently.**

Professor Fionn Stevenson, Housing Fit for Purpose (RIBA, 2019)

03 Conducting the evaluation

Monitoring and testing

To evaluate a dwelling's performance, it will be necessary to conduct monitoring and testing for each of the aspects you have decided to include in your BPE. Monitoring or testing the various aspects of the building's performance is what will enable you to tell whether the dwelling meets the targets you have set.

There are many aspects of building performance that you may wish to evaluate. The most commonly-considered aspects are:

- Airtightness
- Energy use
- Thermal bridge analysis
- Overheating analysis
- External environmental conditions
- Heat loss
- Water use
- Internal environmental conditions (including internal temperature, indoor air quality, relative humidity)

The testing or monitoring methods, relevant standards and other key information for each of these is set out in the tables below.

Airtightness: Unwanted drafts and uncontrolled airflow through a dwelling can cause heat loss and occupant discomfort.

Aspect	Airtightness
Test Method Blower Door	Blower Door: A specialist test that pressurises or depressurises a building by installing a calibrated fan in an external opening (usually a doorway) and measuring the air leakage of the dwelling created by the pressure differential generated by the fan between the building pressure and external pressure.
OR Pulse test (now approved for Part L).	Pulse test: A specialist test that uses compressed air to measure a building's air leakage at a near-ambient pressure level. Unlike the Blower Door method, the building fabric is not penetrated.
Standards & Metrics	Air permeability value (q50) and (optionally, unless for a PassivHaus) air changes per hour (n50)
Conducted by	ATTMA, IATS or UKAS registered Air Tester.
Timing	Prior to handover; any time. However, testing when building envelope is closed, but prior to internal finishes being installed, allows any leakages to be addressed relatively easily. If leakages appear at completion, they will be associated with activities following the first envelope closure.
Other considerations	Testing should confirm level meets the target/comparator. Identification of air leakage paths is not possible using the Pulse test method. If a more investigative approach is called for, you may want to use thermal imaging and/or smoke pens to detect air movement paths.

Energy use: Ensuring energy use is as expected can limit energy use and cost. Additionally, high energy use can be an indication of other issues.

Aspect	Energy Use
Test Method Energy use data (ideally by energy type and usage)	Smart meter data is preferable for convenient monitoring as it can be analysed easily. Alternatively, a professional may need to visit and collect data.
Standards & Metrics	KWh per unit floor area
Conducted by	Appropriate person with access to energy usage data
Timing	Any time. 12 months of data is preferable to give a full picture.
Other considerations	Data should be split out into different energy sources (e.g. grid electricity, grid gas, solar etc) and uses (e.g. heating, cooking etc) where possible. Use of smart meter data requires occupant consent. In addition, floor area is required to enable comparisons.

Thermal bridges: Understanding thermal (or cold) bridging can help identify and avoid locations of heat loss and resulting colder surfaces which are often linked to mould formation.

Aspect	Thermal bridging
Test Method Accredited Construction Details (ACDs) or similar	Not actually a test but ACDs are very useful and can contribute to the understanding of a design. ACDs are standardised details for which thermal bridging has been reduced and pre-calculated. Other similar standardised calculations exist (e.g. for Timber buildings: Zero Carbon Hub's Thermal Bridging Guide). Where used, these will be incorporated into SAP calculations. The performance specification for a project should specify a target thermal bridging value for the whole home (Y-value).
Thermal bridging analysis	If required, detailed thermal bridging analysis calculations can be performed by a specialist at design stage. It involves calculating the Ψ-value (rate of transfer of heat) for all non-standard details, calculating the Y-value (heat transfer coefficient) for each unit, and comparing against the design target.
Standards & Metrics	Y-value for overall thermal bridging (W/m^2K), Ψ-value for individual thermal bridges (W/mK) Thermal bridges are taken account of in SAP calculations for Building Regulations Part L1A. Changes to SAP may change how thermal bridges are considered.
Conducted by	Architect, building physicist, Passivhaus designer, energy modeller
Timing	Design stage and during construction, as very difficult to investigate post-construction without invasive assessment.
Other considerations	Reviewing thermal bridges at Detailed Design Stage is a good opportunity to assess how details are designed, whether they could be improved and how they will be built including the sequencing. Use Accredited Construction Details (ACDs) (for which reliable thermal bridging calculations exist) where possible to limit the need for more complex thermal bridging calculations. Some standards, such as Passivhaus, require a "thermal bridge free" envelope.

Heat loss: Understanding how the building fabric performs in terms of heat loss and retention can be useful for reducing heat loss and increasing energy efficiency.

Aspect	Heat loss (Heat transfer coefficient/ HTC)
Test Method	
Co-heating	Co-heating tests measure the amount of heat lost through the thermal envelope of the completed dwelling and are typically performed with ventilation openings and systems off or blocked. These require the dwelling to be unoccupied and undisturbed for 3 weeks.
Dynamic co-heating	Similar to the "standard" co-heating test, but carried out over much shorter periods, these tests use controlled heating and cooling combined with power input and external temperature data to measure heat loss. Methods include QUB, Veritherm and P-STAR.
In-use measurement	In-use measurement techniques use energy consumption data in combination with internal temperature and external weather data to calculate the whole house Heat Transfer Coefficient (HTC) and provide a measure of how well the building fabric is insulating. At the time of writing, the only commercially available method in the UK is SmartHTC. Other methods developed under the BEIS SMETERS project may be available in the future or on request. Testing is non-invasive, so measurements can be carried out whilst the property is normally occupied (during winter conditions) and therefore at significantly lower cost than other methods.
Standards & Metrics	Part L of the UK Building Regulations requires heat loss calculation which are embedded into SAP, RdSAP, and PHPP calculations. These results can be readily compared to measured values using the methods above. The Heat Transfer Coefficient (HTC) is measured in Watts per Kelvin (W/K)
Conducted by	Building performance evaluator
Timing	Testing in winter is advisable so there is sufficient difference between internal and external temperature. Traditional co-heating testing requires 3 weeks unoccupied dwelling.
Other considerations	A thermographic camera can be used to provide qualitative assessment or sense-check heat loss. Air tightness testing and in-situ U-value measurement can be used to calculate the proportion of the heat loss which is due to infiltration or individual elements. The results are best interpreted by a professional Building Performance Evaluator.

Ventilation rates: Ensuring ventilation system and ventilation rates are as intended can help keep air fresh and prevent build up of pollutants, moisture and odours.

Aspect	Ventilation rates
Test Method Volume air flow rate measurement of fans	A specialist test that uses a calibrated meter to measure the air flow rates either directly through a fan or via ventilation grilles and valves that are connected to a fan unit.
Visual inspection for natural ventilation	For naturally ventilated dwellings ventilators should be installed in all rooms (and in bathrooms, kitchens, and utility rooms where a continuous mechanical extract system is used). Ventilators, either fitted in windows or through walls, should be checked to confirm correct size and location (in accordance with Approved Document F), and that they are open.
Visual inspection for cross flow ventilation between rooms	For all ventilation systems, cross ventilation is important to ensure continuous ventilation is possible between rooms. Usually provided via undercut beneath internal doors -i.e. 10mm between the bottom of the door and the floor finish.
Standards & Metrics	Litres per second of fresh air supplied (supply fans) or stale air extracted (extract fans). For PassivHaus, cubic metres per hour is often used as an alternative.
Conducted by	A ventilation specialist or commissioning engineer for fan measurements. Building performance evaluator for natural ventilation and cross ventilation checks.
Timing	Prior to handover; any time.
Other considerations	Testing should confirm that the measured air flow rates meet both the target (design) and the minimum rates specified in Approved Document F. If fan systems have an adjustable flow rate setting, they should be adjusted/commissioned, and the air flow rates re-tested if necessary.

Indoor Air Quality: Ensuring air quality is good and pollution minimal will help protect human health.

Aspect	Indoor air quality
Test Method Internal air quality sensors	Check design meets Building Regulations Part F for background AND purge ventilation rates
Standards & Metrics	UK Building Regulations Part F
Conducted by	Building performance evaluator
Timing	Preliminary BPE assessment will indicate pollutants which would be useful to look into further. Length of testing may vary depending on tests required, time of year etc.
Other considerations	Indoor air quality parameters are usually more expensive to monitor, but this may be justified if there are causes for concern. CIBSE TM40 provides a summary of appropriate levels.

Water use: Ensuring water use is as expected can limit water wastage and cost. Additionally, high water use can be an indication of other issues.

Aspect	Water Use
Test Method Water use data (ideally by usage)	Smart meter data is preferable for convenient monitoring as it can be analysed easily. Alternatively, a professional may need to visit and collect data.
Standards & Metrics	UK Building Regulations Part G requires water consumption less than 125l/person/day and water usage calculated in accordance with the 'Water Efficiency Calculator for New Dwellings"
Conducted by	Appropriate person with access to water usage data
Timing	Any time. 12 months of sequential monthly data is preferable to give a full picture.
Other considerations	Set an appropriate target, and measure how much is actually used. In addition, floor area is required to enable comparisons.

Overheating analysis: Ensuring that the dwelling is not susceptible to overheating and, if it is, understanding the causes can be very important to attaining comfortable temperature.

Aspect	Overheating Analysis
Test Method GHA overheating tool	The tool consists of a scoresheet containing 14 questions with accompanying guidance notes for each question: how it identifies an overheating risk or mitigation factor, how to estimate the score, and related references for further reading.
Standards & Metrics	UK Building Regulations Part O, UK Building Regulations Part F
Conducted by	Self-gathered/building physics consultant
Timing	Any time. The tool relies on static variables
Other considerations	This tool provides guidance on how to assess overheating risk in residential schemes at the early stages of design. It is specifically a pre-detail design assessment intended to help identify factors that could contribute to or mitigate the likelihood of overheating. Versions for both new build and retrofit available.

External environmental conditions: External environmental conditions will influence what performance your building can achieve.

Aspect	*External environmental conditions*
Test Method Local weather station data	Data from local weather station(s). Can be obtained from publicly available sources such as www.metoffice.gov.uk and www.climate.copernicus.eu
Standards & Metrics	Rainfall (mm); Sunshine (hrs); Temperature (°C)
Conducted by	Self-gathered/BPE advisor/Retrofit coordinator.
Timing	Ideally prior to commencement AND for periods of other testing.
Other considerations	Knowing if abnormal weather conditions have occurred during any testing or survey periods can help avoid drawing inaccurate conclusions.

Qualitative considerations

In addition to the specific monitoring and testing techniques mentioned in above, there are some key considerations that can make monitoring easier and more effective for all parties.

Site visits and inspections: Visiting the dwelling at important stages of the project can give insights that cannot be gained from documentation and testing alone.

Type	Refurbishment
Overview	Visiting the property can provide valuable insights into the current state as well as any extenuating issues. As discussed in section 2 it is important to engage occupants appropriately well in advance, and ensure the principles of good engagement, including right of refusal and GDPR requirements are fulfilled.
Timing	***Scoping***: visiting during scoping can provide valuable insights into the current state as well as any extenuating issues. It may be possible to collect pre-existing data (such as smart meter data) from residents whilst on site, which can save time and effort later. A preliminary survey, including an occupant survey, can provide baseline data to help make future monitoring and evaluation more targeted and efficient, as well as causing less disturbance to occupants. It can also help identify occupants who are willing to participate in more detailed or investigative surveys. ***Ongoing***: if ongoing monitoring is required, it may be possible to integrate remote monitoring sensors or utilise data that is already collected (for example the heating system may already be able to collect temperature measurements for integration into data collection).
Conducted by	Architect or BPE specialist.
Other considerations	In the case of multiple-dwelling projects, a representative sample of properties should be visited. When sampling, care must be taken to ensure the dwellings selected are representative.

Type	New Build
Overview	In addition to design team meetings, site visits during construction and handover can be beneficial in giving a clear perspective of how the design targets are being implemented in practice, and any potential issues.
Timing	Ongoing through construction, prior to internal finishes being installed and at handover
Conducted by	Architect or BPE specialist.
Other considerations	Ongoing validation to avoid hidden issues. Adherence to design and specification is key to ensuring performance.

Occupant comfort and satisfaction: Obtaining insight into occupant comfort and satisfaction can provide useful information to inform all aspects of BPE. (See section 2 above).

Type	Refurbishment
Overview	Survey to understand existing issue and what occupants want from the refurbishment. Survey after to ensure performance is as designed.
Timing	Prior to refurbishment works, and then the summer and winter after.
Conducted by	Architect or BPE specialist.
Other considerations	BS 40101 sets out standard requirements for occupant comfort, satisfaction, wellbeing, needs and usability assessments, including minimum requirements for in-use occupant surveys.

Type	New build
Overview	Survey to understand what occupants want from the building. Survey after to ensure performance is as designed.
Timing	Following occupation. Surveys to establish occupant comfort should be conducted at least 9 months after the initial occupation.
Conducted by	Architect or BPE specialist.
Other considerations	BS 40101 sets out standard requirements for the evaluation of occupant comfort, satisfaction, wellbeing, needs and usability assessments, including minimum requirements for in-use occupant surveys.

Commissioning and handover

The commissioning and handover phase can have a significant impact on ensuring the systems and controls are all up and running correctly, but also on how well occupants understand and are able to use the systems.

It is important that the BPE practitioner reviews the commissioning process to ensure that:

- the relevant tests (e.g. air tightness tests) have been performed and the target performance levels have been attained
- relevant equipment (such as heating and ventilation systems) have been adequately commissioned and are in working order.
- any BPE issues noted are remedied before Practical Completion wherever possible, as build teams' focus inevitably moves to the next job soon after and it may take longer to resolve matters and be more difficult to engage individuals with knowledge of the project after that point.

During handover, it is beneficial for the BPE practitioner to play a key role. They should ensure:

- any ongoing or future monitoring and evaluation process is fully explained to the occupants.
- occupants are aware of how to use any controls or monitoring equipment which might better enable them to use their homes effectively and efficiently.
- sufficient information on how to use controls or monitoring equipment is provided in the building user guide and to ensure such a guide exists.

Red flags

Warning signs or "Red flags" can give an indication of problems with the current building performance. Many of these can be identified through occupant surveys and feedback.

- **Lack of response from design/build team.**
  Sometimes, the design or build team may just be busy with other priorities. However, sometimes a lack of response to BPE questions or requirements can indicate a problem. It may be that they do not believe the target is realistic or that they are aware of an issue but not sure how it can be addressed. Regular, scheduled and open communication can help guard against these types of problems.

- **Anomalous results for one dwelling of sample.**
  If the results for one dwelling amongst a sample differ substantially from the rest it may indicate either a testing error, unusual externalities (e.g. weather conditions), or different occupant behaviours. The result may be an outlier. However, it is still important to the occupants of that dwelling and should be investigated to understand the cause.

- **Anomalous results for one aspect.**
  If the results for one aspect are particularly high or low (for example, if the results for heat loss are very poor but the results for other building fabric testing are fine) then there may be a testing error. Further investigation of the test results will be required.

- **A rushed commissioning or handover.**
  Timing is often tight at commissioning and handover. However, studies show these stages are when many building performance issues occur. It is vital that sufficient time is provided in commissioning to check that all building performance aspects are covered off and all equipment is working effectively. Likewise, a clear and effective handover is essential to ensure that occupants (and maintenance teams) know how to use equipment.

- **Large quantities of occupant feedback where only a few words would suffice.**
  Generally, if people are happy, they'll just give you a few words of positive feedback, or a neutral response in some cases. This follows the adage of 'no news is good news', but that's only true if you've put in the effort to ask for news in the first place, as well as asking the questions via appropriate, often multiple, channels (e.g. a QR code and online survey may not reach an audience of less tech savvy occupants). If they are unhappy, they may offload volumes of complaints, frequently with a number of them being seemingly unrelated to the questions being asked.

- **Occupant feedback which is contrary to the intended outcomes of a project.**
  If, for example, an occupant of a home which has received extensive fabric and services upgrades as part of a whole house retrofit (for example major insulation of building elements with a heat pump) reports that they're colder and their bills have gone up, that's an indication something's gone wrong. It could be as simple as the users being unclear about how to operate a new heating system, or it could be a more insidious problem of insulation being poorly installed, the home not being as airtight as it should be, or the heat pump being improperly commissioned. Then more detailed investigation and information is warranted, to help clarify, identify the cause and solve the problem.

- **Occupant feedback on topics other than BPE.**
  If, when occupants are asked about the building performance, they provide limited comment on it and instead focus on other aspects, like the waste collection or local services, it may indicate that the performance of the building is not a major concern. That does not mean it can be assumed there are no issues, however, so surveys should be designed to focus respondents' attention on to building performance issues specifically. If a well-designed occupant survey/questionnaire/interview gives neutral or positive feedback, more detailed monitoring and evaluation can be undertaken with the confidence that nothing of immediate concern to the homeowner is lingering whilst more detailed data is being collected and analysed.

04 Continuing the performance evaluation

The role of monitoring and testing does not stop upon completion of the initial evaluation. BPE brings most benefits when it is an ongoing process that includes further evaluation of the building's performance over time. Ongoing BPE can:

- Ensure that any mitigation measures that have been implemented continue to be effective
- Highlight any new performance issue that have occurred
- Demonstrate continued delivery of required quality for building assurance

There are three things that will influence the ongoing good performance of a dwelling:

- The external environment
- Changes to the building fabric or services (e.g. through lack of routine servicing or maintenance)
- How occupants use the building

User engagement and feedback are key parts of ongoing performance improvement. Therefore having a clear and positive strategy for engaging with occupants is key. (See Module 2 for further guidance on engaging occupants).

Ongoing evaluation need not be an onerous task: new easy-to-use technologies and user interfaces (such as digitally-connected thermostats and smart meters) can make gathering time-series data for ongoing monitoring easy and efficient.

Future innovation

Given the broader context of the global and UK carbon reduction commitments, public and private sector Net Zero targets, and policy aims such as the UK government aim of no new gas boilers in new homes after 2025, better building performance in use will be essential. Adding to this is the requirement that all domestic properties must have an Energy Performance Certificate (EPC) to be sold, and the government commitment to upgrade as many private rented sector homes as

possible to EPC Band C by 2030. As requirements and expectations increase, BPE will be necessary to demonstrate and achieve these standards.

The Building Performance Network advocates for building performance evaluation to become standard practice. Potentially, assessment of the performance gap and elements of in-use building performance evaluation may become a regulatory requirement. Monitoring technologies, using machine learning, AI, cheaper data collection, data from consumer goods such as smart watches and heating controls, cheaper equipment; better means of sharing and communicating data (for example, see Active Building Centre data repository; and standards are evolving at a rapid pace that would support this.

While innovation is welcome, as techniques and technologies emerge, it is worth considering the following:

- Is there transparency regarding the nature of the methodology and any uncertainty in accuracy?
- Is robust, verifiable data, including error margins, produced?
- Do the error margins allow for assurance in achieving performance targets? For example, if the error margin is larger than the improvement expected via an intervention, the BPE technique may not suitable.

05 Data analysis

Once monitoring and testing is complete, you will need to undertake data analysis. Organising and collating the data well, and knowing how to interpret it effectively and efficiently will make your BPE programme much easier and more effective. Module 4 covers data analysis in more detail, but this section gives an overview of key principles for structuring, interpreting and reporting data.

Collecting, storing and structuring data

During the BPE programme you will obtain a large quantity of data. It is useful to set up a clear and simple way of collecting this information, such as a spreadsheet or a series of folders on your computer. Data should be stored with clear version control (e.g. dates) so that it is obvious which data is most recent and accurate. Some tests will come with reports from the relevant specialist. These may be required under regulation or standards, so be sure to store these appropriately.

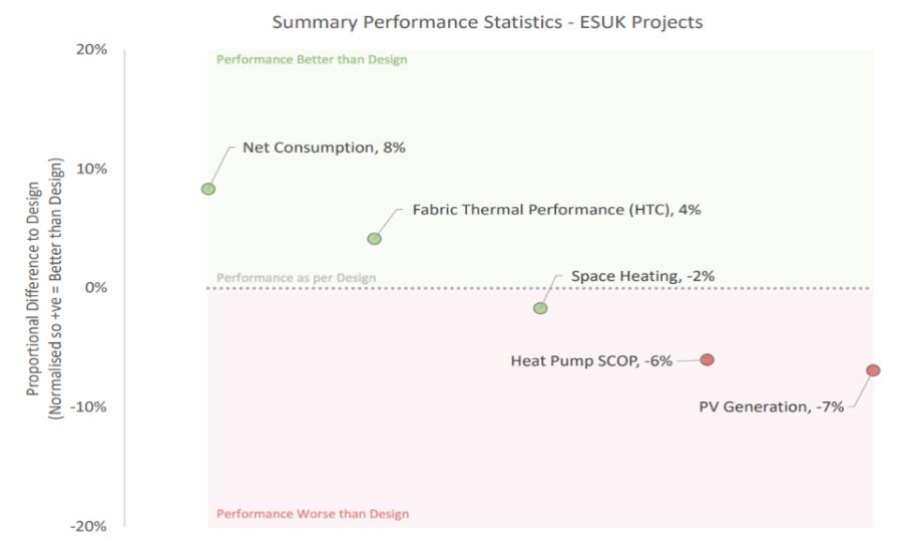
Careful attention should be paid to General Data Protection Regulation (GDPR) which will be applicable to collecting and storing data. Your procedures should be properly reported to participants and their agreement obtained as necessary.

Interpreting data

When analysing and interpreting data, a vital element is comparison against your comparators, whether these are from the brief and specification; industry standards, or other similar buildings (as discussed in section 2).

However, before beginning comparison, it may be necessary to clean or normalise your data. When analysing data from a number of dwellings, it is not unusual to have some outliers, because factors such as occupant behaviours and occupancy patterns can vary. If outliers are to be excluded from an aspect of analysis, you should have robust, defensible reasons for doing so. Outliers might tell you something useful, with further analysis. Likewise, variation in weather patterns year to year can affect results. It is important not to draw excessively broad conclusions from a preliminary BPE, especially if assessing a single home or using a small sample. When using a sample of homes for assessment of a larger development, considering the average results and the distribution can provide useful information to inform further investigation. It can also be useful to view occupant surveys and feedback as an important source of information which can often help to explain any anomalies in the quantitative performance data.

Figure 4 *An example of assessing results against comparators*



Courtesy SOAP Retrofit

If your data are complex and data analysis is not your specialism, you may decide to engage a building performance evaluator, retrofit coordinator, building physicist or architect to conduct the analysis.

Reporting data

Reporting should be clear, fact-based and accessible. Your report should clearly set out:

- the purpose of the BPE
- the aspects that were assessed, and for each aspect:
    - monitoring and testing techniques used
    - the targets and comparators for each aspect
    - when monitoring was conducted and by whom
    - the results
- any conclusions drawn (either for future BPE or mitigation).

Again, care should be taken to publish any information in accordance with GDPR.

Module 4 provides further guidance on data analysis and reporting.

Resource Hub

Report Template Title

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