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Building Performance Evaluation in Domestic Buildings

A guide to effective learning

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1 INTRODUCTION

The UK building stock is made up of a significant number of domestic buildings that were built prior to the introduction of energy efficiency standards into Building Regulations. Given that the domestic sector accounts for approximately a quarter of the UK's energy consumption, the contribution of this sector in reducing emissions in existing as well as new build homes will be vital if the country is to meet its target of 80% lower greenhouse gas emissions by 2050.

Despite the housebuilding industry's genuine intentions to develop efficient homes, academic and industry research has shown that homes do not always perform in the way that was originally intended. This results in inefficiencies in the form of higher than anticipated energy use and consequently running costs. There is an expectation that new homes built to recent standards of energy efficiency will be more comfortable. As a result of these homes being built to higher standards of energy efficiency, smart and innovative mechanical systems for heating and ventilation are expected to be incorporated into designs. These are often unfamiliar to occupants, and can counterintuitively lead to less than optimum use and lower occupant satisfaction.

This guide is intended to support the industry by explaining how to use Building Performance Evaluation (BPE) to understand how homes are performing, and to investigate and address these issues. It gives a general introduction to BPE, and explains why it is important and how it can be carried out. It is aimed at helping clients, designers, developers, contractors, housing associations and social landlords improve their understanding about BPE and its benefits.

Throughout this guide the terms user, occupant and resident have been used interchangeably to describe the building user. The term 'home' includes all dwellings, whether they are houses or flats.

1.1 What is Building Performance Evaluation?

BPE is the process of evaluating the performance of a building and can be carried out in both new and existing homes. The activities of BPE integrate into BSRIA's Soft Landings process (described later in this guide) to help deliver effective and efficient buildings. The scope of a BPE programme is flexible and can vary depending on:

- the scale of the development, for example a single home, a building with multiple dwellings or a development with buildings of mixed use and tenure.
- the complexity of the design in terms of passive elements (such as thermal mass) and building services (such as mechanical ventilation, district heating or renewable energy technologies).
- the project stages through which the BPE can extend, which would influence the tools and processes that could be used.
- the time available for the evaluation.

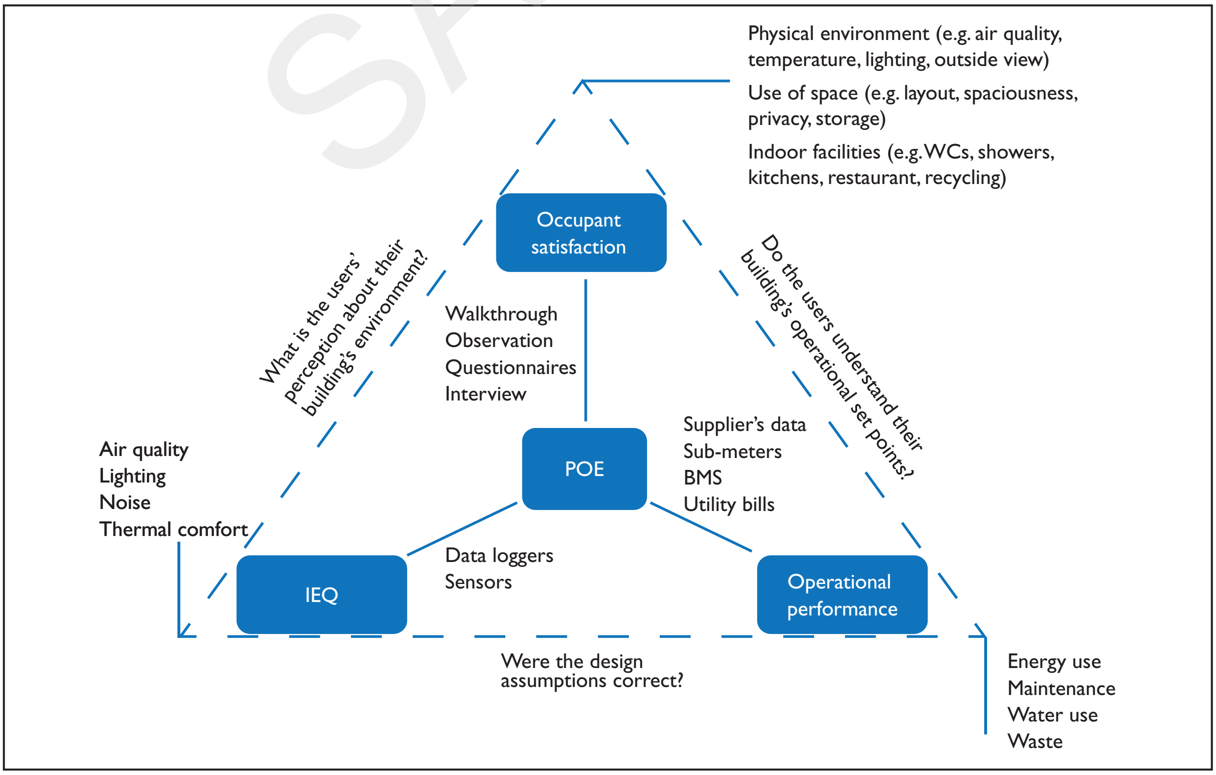
A key factor that contributes to the perpetuation of the performance gap in homes is the discontinuity in the involvement of the design and delivery teams with the homes once they are handed over and occupied. BPE can play a vital role in facilitating this feedback and help close this gap.

The terms "POE" and "BPE" are sometimes used together and there is often confusion between what the scope of each is. Post-occupancy Evaluation (POE) constitutes the activities of the BPE process once the building is occupied and in use, focusing on the operational performance and the occupants using the building. It is important to know to what extent the building maintains its occupants' satisfaction and perceived comfort. To do this in a systematic and structured way, post-occupancy evaluation (POE) can be employed as a major part of BPE. This would involve collecting feedback (sometimes described as soft data) from the occupants, and facilities team where applicable, through survey questionnaires, interviews and/or workshops (see Figure 1). Feedback would ideally be collected one year after building occupation to cover at least one seasonal cycle.

As shown in Figure 1, physical and technical data should also be collected to support and validate the soft data. This should include:

- Information about resource use (energy, fuel, water) of individual homes (through basic metering) and, where possible, a breakdown of where these resources are being consumed (through sub-meters)
- Information on the indoor environmental quality (IEQ) which can be evaluated by measuring temperature, humidity, CO_2 and pollutant levels, light levels, noise, and other factors that would impact the comfort and wellbeing of users

Figure 1: POE activities and methods



Powered flow hood, used for measuring flow rates from mechanical ventilation systems

- Energy monitoring
  - Energy monitoring – by installing monitoring equipment or using data from energy providers where available or from energy bills.
  - Data collection and analysis – by devising a collation and analysis strategy using a sub-metering or data collection facility already present in the building.
  - The results from the analysis may be compared to the design targets and/or other benchmarks such as those found in CIBSE TM46[5] and those published on www.carbonbuzz.org. This is a RIBA/CIBSE platform for benchmarking and tracking energy use in projects from design to operation. Energy monitoring, data collection and analysis are described in more detail in section 4.5.
- Understanding user perception – The following techniques can be carried out once a building is occupied. They can also be carried out at design stage if the occupants of the building are known, for example in the case of bespoke dwellings and refurbishments.
  - Walkthroughs
  - Survey questionnaires – these are described in more detail in section 4.6.
  - Semi-structured interviews
- Indoor Environmental Quality (IEQ) evaluation – A number of parameters can be measured and tested to evaluate the quality of the indoor environment in domestic buildings. Key parameters, such as temperature, humidity and CO_2 levels, can be give an overall idea of IEQ, and can be selected to investigate any specific issues reported by residents. The perception of users should be considered when making the evaluation. IEQ evaluation is described in more detail in section 4.7.

4.1 Building fabric: Airtightness testing

Airtightness testing (also known as air leakage testing, air pressure testing or air permeability testing) evaluates the rate of air infiltration through the entire building envelope. This is generally expressed in terms of the volume of air that escapes through the building fabric, and gives an understanding of uncontrolled heat losses that would take place. The test involves using a fan (or set of fans) to pressurise (and ideally depressurise) a building, and measuring the air flow rate required to maintain a pressure differential of an average of 50 Pascals.

Airtightness testing to specified standards must be carried out in all new buildings to demonstrate compliance with Building Regulations. However, the test can be used to carry out a more detailed investigation of the building fabric and can also be carried out on existing buildings. Achieving a good level of airtightness is important for the energy efficiency of a building.

Test methods and standards	
BS EN ISO 9972:2015[6]	*Thermal performance of buildings. Determination of air permeability of buildings. Fan pressurization method* – This standard superseded one of the same title, **BS EN 13829: 2001**, which is still widely referenced.
ATTMA Technical Standard L1[7]	*Measuring Air Permeability of Building Envelopes (dwellings)* – This standard, commonly referred to as ATTMA TSL1 applies to houses and flats.
ATTMA Technical Standard L2[8]	*Measuring Air Permeability of Building Envelopes (non-dwellings)* – This standard, commonly referred to as ATTMA TSL2, applies to buildings such as student residences and care homes, and covers the complexities involved with testing larger buildings.
CIBSE TM23:2001[8]	*Testing Buildings for Air Leakage*

Testing programme

- The building airtightness test should be carried out by a tester registered with ATTMA (The Air Tightness Testing and Measurement Association) or by a UKAS-accredited testing company.
- Testing should be carried out in accordance with the relevant standard.
- Pre-test: All mechanical ventilation openings should be sealed. All internal doors should be wedged open.
- During test: All exterior doors and windows must be kept closed during the actual pressurisation tests. Tests usually last for about 1 hour.
- Further information on the test regime can be found in the relevant standard.

4.2 Building fabric: Thermography

Thermography uses a special camera to provide an infrared image, indicating the temperatures of surfaces. This graphic representation helps illustrate the continuity of insulation installed and identify weaknesses in the thermal integrity of the construction.

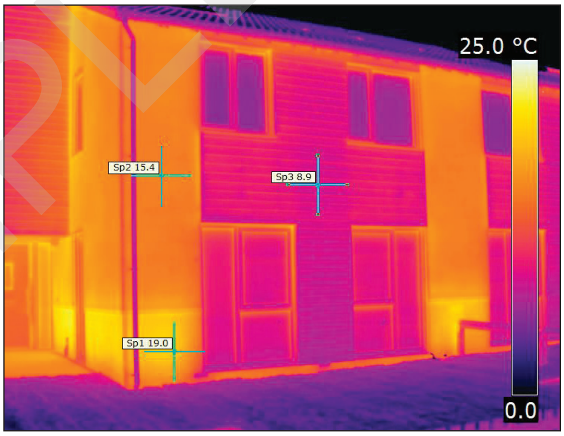
Thermographic images can also help locate air leakage paths, especially when carried out simultaneously with airtightness testing, which accentuates air movement through the fabric. While predominantly used to help evaluate the building fabric, thermography can be used to test underfloor heating installations as well, including acceptance tests for the system.

Test methods and standards	
BS EN 13187: 1999[11]	*Thermal Performance of Buildings. Qualitative detection of thermal irregularities in building envelopes. Infrared method.*
BG 39/2011[12]	*Thermal Imaging of Building Fabric*

Infrared camera used for thermal imaging

Picture courtesy of Flir Systems

External thermal image of a house



Testing programme

To carry out a successful thermographic survey, suitable environmental conditions are required prior to and during the survey, as follows:

- Ambient air to internal air temperature difference at least 5 K for previous 24 hours
- Wind speed <5 m/s
- No rain, mist or fog in the previous 2 hours or during the test
- Ambient temperature variations within ±3 K during test and for previous 1 hour and ±10 K during previous 24 hours
- No direct solar radiation on building surfaces to be imaged in the past four hours for masonry and one hour for lightweight construction

The survey may need to be undertaken during the evening or night. It is advisable to take a corresponding photograph to support the analysis and results.