PROSIECT CARTREFI O BREN LLEOL
THE HOME-GROWN HOMES PROJECT

BPE PROJECT TIMELINE

For further information:
https://woodknowledge.wales

BRIEFING & EARLY DESIGN

Define performance objectives – > ***Client sheet***

Identify relevant BPE lessons from past projects

Visit the site, ideally with future inhabitants

Use BPE lessons from past projects to inform the proposals

DESIGN DEVELOPMENT
See Design Stage sheet

- [ ] Site visit if possible, ideally with residents
- [ ] Design and documentation review
- [ ] Handover review
- [ ] Commissioning review
- [ ] Early stage overheating analysis
- [ ] Energy strategy review
- [ ] Airtightness review
- [ ] Thermal bridging and moisture review
- [ ] Acoustic review

Gather BPE lessons for future projects

If possible on larger projects, use BPE lessons from early phases to inform later stages of design and construction

IN CONSTRUCTION
See Construction Stage sheet

- [ ] Design and documentation review
- [ ] Handover review
- [ ] Site inspections and spot checks
- [ ] Airtightness checks and preliminary tests, and monitor change
- [ ] Commissioning
- [ ] Acoustic checks and testing of ventilation system
- [ ] Early stage overheating analysis – monitor change
- [ ] Energy strategy review – monitor change
- [ ] Thermal bridging and moisture inspections, and monitor change
- [ ] (if possible – Thermography spot checks)

Gather BPE lessons for future projects

If possible on larger projects, use BPE lessons from early phases to inform later stages of design and construction

COMPLETION & HANDOVER
See Completion & Handover Stage sheet

- [ ] Design and documentation review
- [ ] Handover review
- [ ] Site inspection and spot checks
- [ ] Airtightness test
- [ ] Commissioning, and plan for seasonal commissioning if required
- [ ] Acoustic checks and testing of ventilation system
- [ ] Early stage overheating analysis – record final, monitor change
- [ ] Energy strategy review – record final, monitor change
- [ ] Thermal bridging and moisture – record final, monitor change
- [ ] (if possible – Thermography spot checks)
- [ ] Put things are in place for in-use BPE: metering and monitoring systems, permissions and engagement from inhabitants and other users etc.

Gather BPE lessons for future projects

IN USE
See In Use Stage sheet

- [ ] Design and documentation review
- [ ] Handover review
- [ ] Review of design strategies: energy strategy, overheating risk, thermal bridging and moisture
- [ ] Site visit, if at all possible with inhabitants
- [ ] Airtightness re-test
- [ ] Commissioning review and recommissioning if required
- [ ] Acoustic checks and re-testing of ventilation system if required
- [ ] Energy use audit
- [ ] Water use audit
- [ ] Survey of inhabitants and other users
- [ ] (if possible – Thermography spot checks)
- [ ] (if possible – IEQ spot checks)
- [ ] **Making sense of it all:** Analyse BPE results altogether, to gain a holistic view of building performance
- [ ] **BPE reporting:** BPE techniques applied
- [ ] Results against initial objectives, regulations and best practice
- [ ] Overall building performance, what seems to work well and not
- [ ] Recommended next steps: interventions (if any), detailed BPE (if any)
- [ ] Lessons learnt

Gather BPE lessons for future projects

PROSIECT CARTREFI O BREN LLEOL
THE HOME-GROWN HOMES PROJECT

CLIENT SHEET

Project Name:

Date:

For further information:
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OBJECTIVES	TARGETS	Targets set? (tick boxes)	Target details	Results details
Inhabitants				
To not overheat	**OVERHEATING:** GHA tool to evaluate overheating risk level (Low/Med/High)	☐		
	CIBSE TM59 or other target	☐		
To keep warm in winter	See **ENERGY AND FABRIC PERFORMANCE**			
To have good daylight	**DAYLIGHT:** daylight factor/uniformity ratio etc	☐		
To be quiet inside	**ACOUSTIC COMFORT:** Do noise conditions on site (day and night) require an acoustic survey?	☐		
	Noise from HVAC services (dBA)	☐		
	Acoustic separation between adjoined units (dBA)	☐		
To have good air quality	**INDOOR AIR QUALITY:** Check design meets Building Regulations Part F v for background AND purge ventilation rates	☐		
	Indoor pollutant targets e.g. Max. VOC levels, formaledehyde (mg/m^3) or CO_2 (ppm)	☐		
To be mould/rot free	**MOISTURE CONTROL:** establish approach (permeable/not) and how timber elements will dry	☐		
	Set design moisture levels for major timber elements	☐		
User satisfaction	Commit to evaluating the satisfaction and comfort of inhabitants and, if applicable, other users e.g. facilities management team	☐		
Energy To minimise use	**ENERGY PERFORMANCE:** total energy consumption ($kWh/m^2/yr$, kWh/ dwelling/yr); space heating demand; Passivhaus certification	☐		
	On-site renewable energy generation (in addition to building performance consumption target)	☐		
	Associated metering and monitoring strategy	☐		
	FABRIC PERFORMANCE: Air tightness target ($m^3/hr/m^2$@50Pa or ach)	☐		
	Minimise thermal bridges e.g. Y-value per unit (W/m^2K)	☐		
	Maximum Ψ value for all thermal bridges (W/mK)	☐		
	Heat Loss/Heat Transfer Coefficient (W/K) & form factor	☐		
Water To minimise water use	**WATER CONSUMPTION:** (l/person/day)	☐		
BESPOKE TARGETS:	e.g. embodied carbon, social value	☐		

EVALUATION

Relevant BPE techniques & guidance

< DESIGN AND DOCUMENTATION REVIEW, HANDOVER REVIEW >

< SITE VISITS AND INSPECTIONS >

< COMMISSIONING AND PERFORMANCE TESTING >

< ASK INHABITANTS - SIMPLE USER SURVEY >

OVERHEATING
Overheating check

ACOUSTICS
Acoustic review, checks and tests

MOISTURE
Thermal bridging and moisture review

ENERGY STRATEGY
Energy strategy review

ENERGY USE
Simple energy use audit

AIRTIGHTNESS
Airtightness testing during construction and post-completion

WATER USE AUDIT
Simple water use audit

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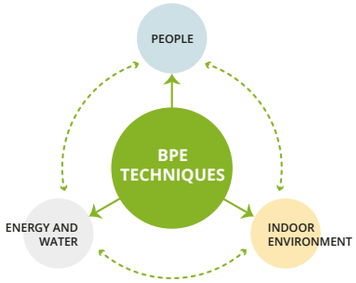
THE HOME-GROWN HOMES PROJECT

MAKING SENSE OF IT ALL:
Using BPE techniques to gain a holistic picture of building performance

For further information:
https://woodknowledge.wales



PEOPLE

- Direct user feedback
- Site observations and indications on user satisfaction with the operation of the building and its systems, and with the indoor environment

How are occupancy patterns and behaviour likely to affect energy consumption?

e.g. appliances, operation of windows and ventilation systems, occupancy density and hours etc

How do building and systems performance affect in occupant feedback?

e.g. winter and summer thermal comfort, noise from outside and from ventilation systems, perceived air quality, complaints about energy costs and risk of fuel poverty

BPE techniques

Design and documentation review
Commissioning
Handover review
Site visits

Energy strategy review
Airtightness review, site checks and tests
Thermal bridging & moisture review and checks
Early stage overheating analysis (GHA)
Acoustic checks & testing of ventilation system
(Thermography spot checks)
(IEQ spot checks, short-term monitoring)

Energy use audit

Water use audit
User surveys

How is IEQ affecting feedback from occupants? Are quantitative measures and qualitative feedback consistent with each other, and what may this indicate?

e.g. Comfort: feedback of summer discomfort but reasonable air temperature measurements: are there sensitive individuals? High humidity levels? Radiant discomfort from large glazed areas? Little air movement through limited openings ? How does this compare with the early stage overheating analysis?

e.g. Air quality: feedback on headaches vs measured formaldehyde levels, feedback on stuffiness vs CO_2 levels, feedback on dry air vs humidity levels ?

Are there causes for concerns about pollutant levels which occupants should be made aware of?

How may occupancy patterns and behaviour affect IEQ?

e.g. high washing / bathing impacting humidity levels; high occupancy affecting humidity and CO_2 levels; have occupants modified the intended operation of ventilation systems?

ENERGY AND WATER

- Metered data on energy and water use
- Physical (qualitative and quantitative) measurements of the performance of fabric and systems
- Site observations and indications on occupancy, behaviour, and the operation of the building and its systems, which may affect energy performance

Are there signs that building design, installation or operation may affect both energy consumption and indoor environment i.e. the operation of ventilation systems leading to energy inefficiencies, noise and poor air quality?

e.g. poor airtightness leading to pollutant ingress, draughts, and high energy use for heating; poor thermal bridging details leading to heat loss as well as condensation and mould growth?

INDOOR ENVIRONMENT

- Physical acoustic measurements (+ possibly IEQ)
- User feedback on perceived IEQ
- Site observations on perceived IEQ: BPE team's own perceptions, and indications of user interventions related to noise, air quality, thermal comfort, daylight and glare

PROSIECT CARTREFI O BREN LLEOL
THE HOME-GROWN HOMES PROJECT

CORE BPE TECHNIQUE

For further information:
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CORE BPE TECHNIQUE	WHEN CAN THE BPE TECHNIQUE BE APPLIED ?				WHAT PERFORMANCE OBJECTIVE DOES THE BPE TECHNIQUE HELP WITH?			DOES IT NEED AN EXPERT?	COST & TIME
	Design	In construction	Completion & handover	In occupancy	Energy & Water	IEQ	People		
Design & documentation review	✓	✓	✓(be aware to distinguish BPE from official PC sign-off)	✓	✓	✓	✓	No, but BPE experience is useful	£
Handover review	✓	✓		✓	✓	✓	✓		£
Site visits and inspections	✓if possible, ideally with residents	✓		✓	✓	✓	✓		£
Commissioning	✓	✓	✓	✓	✓	✓	✓	Yes - commissioning engineer	£-££
Energy strategy review	✓	✓	✓	✓	✓		✓(fabric first approach helps comfort)	No, but BPE experience is useful	£
Early overheating analysis	✓	✓	✓	✓	✓(overheating may lead to energy use for cooling)	✓	✓		£
Acoustic review, checks and tests	✓	✓	✓	✓	–	✓	✓	Yes - acoustician	£ £
Fabric Airtightness review, checks and testing	✓	✓	✓	✓	✓	✓	✓	Yes, for blower door test or low-pressure pulse test	£-££
Fabric Thermal bridging and moisture review and checks	✓	✓	✓	✓	✓	✓if severe e.g. mould growth, condensation	✓if severe and noticeable e.g. mould growth, condensation	Yes - someone experienced in thermal bridge analysis	£
Energy use audit	–	–	–	✓	✓	✓	✓especially. for residents in fuel poverty	No, but BPE experience is useful	£-££ depending on number of homes & metered data quality & quantity
Water use audit	–	–	–	✓	✓(hot water)	✓	✓e.g. poor quality fittings may be frustrating or get replaced		£
User surveys	–	–	–	✓	✓(poor usability may affect energy consumption)	✓(beware perceptions cannot be relied on for air quality)	✓	No, but BPE experience is useful	£ £

Generally speaking, the only Core BPE techniques which require an expert and are more expensive are those which are also linked to regulatory requirements; additional BPE costs may therefore actually be limited to doing it properly, not the full costs of that technique. The exception is for user surveys: this will vary with the number of homes, type of survey used, extent of time spent on site with residents to accompany the surveys etc; in addition, someone with BPE experience is recommended for depth of analysis and to liaise with residents sensitively.

PROSIECT CARTREFI O BREN LLEOL
THE HOME-GROWN HOMES PROJECT

PROJECT STAGE PROMPT SHEET

DESIGN

For further information:
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EMBEDDING PERFORMANCE IN THE DESIGN AND TEAM CULTURE

Performance objectives

- ☐ What are the performance objectives (energy, water, people, others), and are they clear? How have they been recorded and communicated to the team? How do they compare with regulatory minima and best practice? See > ***Client sheet***
- ☐ Overall, is there evidence these objectives have been incorporated in the design proposals? See > ***Design review***

Early in the design

- ☐ Is there a plan for BPE activities, and who will carry them out, with appointments in place?
- ☐ If the airtightness target is onerous (e.g. Passivhaus or equivalent), is an airtightness champion appointed?

Holistic design

- ☐ Carry out regular (at least at each RIBA checks) on the design, how it works together and how it compares with performance objectives – see list of BPE activities at this stage
- ☐ Have relevant project precedents been identified, especially those with BPE to identify performance issues, and lessons incorporated in the design?

Taking users into account

- ☐ Have future inhabitants and other users (including FM and building management teams) been given the opportunity to visit the site with the design team, or are there plans for this to happen?
- ☐ Have they had an opportunity to express what they want (e.g. workshop with the design team), and to comment and input into the performance objectives and design proposals? This is a good opportunity to embed sustainability objectives into the project. During the design development, what is the process for keeping them informed and involved with changes which could impact them? An early draft of the Building User Guide is useful for future users to comment on the format, outline content, and language, and an opportunity for the team to explain proposals clearly and to test whether they could work for future users
- ☐ If future residents and other building users are not known at this stage, what is the process for taking user considerations into account e.g. user representative? Learnings from other schemes?

EMBEDDING PERFORMANCE IN THE DESIGN AND TEAM CULTURE

Preparing for construction

Before start on site, check the following is in place, to deliver performance and facilitate in-construction BPE:

- ☐ Performance objectives are incorporated into the tender packages, and associated design checks and calculations (e.g. energy review, overheating risk review etc.)
- ☐ Construction team are aware of the performance objectives and of best practice procedures to follow
- ☐ Clear and agreed plan for in-construction BPE, with associated appointments, programme, resources and training
- ☐ Have the team identified design features which, based on past lessons, are likely to need careful follow-up during construction and handover e.g. complex systems; relatively new solutions to the wider industry or to the project team?

Preparing for handover

- ☐ Handover may seem a distant event during the design stage, but in fact the plans for handover and associated documentation should start being prepared at the design stage, including a dedicated period in the programme for handover activities and an agreed format and outline content for the Building User Guide – see > ***handover review***, and “taking users into account” above

Preparing the future BPE

- ☐ Have a plan for the in-use BPE stage: ideally, a scope of BPE activities to be carried out at the in-use stage, and who will carry them out; if future users are known, arrangements could start being put in place to explain to them the benefits of BPE, what it would entail, and check privacy and ethics implications
- ☐ Does the design allow in-use BPE? Have the requirements for future in-use monitoring been discussed and incorporated in the specifications, including the level of sub-metering and associated capability (logging, remote reading etc)? – see > ***design review***:

BPE ACTIVITIES AT THIS STAGE

- ☐ Design & documentation review
- ☐ Handover review
- ☐ Commissioning review
- ☐ Energy strategy review
- ☐ Airtightness review
- ☐ Thermal bridging & moisture review
- ☐ Early stage overheating risk analysis
- ☐ Acoustics review

BPE LEARNING LOOPS

- ☐ Identify and record BPE lessons from this stage. For example, this could be an early stage design decision (e.g. single-aspect building layout, highly glazed façade) which was flagged up in the design checks to create performance issues such as energy consumption and overheating risk, and which subsequently needed substantial amendment.

PROSIECT CARTREFI O BREN LLEOL
THE HOME-GROWN HOMES PROJECT

PROJECT STAGE PROMPT SHEET

IN CONSTRUCTION

For further information:
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EMBEDDING PERFORMANCE IN THE CONSTRUCTION PROCESS AND TEAM CULTURE

Performance objectives

- [ ] Are the whole team aware of performance objectives?
- [ ] Have the team been provided with appropriate induction and training? In particular, have site teams, including sub-contractors, received inductions and training on best practice construction for airtightness, including installation as well as storage?

Before start on site

Programme – is it in line with BPE plans and performance objectives?

- [ ] Is it in line with the sequencing strategy agreed before start on site to achieve the targeted airtightness? Is it clear when inspections of the thermal and airtightness lines, and preliminary and final airtightness tests will be carried out?
- [ ] Is there an allocated period for commissioning, in line with good practice and the original programme?
- [ ] Is there a buffer period identified for remediation / changes if required, and an agreed strategy in case of test failure or delays? Ideally this should include identifying opportunities for early inspections and checks e.g. inspections of construction details and commissioning of ventilation system on an early dwelling before roll-out across the scheme
- [ ] Is there a suitable period for handover?

BPE scope and appointments

- [ ] Are all appointments in place for BPE activities throughout construction? This should include: contractor and sub-contractors; design team members for input to final design, monitoring of changes and site inspections; BPE site visits, inspections and testing (e.g. early airtightness testing, construction details to minimise thermal bridging); commissioning; additional appointments if required e.g. clerk of works
- [ ] Is there an airtightness coordinator, or "champion"? This is recommended if the target is onerous e.g. Passivhaus.

Checking the installation is as intended

See > ***site inspections – in construction***
Change management: If design issues that are still being detailed, or if changes and substitutions occur, their possible impact on building performance should be assessed, including a review of performance objectives. A revisit of the design checks is then useful (i.e. > **design review, airtightness review, overheating review, thermal bridging** and **moisture review**)

Taking users into account

- [ ] Have future inhabitants and other users (including FM and building management teams) been given the opportunity to visit the site?
- [ ] What is the process for keeping them informed and involved with changes which could impact them?
- [ ] Is there a draft of the Building User Guide? Have future inhabitants, FM and building management teams had an opportunity to comment?

PREPARING THE NEXT STAGE

Preparing for handover

- [ ] see > ***Handover review***

Preparing the future BPE

If possible, start to put in place the plans for the in-use BPE stage:

- [ ] Which BPE tests will be carried out, and who will carry them out
- [ ] Arrangements with future residents and other building users

BPE ACTIVITIES AT THIS STAGE

- [ ] Design & documentation review
- [ ] Handover review
- [ ] Site inspections and spot checks
- [ ] Airtightness checks and tests
- [ ] Commissioning
- [ ] Acoustic checks and tests
- [ ] Review implementation, record and monitor change: energy strategy, thermal bridging and moisture, overheating

BPE LEARNING LOOPS

- [ ] Identify and record BPE lessons from this stage. For example, this could be a design detail making airtightness inspections and remediations more difficult.

PROSIECT CARTREFI O BREN LLEOL
THE HOME-GROWN HOMES PROJECT

PROJECT STAGE PROMPT SHEET

COMPLETION & HANDOVER

For further information:
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CHECKING PERFORMANCE OBJECTIVES HAVE BEEN IMPLEMENTED DURING DESIGN AND CONSTRUCTION

Performance objectives

- ☐ Check and record test results vs performance objectives (see > ***client sheet***).
- ☐ Note - It is important not to confuse the BPE exercise with the formal signoff process and regulatory checks: BPE checks have a specific focus, and do not negate the need for the formal approval process, which should be covered by dedicated appointments.
- ☐ Pay particular attention to the airtightness test and commissioning, as these are essential elements which affect all aspects of performance including energy use, comfort, and air quality. Airtightness is also a good indicator of overall build quality.

Additional actions and remediations

- ☐ Apply remediation before Practical Completion wherever possible, as the focus of teams tends to move away from the project afterwards; where this is not possible, agree whether remediation will be part of the defects list, who will carry it out, and timescales
- ☐ If seasonal commissioning will be required, include it in appointments and the programme, and inform users of why it is beneficial

Taking users into account

- ☐ Is all handover information ready and satisfactory, and have future residents and other building users had the opportunity to comment and confirm it meets their needs?
- ☐ Have site visits and inductions been carried out with future residents and other building users?
- ☐ See Review of handover processes and documentation Have future inhabitants and other users (including FM and building management teams) been given the opportunity to visit the site?

PREPARING THE NEXT STAGE

Preparing the future in-use stage and BPE

- ☐ Are all systems which will be used in the BPE activities (e.g. meters, sensors) commissioned?

Put in place the detailed plan for in use BPE:

- ☐ Scope of BPE activities, who will carry them out, and when
- ☐ Arrangements with users – timing and access, clear proposals for what will be done and the implications it will have for them (time, disruption, installation of equipment etc) as well as the benefits they can gain from it (e.g. opportunity to feedback on what doesn't work, or to get additional support if things are too complex), ethics and privacy approval.

BPE ACTIVITIES AT THIS STAGE

- ☐ As-built design & documentation review
- ☐ Review of handover process and documentation
- ☐ Site inspection and spot checks
- ☐ Airtightness test
- ☐ Commissioning
- ☐ Acoustic checks and testing of ventilation system
- ☐ Review of strategies against as-built state: Early stage overheating analysis, energy strategy, thermal bridging and moisture – record final, monitor change

BPE LEARNING LOOPS

- ☐ Identify and record BPE lessons from this stage. For example, this could be the ventilation design making measurement of air flow and commissioning more difficult.

PROSIECT CARTREFI O BREN LLEOL
THE HOME-GROWN HOMES PROJECT

PROJECT STAGE PROMPT SHEET

IN USE

For further information:
https://woodknowledge.wales

EVALUATING OVERALL BUILDING PERFORMANCE

Performance objectives

- [ ] Record any performance objectives set for the project - see > ***client sheet***
- [ ] Check and record results of BPE tests against performance objectives (if applicable).

Note - It is important not to confuse the BPE exercise with the snagging and defects period: BPE checks have a specific focus, and do not negate the need for formal processes, which should be covered by dedicated appointments. This is also why it is useful for the in-use exercise to take place after the first year of occupation, to distinguish it with a clear focus on in-use performance.

Before any in use BPE

- [ ] Ensure agreements are in place with inhabitants and other users, taking account of privacy and ethics and ensuring they understand the implications e.g. equipment, time, disruption etc
- [ ] Ensure any installed meters and sensors to be used in the BPE are commissioned – as a very minimum, this should cover the mains energy and water meters; ideally, sense checks on the monitored data could be done before the in-use BPE exercise proper, to make sure the data will be reliable enough. This should not be neglected and can take time.

Taking users into account

- [ ] See agreements, privacy and ethics above
- [ ] Involve inhabitants and other building users as much as possible in the BPE exercise: this should include the feedback surveys, but also site visits and informal interviews at that time, if they agree. They will be invaluable sources on information and insights on how well the homes work.

Making sense of it all

- [ ] Review BPE results against performance objectives, good practice, and regulatory minima. Ideally, this should include a comparison of how objectives and BPE results evolved from the briefing stage, specifications, as-built tests (if available), and the in-use BPE tests: this can give a good indication of how much importance was given to performance and how well it was embedded in the project. Pay particular attention to the airtightness test and commissioning, as these are essential elements which affect all aspects of performance including energy use, comfort, and air quality. Airtightness is also a good indicator of overall build quality.
- [ ] It is essential to review results from all the BPE techniques together, in order to build a holistic image of building performance and start to identify possible causes and solutions: conclusions based on the results from a single BPE technique should generally be treated with a lot of caution - See diagram > ***making sense of it all***

REPORTING ON BPE

The BPE report should include the following:

- [ ] a brief description of the project, building, and its context
- [ ] Key findings: overall performance in each aspect (people – satisfaction and comfort, IEQ, energy, water, fabric); what works well, what less so
- [ ] Possible causes for under-performance and possible improvement measures
- [ ] Recommended detailed BPE as a next step, why, what it could bring
- [ ] Other recommended next steps, if relevant. For example, this could include recommissioning, additional training to residents, a revised Building User Guide. Note that substantial interventions on the building are not recommended as a result of core BPE alone, unless the issue that needs addressing has very clear reasons and solutions. Usually, a more detailed investigation would be required.
- [ ] Lessons for future projects
- [ ] Give sufficient time and opportunities for the client and the residents and building users to comment on the report before final versions, and to confirm they are happy with the information included, including confidentiality and privacy issues

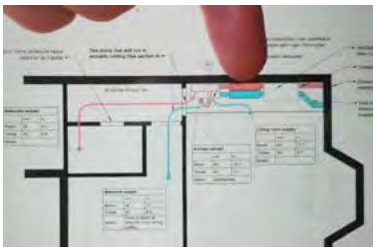
BPE ACTIVITIES AT THIS STAGE

- [ ] Site visits – home tour, ideally with inhabitants and with a simple photographic survey.
- [ ] Design and documentation review
- [ ] Handover review
- [ ] Review of design strategies: energy strategy, overheating risk, thermal bridging and moisture
- [ ] Airtightness re-testing
- [ ] Commissioning review and re-commissioning if required
- [ ] User surveys (i.e. inhabitants but also FM, building manager and others if relevant)
- [ ] Energy use audit
- [ ] Water use audit
- [ ] Acoustic checks and re-testing if required

BPE LEARNING LOOPS

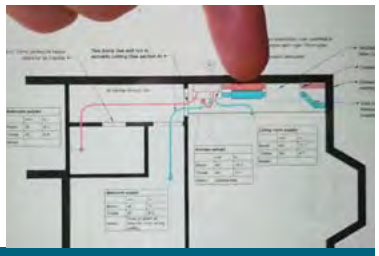
- [ ] Identify and record BPE lessons from this stage. There should be plenty of them, covering all aspects of building performance (energy, people, indoor environmental quality), and ranging from design issues, procurement, through to construction, or about the BPE activities themselves.

DESIGN AND DOCUMENTATION REVIEW



CORE BPE TECHNIQUE	
Applicable performance objective and target	All.
Why do it i.e. where it adds value, what it can help with	A design and documentation review helps to assess how building performance is embedded in a project, from the overall strategy to individual design elements. At the design stages, it can help identify changes which would benefit performance. In use, it can help identify problems and potential causes and remediation, often before even visiting a building or receiving feedback.
When to do it	It is useful to have building performance as standing item on meeting agendas; in addition, formal reviews should happen ideally at each RIBA stage, before sign-off, to embed building performance. Reviews evolve as the project progresses, starting with strategic issues such as elevations, site and building layout, and moving to details and change management in later stages. In-use: to contribute to the overall evaluation of performance.
How to do it Tips and tricks	The review should at the minimum include the following: ☐ Outline brief and performance objectives, with a holistic view: energy and carbon, people, and indoor environmental quality ☐ Key drawings for the home or a typical home in the scheme ☐ Energy & sustainability strategy, systems, controls, metering. Consider not only the design proposals, but also their operational and maintenance implications, how users have been considered and involved, and whether the design took account of past projects and BPE lessons – this would be a very positive sign. See prompts below for issues to look at. More detailed design checks should be carried out alongside: ☐ **> Core BPE - *Handover review*** ☐ **> Core BPE - *Energy strategy review*** ☐ **> Core BPE - *Thermal bridging and moisture review*** ☐ **> Core BPE - *Commissioning - design stage*** ☐ **> Core BPE - *Acoustic review, tests and checks*** ☐ **> Core BPE - *Airtightness review*** ☐ **> Core BPE - *Early overheating risk (Good Homes Alliance)***
Needs an expert?	No, but someone experienced in design and building performance.
Cost and time	£. Typically up to a day of the BPE team per review; the design team and possibly client should be involved at design stages.
Regulations	No.
Specific considerations for timber construction	Designing for moisture and airtightness; low-VOC specifications.
What to do with the results? i.e. how to interpret results & identify next steps (remediation or BPE)	Alongside other BPE techniques: picture of how well performance objectives were embedded in the project; identify elements that need resolving and/or detailing in the next stages; recommended changes for the project team to consider. **Possible detailed BPE as next step:** tbc with other BPE findings.

DESIGN AND DOCUMENTATION REVIEW



PROMPTS FOR QUESTIONS AND ISSUES TO LOOK AT

Note – this is not meant as design guidance, but to highlight key principles that the BPE and design teams should be aware of and raise at BPE design reviews to identify possible performance issues and facilitate future BPE. Additional issues will be identified on each project, for example through past BPE lessons.

Taking users into account

- [ ] Have future inhabitants and other users (e.g. facilities managers) been considered in the design? This could include their input directly if possible, via a user rep, or at the very least via past BPE lessons.
- [ ] If they are known, have they had the opportunity to comment on the scheme? Has their feedback been incorporated, or are there plans for this to happen?
- [ ] What is the strategy and type of controls (including lighting, temperature, and ventilation)? How easy and useful do they seem to be?
- [ ] **Ease of use and maintenance:** Do the proposals seem appropriate for the resources expected to be available once homes are occupied? Proposals should be very simple for individual homes without FM or management team, but even larger schemes may only have limited resources, so complexity should be avoided.

Designing for good Indoor Environmental Quality, health and comfort

- [ ] Do all habitable rooms have openable windows? What are the opening mechanisms? Are there security or health and safety implications, or other barriers to having windows open?
- [ ] Has there been a team discussion on the most appropriate ventilation strategy, considering air quality as well as energy efficiency? e.g. humidity control, provision of fresh air, outside air pollution, internal finishes.
- [ ] If mechanical ventilation is provided, do mechanical air inlets avoid sources of pollution e.g. from roof or courtyard side, rather than onto a busy road?
- [ ] If the site is exposed to pollution (e.g. most urban areas in the UK), is mechanical ventilation with a filter for fine particulates provided? Is this accounted for in energy calculations and ventilation design?
- [ ] Designing to limit overheating risk: see > ***Core BPE - Early overheating risk***
- [ ] Have general principles of designing for good daylight been incorporated? This should include, as very minimum:
  - [ ] Do proportions of glazing seem reasonable? Beware rooms where glazed areas are below 20% of the floor area, as this could be insufficient for good daylight; inversely, check that glazed areas are not excessive, as this could cause winter discomfort, heat loss, and summer overheating.
  - [ ] Position of glazed areas: glazing below sill height and in corners will contribute little to daylight, but contribute to heat loss and solar gains.
  - [ ] Types of window openings that consider ventilation (background, purge, and summer comfort), safety, security; interaction with shading devices.

Water strategy review

- [ ] Are the design and specifications in line with water performance objectives? This should be relatively simple, as efficient water appliances are becoming routine, but it is important to check their quality as otherwise they may be frustrating for users and even get replaced. Feedback from previous schemes is useful here, to identify appliances and fittings to select or avoid. Check consistency between architecture and engineering specs (e.g. fittings may be in the architectural package, and restrictors in the public health engineer's package).
- [ ] Water metering & monitoring: water meters should always be provided, and easily accessible for residents. For BPE, ideally they would have logging and remote monitoring capability. Water recycling systems should be submetered so their contribution can be established.
- [ ] Pay attention to complex systems with operational and maintenance implications e.g. greywater recycling, or rainwater recycling if other than a simple water butt. Make sure they are appropriate for the expected maintenance resources, and that future users are aware of it.

Overall performance, and how things work together

Are performance objectives clear and recorded? Depending on their appointment, the BPE team may highlight opportunities for improvements to targets or design assumptions, or where they may be over-optimistic.

Do the design and specifications overall reflect the objectives and/or best practice for energy, water, indoor environmental quality, and user comfort and satisfaction?

Do the design proposals work together as a whole, noting interactions between disciplines and building elements? Are assumptions and design proposals consistent with each other? For example, pay attention to assumptions on window openings in acoustic report, overheating risk assessment, architectural design, and engineer's ventilation assumptions

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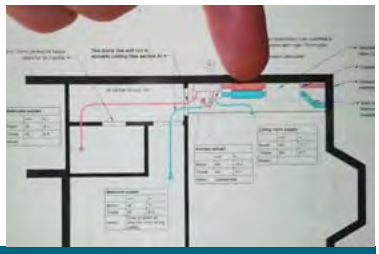
DESIGN AND DOCUMENTATION REVIEW

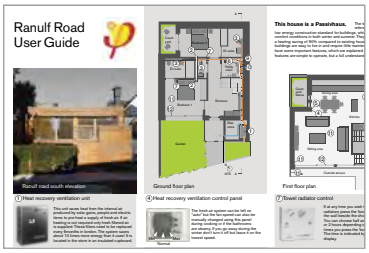


PROMPTS FOR QUESTIONS AND ISSUES TO LOOK AT (Cont.)

Embedding BPE and learning loops

- [ ] Have relevant project precedents and BPE been identified, and lessons incorporated? This can apply to the design proposals but also wider elements of the project, such as the procurement route or appointments.
- [ ] Have the team identified elements which, based on past lessons, are likely to need careful follow-up during the next design stage, construction, practical completion and handover e.g. complex systems; relatively new solutions to the wider industry or to the project team?
- [ ] Are there clear plans for BPE in construction and in use, and does the design allow this? In particular, have the requirements for in-use monitoring been discussed and incorporated in the specifications, including the level of submetering and associated capability (logging, remote reading etc)? This should include:
  - [ ] Energy metering and monitoring: see > ***Core BPE Energy strategy review***
  - [ ] Water metering and monitoring: see > ***water strategy review***.
  - [ ] Indoor Environmental Quality monitoring: What aspects need to be validated/verified by monitoring? This should consider the data that would be useful, how monitoring should be integrated in the design, or whether it can be addressed through bespoke equipment later on, as part of in-use BPE. For example, while temperature and humidity sensors are relatively common and cheap, they typically would not have logging capability, but this could be specified if the need is identified e.g. if there are concerns about fuel poverty and risks of under-heating, or concerns about overheating. Some projects may want to monitor other pollutants but this is less common and likely to be with a research outlook or specific to circumstances e.g. particulate matters to assess new filtering systems or if future inhabitants are known to be sensitive; formaldehyde to check the impact of low-VOC specifications on indoor air quality.

HANDOVER REVIEW



CORE BPE TECHNIQUE

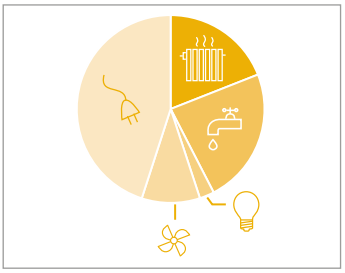
Applicable performance objective and target	All
Why do it i.e. where it adds value, what it can help with	The handover is often neglected due to programme and commercial pressures near project completion. It is essential to good performance and maintenance, and should include: ☐ Documentation on the home and how to operate it well, aimed at residents and other users (e.g. FM); the information should be complete, relevant, and easy to understand. ☐ The process itself including training and inductions.
When to do it	Handover itself occurs around practical completion (PC) but must be prepared during design and construction. A handover review is also useful in-use, to assess the support provided to users on how homes are meant to work. A poor handover could, at least partly, explain a lot of issues.
How to do it Tips and tricks	**Note** - It is important to distinguish the BPE handover review from the formal sign-off process and regulatory checks: BPE has a specific focus and does not replace the formal approval process. **Design stage:** ☐ Are there proposals for the format and content of the Building User Guide? Will future residents, FM and building management teams be given an opportunity to comment? Early drafts of the Guide are an opportunity to explain design proposals and get feedback from future users. ☐ What are the plans for handover? Do they include site visits and training? Will there be support (on or off site) for a period after completion? Are residents and other users satisfied with the plan e.g. would they like “live” inductions, not online? **Completion and handover stage, and in-use:** ☐ Are handover documents (including a simple Building User Guide) available at or near completion? Have residents and other users had the opportunity to comment before the final version? Are they even aware these exist (often not the case)? ☐ Do these documents seem complete, accurate, and easy to understand? Do they cover features which may be complex or unfamiliar (e.g. mechanical ventilation, thermal mass or movable external shading), or need maintenance (e.g. filters)? ☐ Was additional support available in a variety of methods for at least a few weeks or months around completion e.g. visits, training, online, recorded videos, support team on- or off-site?
Needs an expert?	No.
Cost and time	£
Regulations	O&M documentation.
Specific considerations for timber construction	–
What to do with the results? i.e. how to interpret results & identify next steps	tbc, depending on issues uncovered, but often will recommend better handover documentation and/or support to residents. **Detailed BPE as next stage:** n/a

INITIAL OVERHEATING ANALYSIS (GHA TOOL & GUIDANCE)

CORE BPE TECHNIQUE

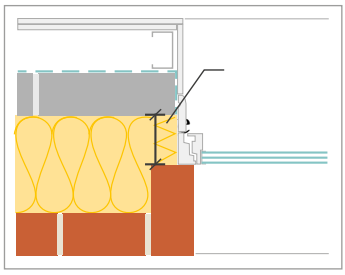
Applicable performance objective and target	To not overheat. **Target:** GHA overheating tool score.
Why do it i.e. where it adds value, what it can help with	Overheating in homes has become a significant issue, affecting the comfort and wellbeing of many thousands of people. In the worst cases overheating extends throughout large parts of the year, not just in the warmest months, and the frequency and extent of this are expected to increase with climate change. Use the GHA overheating in new homes tool to assess level of overheating risk. Base the assessment on the scheme as a whole, but take note of any individual units likely to score higher, and consider specific mitigations.
When to do it	At an early design stage, and absolutely before planning. It is wise to review the assessment at key points to check that any design changes won't have unintended consequences impacting on the overheating risk.
How to do it Tips and tricks	The tool includes a one page reckoner that asks 14 questions split between risk factors and mitigations. Each question is scored based on the scheme assessed, with the total score summed at the bottom. An overheating risk assessment cannot guarantee that a home will never overheat during a heat wave or a very swinging party but it is important that any home can cool effectively once a heat event passes, and this is usually achieved via opening windows. Where there are barriers to windows opening the situation becomes more challenging and other options may need to be considered. Mechanical cooling will increase energy consumption, can be costly to run, and the heat rejection can increase temperatures in the local microclimate exacerbating the problem for neighbours. For these reasons mechanical cooling solutions are not recommended if they can possibly be avoided.
Needs an expert?	No.
Cost and time	£
Regulations	Building Regulations do not currently include an effective overheating check (SAP criterion 3 is not considered very robust). It is anticipated that some form of new overheating check may be consulted on soon. The use of the GHA assessment tool is now required by the Greater London Authority (GLA) for referable developments in London.
Specific considerations for timber construction	No significant implications for timber construction. Timber construction dwellings are typically of lighter thermal mass, and lightweight dwellings are more likely to heat up quicker, but equally will cool down faster when well ventilated with cooler air.
What to do with the results? i.e. how to interpret results & identify next steps	If the tool predicts a significant overheating risk (a total score >10) then review elements triggering the higher risk and whether design can be adapted to mitigate some of this risk. **Possible detailed BPE as next step:** If the score cannot easily be reduced then commission a CIBSE TM59 assessment to further explore the risks and suitable mitigation measures.

ENERGY STRATEGY REVIEW



CORE BPE TECHNIQUE.	
Applicable performance objective and target	To minimise energy consumption, to keep warm in winter **Targets:** Energy consumption (kWh/m²), space heating demand (kWh/m²), Heat transfer coefficient (W/K), thermal bridges (W/m²K), contribution from on-site renewables (kWh/m²).
Why do it i.e. where it adds value, what it can help with	It is necessary to have some understanding of the energy performance of homes being designed, to be able to meet minimum standards and strive for enhanced performance. Energy performance will be affected by the building form, building fabric, services and equipment. Best results are achieved when all factors are optimised. As a very minimum, all projects should include SAP calculations and a review of the design from an energy perspective. For more onerous targets anddesign input, detailed calculations are recommended – see > ***detailed energy modelling.***
When to do it	At the design stage. Calculations usually need to be revisited several times to ensure that targets continue to be met as the design evolves. Very early stage calculations might only cover one or two sample units, with more units included as the design settles. Calculations must be updated to reflect 'as-built' at completion.
How to do it Tips and tricks	At the design stage, a review of the energy strategy should include: • Passive design principles including orientation, building form and layout, glazing location, glazing areas, and shading • Ventilation: if mechanical (recommended in airtight homes), optimise heat recovery % within MVHR units • Check the duct types and routes; are bends and length minimised? • Heating and hot water: plant efficiency, at full and part load? • SAP calculations: high-level review of results, inputs, consistency with design documentation; is SAP sufficient for the objectives, or are more detailed calculations required – see > ***detailed BPE Energy Modelling*** • Thermal bridging review – see > ***core BPE*** • Designing for airtightness – see > ***core BPE design review*** Focus on predicted energy consumption rather than carbon emissions as these fluctuate depending on carbon factors used.
Needs an expert?	Yes and no: an accredited SAP assessor is required for Building Regulations at completion; at the earlier stages, experienced modellers can carry out the calculations and review, and add value to the design.
Cost and time	£
Regulations	SAP calculations are required to produce an Energy Performance Certificate (EPC) at completion and demonstrate compliance with Part L. The current version (as of August 2020) is SAP 2012. SAP 10.1 has been released and consulted on.
Specific considerations for timber construction	None.
What to do with the results? i.e. how to interpret results & identify next steps	Compare energy calculation results with targets and review possible improvements. Calculations can factor in the contribution from any onsite renewables, but results should also be presented without to represent the performance of the building itself. **Possible detailed BPE as next step:** PHPP, dynamic modelling – see > ***Detailed BPE energy modelling***

THERMAL BRIDGING AND MOISTURE REVIEW & SITE CHECKS

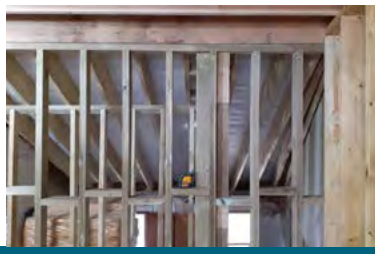


CORE BPE TECHNIQUE.	
Applicable performance objective and target	Low energy use; prevent fabric degradation and mould growth **Targets:** Y-value for overall thermal bridging (W/m²K), Ψ value for individual thermal bridges (W/mK).
Why do it i.e. where it adds value, what it can help with	Understanding thermal (or cold) bridging is an important aspect of fabric performance, and it will feed into energy calculations. Thermal ridges are not just a location of heat loss, but can also lead to condensation and mould growth. The design stage review should also check the strategy for moisture content and movement, and assess how details will be built: more complex details introduce greater risks of heat loss and of buildability, so they should be justified.
When to do it	At design stage to inform the proposals and energy calculations. Inspections and spot checks during construction.
How to do it Tips and tricks	**Design stage:** review whether the proposals introduce a risk of high thermal bridging e.g. very articulated facades, discontinuity of insulation at junctions and penetrations, complex details. If so, simplifications should be considered. Establish whether details from Accredited Construction Details (ACDs) or reliable sources can be used, otherwise bespoke calculations will be required – see > ***detailed BPE - Thermal bridge analysis*** and > ***Detailed BPE - Moisture dynamic analysis*** Key principles to check related to moisture include: • Have inwards and outwards moisture flows been considered in the design e.g. selection of materials, air gaps, rain screens etc? Is the approach consistent with the approach to heat flows i.e. vapour control, or breathable approach? • Are the specifications clear on moisture content, and the need to check it at arrival on site and before installation? **Construction:** Inspect how materials are stored and protected from water damage, and spot check the moisture content of timber being installed; spot checks the installation, particularly complex details and possibly with a thermal imaging camera; spot checks the build-up is as per specified, particularly the elements responsible for air, heat and moisture flows (e.g. air gaps, insulation, breathable membranes etc).
Needs an expert?	Could be architect, energy modeller, or Passivhaus designer, but with a good understanding of building physics and materials properties, and experienced in thermal bridging analysis.
Cost and time	£ (review) £-££ (if bespoke thermal bridging calculations required).
Regulations	Building Regulations Part L1A calculations (SAP) take account of thermal bridges; for non-repeating bridges, this can be based on calculations, or a set value if ACDs are used (tbc with future versions of SAP), or a (worse) default value.
Specific considerations for timber construction	Reducing the risk of condensation (surface or interstitial) is particularly important in timber construction, as it could lead to fabric degradation and even structural failure. Risks are often with the structure, so early input from the timber frame manufacturer is recommended.
What to do with the results? i.e. how to interpret results & identify next steps	Note what the key thermal bridges are and whether there are sequencing or other issues that need to be communicated to the site team to ensure they are constructed correctly. **Possible detailed BPE alongside or as next step:** If concerns cannot be resolved, detailed thermal bridge analysis and/or heat & moisture analysis (e.g. WUFI) may be required – see > ***detailed BPE - Thermal bridge analysis*** and > ***Detailed BPE - Moisture dynamic analysis***

SITE VISIT - IN CONSTRUCTION

CORE BPE TECHNIQUE	
Applicable performance objective and target	All.
Why do it i.e. where it adds value, what it can help with	Site visits are an invaluable way to gather information on all aspects of building performance. They should aim to capture general observations as well as key aspects of the fabric and services installation.
When to do it	At several points in the build programme, ideally agreed with the project team early and considering key elements such as airtightness and thermal lines, and ventilation systems.
How to do it Tips and tricks	**Note** - The intention is spot checks with a BPE focus, not a thorough review of the installation such as that from Clerks of Works, which would require a more expansive and defined scope. The BPE visits will show site teams that attention is paid to building performance, and will give an overall indication of whether the project has good procedures and generally seems to implement the agreed design strategy. ☐ Make a note of site procedures, site information etc – site tidiness can be a useful indicator of how a project is run and overall attention to quality. ☐ Are the team aware of performance objectives? Do they seem to have received suitable induction, and training and supervision on key issues such as airtightness? ☐ Are site workers encouraged to report issues such as poorinstallation (e.g. no blame culture)? This can be extremely useful to spot errors when they can still be rectified. ☐ Spot checks that key elements of the building performance strategy are incorporated - see prompts below.
Needs an expert?	Not necessarily, but someone experienced in BPE and construction.
Cost and time	£
Regulations	No
Specific considerations for timber construction	Airtightness and moisture – see specific considerations above.
What to do with the results? i.e. how to interpret results & identify next steps	Site visits and spot checks are inevitably limited and may not be representative, so should not be over-interpreted. They can however be useful pointers for further investigation, and to correlate with other findings e.g. from a review of design changes. **Possible detailed BPE as next step:** More thorough inspections and a review of design changes, if the visits indicate a pattern of poor implementation. A broader review of site procedures and quality management may be needed, as this may raise concerns about overall quality, not only building performance.

SITE VISIT - IN CONSTRUCTION



PROMPTS FOR ISSUES TO LOOK AT

Note – this is not meant as guidance on best practice site procedures, but to highlight key issues that the team should be aware of during their BPE site inspections, as they will facilitate future BPE and help reduce the risk of uncovering performance issues in the later stages of BPE. Additional issues will be identified on each project, for example through past BPE lessons.

Airtightness	☐ See > ***Technique one-pager - airtightness***
Thermal bridging & Moisture (particularly in the case of timber construction)	☐ See > ***Technique one-pager – Thermal bridging and moisture***
Indoor air quality	☐ Check indoor materials are installed as per specifications, including low-emission products. Pay particular attention to materials known to often be an issue, such as glues, varnishes, and processed timber products. ☐ Check air inlets are protected from dust ingress during construction; alternatively, ducts will need cleaning on completion ☐ Checking air inlets are free from blockages (towards the end of construction) ☐ See also moisture, above, as poor moisture management could create mould and air quality issues later on ☐ Commissioning of ventilation: see Core BPE > ***commissioning***
Other examples of spot checks and elements usually needing attention	☐ Windows as designed for good air flow, security and safety etc. ☐ Glazing specifications, openings, shading devices (fixed or movable) as per daylight and overheating strategy ☐ Installation of MVHR e.g. type, routing and fixing of ducts as specified, filters if specified ☐ Water strategy – spot checks on water fittings ☐ Any item identified during the design stage as needing care during construction and installation e.g. complex details, complex systems and their controls

SITE VISIT – IN USE

CORE BPE TECHNIQUE.	
Applicable performance objective and target	All
Why do it i.e. where it adds value, what it can help with	A site visit is an invaluable way to gather information on all aspects of building performance. Even a simple walk-around can bring valuable insights, particularly for experienced BPE practitioners.
When to do it	After the first year of occupation, ideally twice in order to capture winter and summer observations. As much as possible this should be when residents are present, for a walk-around with them and to distribute or collect the formal user surveys.
How to do it Tips and tricks	☐ Before any visit, ensure agreements are in place with inhabitants and other users, taking account privacy and ethics. Residents must have explained to them what the site visit will entail, and give permission for any photo and measurement. ☐ It is usually better for at least 2 members of the BPE team to visit together. Surveys should be distributed to all, but not all homes need to be visited – one or a sample is sufficient. ☐ A prompt sheet is provided below with typical issues to look for. In addition, the design review can help identify additional elements that will need checking on site. Furthermore, the visit should be informed by feedback from residents, who may highlight particular issues. Ideally they should be encouraged to show what works and not, room by room. ☐ Note observations on outside conditions during the site visit, and the date and time period (to check local weather and air quality data afterwards).
Needs an expert?	Not necessarily, but someone with experience in both technical and user engagement aspects of BPE.
Cost and time	£
Regulations	No.
Specific considerations for timber construction	n/a, but note any related observations or feedback from users.
What to do with the results? i.e. how to interpret results & identify next steps	Spot checks are inevitably limited and may not be representative, so caution will be needed not to over-interpret them – see advice in "**making sense of it all**". They can however be useful as a pointer for things to investigate further, and to correlate practical observations with user feedback and other BPE results. The site visit may recommend more thorough inspections if the spot checks seem to uncover a pattern of poor implementation. **Possible detailed BPE as next step:** tbc with overall BPE results.

SITE VISIT – IN USE

PROMPT SHEET FOR ISSUES TO LOOK AT

Note – this is not meant as an exhaustive list of issues to look at during site visit, but to highlight typical things to look for during their BPE site visits, as, to cover the main aspects of building performance (people, energy, water, IEQ and fabric) and point to things which often do not work well. Other relevant issues will be identified on a case-by-case basis on each project, including items uncovered through the design and handover reviews, from past BPE lessons, through feedback from inhabitants and other users, and by the very nature of the site visit.

User feedback
(residents, but also facilities managers, building mangers, and other regular users e.g. carers in elderly homes, cleaning staff in common areas etc.)

- [ ] Feedback could be gathered very informally, to capture what users want to raise, particularly if more formal user surveys will be carried out and ensure that issues are explored more systematically– see Core BPE > **User surveys**. Even when informal, this can be a highly valuable way to gather feedback, spot issues which could be missed or dismissed otherwise, and put other BPE results into context.
- [ ] Site observations can be general or specific about how it is to live here and (e.g. for building management teams) work in, operate and maintain the building. This could include ease of use, comfort (summer, winter), light and noise levels, perceived air quality, usability and functionality of the home (e.g. storage, cycle storage, access to and quality of outside space…)
- [ ] Are the residents and building management team aware of performance objectives? This is particularly relevant if the project had high aspirations such as low-energy or low-carbon homes, exemplar timber construction
- [ ] User feedback on the design construction and handover process: how involved do they think they could be before, during and after handover e.g. opportunities to learn about and comment on the design proposals, visit the site and comment on handover documentation? Do they know of their building user guide (if there is one), and is it useful and easy to understand? Is the information relevant? What do they think of the support they received in the early period of occupation?

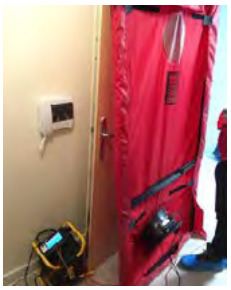
Spot checks on build quality and IEQ

- [ ] Simple visual and hand checks around windows and junctions (on very poor installations on winter days, it is possible to feel the cold air and even, sometimes, to spot gaps)
- [ ] Thermography "spot checks" – see **Detailed BPE > "spot checks"** section; On cold days (and ideally very cloudy days, or early morning / early evening), using thermal imaging to identify cold spots – these could indicate either thermal bridging or air leakage (particularly useful during a depressurisation test, but can still be useful anyway); this could be done informally, outside of a full specialist thermography survey
- [ ] Spot checks on temperature and moisture, using the BPE team's own sensors or taking reading of installed sensors, if present - see **> IEQ "spot checks"** section
- [ ] Signs of mould growth or condensation?
- [ ] Signs of poor air quality e.g. stuffiness, high-VOC smells?
- [ ] General impressions on daylight and views: Do the rooms seem well daylit? Do most have views to the outside, ideally of nature or a pleasant setting such as an active street, rather than, say a car park or busy road?
- [ ] Any observations on temperature, and how this relates to outdoor conditions and the heating set-points?

Spot checks on how well things seem to work

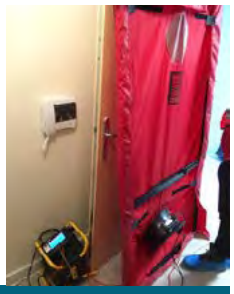
- [ ] Do residents know where their meters are? Are they easy to access?
- [ ] Are all the sensors planned in the design stage (if any) installed, and do they seem to give reasonable readings?
- [ ] **Windows:** do they seem installed as per design including consideration of air flow, security, openings and safety? Are they easy to operate? If the design included restrictors, are they in place, and do they match the design (e.g. they are often installed incorrectly and overly limit opening; inversely, inhabitants sometimes unlock / de-activate them to be able to open windows more widely, for example if they are not satisfied with "stuffiness" or excessive indoor temperatures). Blinds consistently down over glazed areas, particularly full height, could indicate residents feeling too exposed and needing to protect their privacy.
- [ ] **Ventilation:** Do fans seem to work when planned (e.g. intermittent fans on a light switch or presence detection or humidity sensor, depending on the design strategy)? How noisy do they seem to be? Try a few settings, if possible. If there is an MVHR, does it seem easy to use, including different settings? Is it easy to access? Is it easy for residents or maintenance teams to know when to change the filter, and easy to do it? Do residents know they need to do this?
- [ ] **Controls:** How instinctive and useful do they seem to be (e.g. lighting, temperature, ventilation)?
- [ ] **Water strategy:** any feedback from users on the quality of the appliances and fittings? Have they changed (or wish to change) any of them? Note any feedback from users on these elements (if they are present)
- [ ] Note whether changes seem to have been implemented by the users since completion. This could be changes directly aimed at improving usability and comfort (e.g. addition or removal of blinds or other devices for shading and/or glare protection; switching off the ventilation); or changes for other reasons, which could indirectly have an impact on building performance (e.g. furniture stored against glazed areas, impacting light penetration). These issues would be particularly interesting to discuss with users, if they are present, in order to understand why they happened.

AIRTIGHTNESS REVIEW AND TESTING



CORE BPE TECHNIQUE	
Applicable performance objective and target	To keep warm in winter and to minimise energy consumption **Target:** Airtightness – see > ***Client sheet***
Why do it i.e. where it adds value, what it can help with	Good airtightness helps to reduce heat loss, improve comfort by limiting draughts, and reduce the risk of condensation and fabric degradation. It is also useful as general indication of build quality. Checks during the design and construction stages will improve the likelihood of good airtightness being achieved and reduce the need for leak searching and remediation
When to do it	In addition to airtightness tests at completion, checks are recommended throughout: at design stages, during construction, and re-testing in use.
How to do it Tips and tricks	☐ Consider appointing an airtightness champion in charge of management, education and training on site, especially if targets are onerous e.g. Passivhaus. ☐ **Checks at design stage:** see below prompts. ☐ **Checks and inspections during construction:** see below prompts. ☐ First test when the envelope is complete but the airtightness layer still visible, without finishes and services. ☐ Follow-up test once all service penetrations in the fabric have been made and taped. ☐ Final test for PC. At the time of writing, blower door tests are the only ones accepted for Building Regulations purposes. However, low-pressure pulse tests may soon become accepted too. They are less disruptive and offer opportunities for more regular testing during construction and in occupancy. On the other hand, blower door tests offer more opportunities to spot leaks at the same time (e.g. using smoke), while the building is pressurised or during depressurisation.
Needs an expert?	Yes for the final blower door test at PC, but informal tests and checks are possible and recommended throughout construction
Cost and time	££ - formal blower door test, which involves a specialist. Likely to reduce in the future with the spread of low-pressure pulse tests. £ - checks and oversight in design and in construction, possibly additional appointments; will reduce as teams gain experience
Regulations	Yes – blower door test at PC. Low-pressure pulse tests may also become an accepted method in the near future.
Specific considerations for timber construction	Timber dries with heating in use, which may affect airtightness. Good details and installation can address this and allow for movement, but retesting is recommended after a year in use - see > ***moisture management***
What to do with the results? i.e. how to interpret results & identify next steps	Compare airtightness with target and benchmarks. There are several methods to find leaks e.g. smoke during blower door tests; local smoke pen; simply using fingers to feel cold air (easier during pressurisation); thermal imaging to spot colder surfaces indicating air leakage. Leaks should be looked for at all junctions and penetrations e.g. doors, windows, services penetrations, floor-to-wall etc. Wherever possible, apply remediation; options vary with the type of leak and stage of construction, from simple additional tape through to re-installing some elements. **Possible detailed BPE as next step:** n/a

AIRTIGHTNESS REVIEW AND TESTING



PROMPTS FOR QUESTIONS AND ISSUES TO LOOK AT – DESIGN STAGE

Note – this is not meant as detailed guidance for airtight design, but to highlight key principles that the BPE and design teams should be aware of and raise at BPE design reviews. They will facilitate future BPE and help reduce the risk of uncovering performance issues in later stages. Additional issues will be identified on each project, for example through past BPE lessons.

Promts for questions and issues to look at - Design Stage

- [ ] Is the airtightness target specified? Is it in line with initial objectives (see > ***client sheet***)?
- [ ] How simple is the design: articulated facades and complex designs will increase the risk of air leaks and require more complex details, more attention on site, and probably more timeconsuming airtightness testing, leak finding, and remediation.
- [ ] As the design progresses, the aim should be to produce clear drawings for junctions, which can easily be visualised to explain how they will be built. Make a note of risky elements, which will need attention on site.
- [ ] Has there been a buildability and sequencing review, with someone experienced in achieving best practice airtightness?
- [ ] Are airtightness details and sequencing included in the drawings and specifications? Is the airtightness line clear on drawings? If inside the thermal line, this will help with performance and facilitate checks on site.
- [ ] Are the specified materials robust to reduce deterioration over time?

PROMPTS FOR QUESTIONS AND ISSUES TO LOOK AT – CONSTRUCTION STAGE

Note – this is not meant as detailed guidance on site procedures for airtightness, but to highlight key issues that the BPE and design teams should be aware of and raise at BPE design reviews. They will facilitate future BPE and help reduce the risk of uncovering performance issues in later stages. More detailed inspections the appointment of an airtightness specialist would be required for exemplar airtightness, for example if the home targets Passivhaus - see guidance for references on this. Additional issues will be identified on each project, for example through past BPE lessons.

Promts for questions and issues to look at - Construction Stage

- [ ] Do the works follow the sequencing strategy agreed before start on site to achieve the targeted airtightness?
- [ ] Are materials and the installation in line with the airtightness strategy, including the build-up of junctions, the actual selection of as-build airtightness materials (i.e. seals, tapes, etc) and how they are stored and installed. Pay particular attention to the details identified during the design review as particularly complex or risky and to areas which will be difficult to access and improve later e.g. floor-to-wall junctions.
- [ ] The BPE team as well as the site team should carry out inspections and spot checks throughout construction. Areas prone to leaks include all junctions and penetrations, especially complex details.
- [ ] Local testing can also be carried out e.g. first installed windows, mock-ups.
- [ ] Thermography spot checks can potentially be used to help spot sources of air leakage, by highlighting cold surfaces due to cold air (a full survey is not part of the core BPE).
- [ ] **Timber construction:** What are the processes for checking airtightness qualities of timber products are they get delivered on site, and before installation? How are materials stored to limit wetting? See also > **moisture management.**
- [ ] **Timber construction:** Has movement of timber due to wetting / shrinkage cycles been allowed in the installation? e.g. tape between sections of timber, including air tight OSB or SIPs panels, should take account of the likelihood of movement and hence not be applied fully taut; e.g. around openings, using “rabbit-ears”, taping in the corners of openings to minimise the failure of airtightness tapes due to shrinkage of timber elements; on Passivhaus projects, decorators caulk should not be used and silicone mastics should not be part of the airtightness layer.

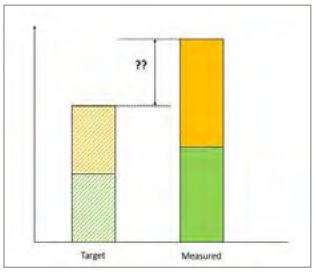
COMMISSIONING

CORE BPE TECHNIQUE	
Applicable performance objective and target	Well performing homes. Energy use, water use, comfort, air quality, noise.
Why do it i.e. where it adds value, what it can help with	Commissioning is an essential activity for enabling systems to operate efficiently and as intended. It is required by regulations but often not done effectively, which can cause many problems e.g. noisy ventilation, insufficient air flow; unreliable metered data. Ideally at each RIBA stage, before sign-off, to embed building performance. Reviews evolve as the project progresses, starting with strategic issues such as elevations, site and building layout, and moving to details and change management in later stages. In-use: to contribute to the overall evaluation of performance.
When to do it	In construction, at post completion, and in use; it needs design consideration to achieve good performance and facilitate BPE.
How to do it Tips and tricks	Commissioning and performance testing must include all systems i.e. heating, cooling (if any), ventilation, lighting, and their controls, as well as metering, monitoring and logging equipment. **Design:** The engineer should specify the performance criteria which systems will be tested against. For ventilation systems, this must include the delivered air flow in each room, operating noise levels, and system balancing. They need to consider how commissioning will be carried out, in particular how the air flow rate will be measured. Time must be allowed in the programme of works. **Construction:** Commissioning happens towards the end of the works, often with pressures on the programme, but the required time must be protected to do it properly. Acoustic testing of the ventilation system (see xx) should be carried out at the same time. On large schemes early homes can be tested and lessons incorporated into the installation of the phases, but all homes should still be commissioned. **PC & handover:** The team should check it has been carried out to the required standards, performance criteria are met, and results are recorded. In the first year there should ideally be seasonal commissioning to check systems work well in different conditions. A check should also be carried out that data from meters, sensors and monitoring equipment seems reliable, to prepare in-use BPE. **In-use:** Records should be reviewed and new tests carried out to check performance and adjust systems if required.
Needs an expert?	Yes – commissioning engineer.
Cost and time	£-££
Regulations	Yes – at completion; no requirement for seasonal commissioning.
Specific considerations for timber construction	No
What to do with the results? i.e. how to interpret results & identify next steps	The systems must be modified until performance criteria are met. **Possible detailed BPE as next step:** some issues may require further investigation to identify remediation options; in severe cases this may even need new installations.

ACOUSTIC REVIEW, CHECKS AND TESTS

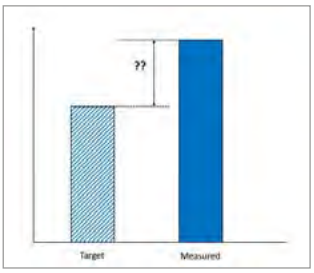
CORE BPE TECHNIQUE	
Applicable performance objective and target	To be quiet and undisturbed inside Targets: regulations + noise from HVAC + others if appropriate
Why do it i.e. where it adds value, what it can help with	Noise levels and disruptions are very important for comfort and satisfaction, and attract some of the highest number of complaints in new homes. Occupants require sufficient levels of sound insulation and appropriate control of noise levels from external and internal (HVAC) sources. Noise from ventilation systems is not controlled under current regulations; it can disrupt sleep and cause inhabitants to turn them off if they are too loud. External noise can limit window opening and increase overheating risk.
When to do it	Review of site noise conditions, acoustic design approach and sound insulation details at the design stage; inspections and tests in construction and at completion.
How to do it Tips and tricks	Acoustic design targets alone are not sufficient – committing to testing helps make sure that appropriate attention is paid to the design, detailing, construction / installation and commissioning of buildings and services. **Design:** The design evolves from the performance targets – whether for site specific aspects such as external noise, or internal details such as sound insulation and design of services. Be aware of external noise sources on site and reflect this in the design e.g. by locating bedrooms on quieter elevations. Ensure the summer ventilation strategy takes account of external noise, with a noise survey if required - see > ***core BPE - early overheating analysis.*** **Construction and PC:** Inspect installation against design and specifications e.g. sealing around partitions; brackets, linings and allowances around water pipes and WCs; fixing of floor decking to avoid creaky floors. Use Robust Details for party walls and floors, or test sound insulation pre-completion (as per Building regulations Part E). Test noise from ventilation systems against targets, as part of the commissioning process.
Needs an expert?	Yes for all the BPE elements: design advice, inspections and testing
Cost and time	~~£~~£
Regulations	**Building Regulations:** sound insulation between dwellings (E1 - Robust Details or completion testing) and within homes (E2- product testing). **Planning:** to control external noise ingress. Specific considerations for timber construction Building Regulations were developed around
Specific considerations for timber construction	Building Regulations were developed around heavy, masonry constructions; some timber frame details provide high levels of sound insulation, while others can comply with regulations but leave occupants dissatisfied. Twin stud walls usually generally perform well in acoustic terms. Floors in timber framed homes need more attention as there is a propensity towards footstep transmission to rooms below.
What to do with the results? i.e. how to interpret results & identify next steps	People differ widely in their tolerance to noise. Acoustic consultants can help interpret user feedback and other BPE results, relate them to targets and good practice, and advise on mitigation and next BPE steps. **Possible detailed BPE as next step:** depending on issues uncovered e.g. testing of indoor and outdoor noise levels; detailed noise survey of inhabitants; detailed review of as-built drawings and installation; testing for low frequency noise (not considered in Building Regulations).

ENERGY USE AUDIT



CORE BPE TECHNIQUE	
Applicable performance objective and target	Low energy consumption **Target:** Energy consumption (kWh/m²/yr)+ Possible additional targets e.g. space heating demand, energy generation from renewables
Why do it i.e. where it adds value, what it can help with	Energy consumption is an essential metric for understanding overall building performance, running costs and carbon emissions. Homes often consume more than expected, which can only be uncovered and improved with more routine monitoring and analysis.
When to do it	In use, covering at least one year of occupation. Ideally excluding the first year, when inhabitants are "settling in" and systems may be getting fine-tuned: use that year to set things up for data collection, permissions and engagement from inhabitants – see > ***Privacy & Ethics***
How to do it Tips and tricks	As a minimum, an energy audit should use annual readings for the main meters of each energy supply (e.g. from bills, provided they are based on actual rather than estimated readings. Benchmarking should help evaluate performance. As a minimum total annual energy use per m² and per dwelling should be captured. If possible with available data, and with reference to targets set, then include: • separate thermal and electrical energy uses • break down thermal uses into space heating and hot water, and estimate space heating demand via estimated plant efficiency • separate any on-site generation, to report on net and total demand • report on building and total with communal heating, if relevant. • review variations: weekday / weekend, day/night, monthly. It is also useful to relate energy use to occupancy (high/low density, at home/out a lot) and heating degree days (warm/cold year).
Needs an expert?	Not necessarily: could be a non-specialist with some BPE experience.
Cost and time	£-££. Do not under-estimate the time and effort to set things up to make sure data is available and correct
Regulations	No
Specific considerations for timber construction	n/a, other than if identified through fabric performance analysis - see co-heating and airtightness and thermal bridge sections
What to do with the results? i.e. how to interpret results & identify next steps	Compare energy use with targets and benchmarks; investigate possible improvements and reasons for under-performance. Be careful not to over-interpret an initial audit: • Energy use can vary widely for identical dwellings, so conclusions are more reliable if related to occupancy, or across larger samples. • Correlate with other BPE results e.g. space heating with air tightness, Indoor Environment Quality (IEQ) spot checks, user feedback or site observations on indoor temperatures; electrical consumption with observations on occupancy and appliances & hot water energy use with water consumption etc – see > ***Making sense of it all***. Improvement measures could cover a wide range. Making sure things are well commissioned and inhabitants know how to operate their home is an essential step before deeper interventions. **Possible detailed BPE as next step:** Energy monitoring and submetering; plant performance analysis; U-value test; detailed energy calculation review and modelling; occupancy patterns analysis.

WATER USE AUDIT

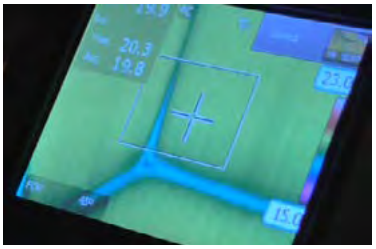


CORE BPE TECHNIQUE	
Applicable performance objective and target	Low water consumption. Water consumption target (l/day/person).
Why do it i.e. where it adds value, what it can help with	Water use is an important performance element in itself, and may also relate to energy use. Drought/water shortage is an increasing concern in the UK (less so in Wales).
When to do it	In use, based on min 1 year of occupation and ideally after the first year of occupation.
How to do it Tips and tricks	Use the first year of occupation to set things up for data collection, permissions and engagement from inhabitants – see > ***Privacy and Ethics.*** Design issues affecting water consumption should be considered at the design stage – see > ***design checklist***. Water use should be benchmarked as a minimum in total water use per person per year. If there is on-site water recycling/ re-use displacing mains water, if possible its contribution should be estimated and separated from total demand; similarly, external water uses should be reported separately if possible. Temporary flow meters can be installed for this purpose. The home tour and user surveys can provide indications such as occupancy density, and amount and types of fittings and appliances, which may explain some patterns of water consumption. If possible with the available data, review variations in water use e.g. continuous night-time water use could indicate leaks.
Needs an expert?	Not necessarily: could be a non-specialist, from inside or outside the project team, but with some BPE experience.
Cost and time	£
Regulations	No.
Specific considerations for timber construction	No.
What to do with the results? i.e. how to interpret results & identify next steps	Compare water use with target and benchmarks; investigate possible improvements and likely reasons for under-performance, if relevant. Be careful not to over-interpret, and correlate with other BPE results e.g. occupancy patterns; energy use for hot water; feedback from inhabitants on their fittings and appliances (e.g. they may have replaced poor quality low-flow fittings for higher-flow ones) – see > ***Making sense of it all***. Improvement measures could include fixing leaks, or changing to lower water consumption appliances and fittings. **Possible detailed BPE as next step:** water monitoring and submetering; deep occupancy studies (range of methods)

USER SURVEYS

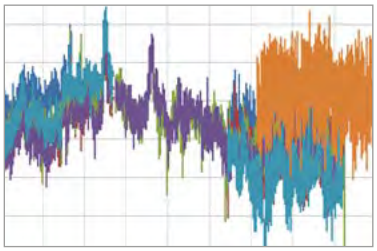
CORE BPE TECHNIQUE	
Applicable performance objective and target	Good user comfort and satisfaction.
Why do it i.e. where it adds value, what it can help with	Inhabitant comfort and satisfaction is an essential performance element in itself. It can also help understand other aspects of building performance e.g. energy consumption.
When to do it	In use, based on min 1 year of occupation and ideally after the first year of occupation; ideally with separate summer and winter surveys, to best capture comfort feedback.
How to do it Tips and tricks	Use the first year of occupation to seek permissions and engagement from inhabitants – see > ***Privacy and Ethics*** Surveys are usually a 2-3 page questionnaire asking basic information about the inhabitants and then their perceptions of all aspects of living in their homes. Standardised surveys (e.g. BUS) add value by using considered and well phrased questions and benchmarking results against similar projects. Use survey results alongside feedback from the home tour. Be mindful that people have different comfort requirements, and that perceptions of air quality, humidity and comfort can be very intertwined: consider feedback on these separately, and together, and alongside "hard" measurements Be careful not to over-interpret; correlate with and shed light on all other BPE results e.g. occupancy patterns & energy and water use audits – see > ***Making sense of it all***.
Needs an expert?	Not necessarily: could be a non-specialist, from inside or outside the project team, but with some BPE experience. Using standard surveys (e.g. BUS) is particularly recommended if carried out by non-specialists to ensure robustness and because it compares results against benchmarks, giving context to the findings.
Cost and time	£-££ depending on number of homes and time spent to develop the survey, and on site with residents.
Regulations	No.
Specific considerations for timber construction	No; note any specific feedback e.g. do inhabitants know it is timber construction? Does it have a "feel good factor?" etc.
What to do with the results? i.e. how to interpret results & identify next steps	Compare survey results against targets (if any) and benchmarks; this is facilitated by the use of standard surveys such as BUS Remediation could cover a wide range. Making sure inhabitants know how to operate their home is an essential step before deeper interventions. **Possible detailed BPE as next step:** studies on inhabitants feedback occupancy patterns, and more in depth monitoring of energy, water and plant performance - see > ***detailed occupancy feedback analysis***, ***energy monitoring***, ***water monitoring***, depending on the findings uncovered.

THERMOGRAPHY



DETAILED BPE TECHNIQUE	
Applicable performance objective and target	Envelope thermal performance and lack of mould growth
Why do it i.e. where it adds value, what it can help with	Thermography can help to locate potential air leakage, mis-applied insulation to fabric and services, thermal bridges and moisture within the building fabric which are not visible to the naked eye. It is nondestructive and non-contact. Thermal imaging results are easy to mis-interpret. A professional survey will provide more robust details and experienced analysis if a detailed inspection and diagnosis are required. However, thermal cameras can be bought or borrowed reasonably cheaply, and used for spot checks as part of a core BPE exercise.
When to do it	During pressure tests in construction or at completion, to help identify areas of air leakage; When homes are occupied, as the tests are nonintrusive and can help spot issues before they become visible and cause serious problems (e.g. condensation, mould growth).
How to do it Tips and tricks	Tests are more useful when performance is poor: surveys may not spot all issues, particularly if very good performance is targeted. Tests are best done in cooler months (there should generally be a temperature difference of at least 10°C between inside and outside) ideally before sunrise, several hours after sunset, or (as a last resort) when very cloudy as direct sun will heat external surfaces and alter results. Focus on areas prone to air leakage or cold bridging such as around windows and doors, at wall/floor/ceiling junctions, on the roof, eaves or within loft space plus around ventilation ducts and drainage pipes. Thermal cameras can also check for continuity of insulation, including in existing buildings. Look at outside of building while the home is pressurised to see where warm air might be leaking out, and inside surfaces while the home is depressurised for cold air leaking in. When surveying services, hot areas indicate poor or discontinued insulation e.g. to pipework or ductwork, or faults to electrical circuits; this is especially useful where services are concealed.
Needs an expert?	Yes for a full survey and detailed analysis; not necessarily for spot checks, but with some experience in order not to mis-interpret results.
Cost and time	£-££
Regulations	None for thermography, but Part C covers continuity of insulation.
Specific considerations for timber construction	None.
What to do with the results? i.e. how to interpret results & identify next steps	Keep a record of the survey with notes on the date, weather that day, where each thermograph was taken and what it may be indicating. **Possible detailed BPE as next step:** U-value calculation; thermal bridging analysis

IEQ MONITORING (AIR, TEMPERATURE, HUMIDITY)



DETAILED BPE TECHNIQUE	
Applicable performance objective and target	Good air quality, mould free, warm in winter, not overheat Project-specific targets e.g. summer temperature, VOC levels
Why do it i.e. where it adds value, what it can help with	IEQ monitoring can apply to a range of parameters important for the health and comfort of inhabitants, and give "hard" data to compare feedback against; it can narrow down issues and remediation options, as inhabitants feedback may be non-specific.
When to do it	In use, ideally after the first year of occupation
How to do it Tips and tricks	Seek permissions and engagement from inhabitants before any monitoring – see > ***Privacy and Ethics***. IEQ monitoring can be expensive and time-consuming, so its scope must be defined by initial BPE e.g. monitor humidity or CO2 if measured air flow rates are acceptable but occupants still complain of "stuffiness"; particulate matter on sites exposed to outdoor pollution (without filters) or indoor fires, particularly if occupants report respiratory issues; temperature over one summer (ideally longer) if feedback indicates serious overheating issues etc. Sensors locations should be agreed with inhabitants and chosen carefully or data will be misleading e.g. avoid direct sun and heat sources. Spot checks and short-term monitoring may be part of a core BPE, with portable and cheaper equipment; results may be less accurate and representative but still add to the other BPE findings.
Needs an expert?	Yes, as results are sensitive to equipment and procedures, and need careful interpretation; in contractual situations or expensive programmes, using accredited labs and equipment is recommended. Simple spot-checks as part of a core BPE could be by a non-specialist, but with some IEQ monitoring experience.
Cost and time	£ for temperature and humidity; £-£££ depending on other IEQ parameters, required accuracy and extent of monitoring. Spotchecks or short-term monitoring in core BPE can be cheaper, but are less accurate and should not be over-interpreted.
Regulations	Could be triggered by radon concerns, by the HHSRS and (in theory but rare) by Approved Document F (RH, NO2, CO, ozone, TVOCs.
Specific considerations for timber construction	Processed wood products, if not specified to be low-VOC, emit formaldehyde. High levels may lead to complaints (e.g. watery eyes, irritation of mouth and noise) and, in the long-term, health issues.
What to do with the results? i.e. how to interpret results & identify next steps	Compare IEQ results against target and benchmarks. Remediationwill depend on the IEQ parameter and the severity of the issue. **If pollutant levels are found above regulatory requirements, the issue must be raised with inhabitants and the client.** **Possible detailed BPE alongside or as next step:** this will depend on IEQ parameters e.g. ventilation performance analysis, detailed comfort survey or occupancy patterns analysis

HEAT TRANSFER COEFFICIENT TEST - CO-HEATING AND OTHERS

DETAILED BPE TECHNIQUE	
Applicable performance objective and target	To keep warm in winter, reduce energy consumption. Target: Heat Transfer Coefficient (HTC)/Heat Loss Coefficient (HLC)
Why do it i.e. where it adds value, what it can help with	Co-heating is an established BPE technique to assess overall fabric heat loss and provide the heat transfer coefficient – HTC (W/K) and heat loss parameter - HLP (W/m2/K). The measured HTC can be related to that predicted by calculations (SAP, PHPP) – see > core BPE - ***energy strategy review***. The test requires 2-3 weeks where the home is empty and heated, and is therefore disruptive and not appropriate routinely. It can be useful following a core BPE exercise where the site visit, documentation review, airtightness test and energy audit indicate high fabric heat loss not explained by poor airtightness. It may also have a role in testing pilot homes before rolling out new housing types. Less disruptive techniques are being developed based on shorter periods or in-use smart meter data. They are not yet at the stage where they could be recommended, but may be soon.
When to do it	Late in construction - the building envelope needs to be complete – and in colder weather.
How to do it Tips and tricks	The test typically needs one week for set up and 2 weeks for testing itself, to obtain results at a range of weather conditions. Essentially, the building is heated electrically to a target temperature, and the test records how much heating is required for temperature to remain stable. It is best carried out in winter as it requires a temperature difference of at least 10°C with the outside. Monitoring of outside conditions (temperature, wind, solar radiation) should happen at the same time; U-value tests and thermography are often carried out alongside to help diagnosis. The heating period will dry out materials, which could affect airtightness; an air pressure test **(core BPE - air tightness testing)** should therefore be done before and after so the average airtightness can be used when interpreting results to calculate the HTC. At the time of writing, co-heating tests are the main accepted method for measuring heat transfer coefficients, and they are a Detailed BPE exercise. However, the BEIS SMETER trials are evaluating options which would, if successful, provide measurements of the HTC in an easier, cheaper and less intrusive way. If this was the case, such tests could usefully be part of a core BPE exercise. Results from the SMETER trials are expected Q2 2021. BPE teams should remain informed of developments, as these innovative tests have much potential for the evaluation of whole building fabric performance.
Needs an expert?	Yes, for the test itself and the analysis.
Cost and time	~~£~~~~£~~~~£~~ for co-heating test due to expert involvement, equipment & disruption. Alternative tests, cheaper and less disruptive, may emerge in the future.
Regulations	No.
Specific considerations for timber construction	None other than noting the possible effect on airtightness, which reinforces the need for airtightness testing before and after.
What to do with the results? i.e. how to interpret results & identify next steps	Compare HTC and HLP with design targets or estimates; use alongside other tests (e.g. thermographic survey) to ascertain possible causes and remediation. **Possible detailed BPE as next step:** will depend on findings e.g. U-value testing (often done together); thermal bridge analysis.

ENERGY MODELLING – PHPP & DYNAMIC MODELLING

DETAILED BPE TECHNIQUE	
Applicable performance objective and target	To minimise energy consumption, to keep warm in winter. Energy consumption (kWh/m²), space heating demand (kWh/m²) and other energy uses, contribution from on-site renewables (kWh/m²).
Why do it i.e. where it adds value, what it can help with	Detailed energy modelling includes PHPP, which is used to support the Passivhaus scheme and is considered more robust than SAP. Dynamic thermal modelling can also be used for more detailed analysis. PHPP or dynamic modelling may be triggered to ensure that onerous targets can be met (e.g. Passivhaus), or for a better understanding of likely energy performance, and to inform design decisions.
When to do it	At the design stage and at completion. Energy calculations, especially detailed ones, can be used to inform various design decisions and finetune the design to reduce in-use energy consumption. Calculations usually need to be revisited several times in order to ensure that targets continue to be met as the design evolves.
How to do it Tips and tricks	See > ***core BPE energy review*** tips and tricks, to cover basic principles. Detailed modelling is often used to perform sensitivity analysis on a number of design options e.g. which design strategy or detail performs best for reducing heating energy and reducing overheating risk? Design principles might be tested in detail on a smaller sample of units rather than include an entire scheme. Targeting Passivhaus requires exemplarily low levels of thermal bridging, so PHPP calculations are likely to also require thermal analysis at the same time – see > ***detailed BPE*** Dynamic modelling is more commonly used where new construction techniques or materials are being considered or if there is a specific research angle.
Needs an expert?	Yes: PHPP designer or experienced dynamic modeller.
Cost and time	~~£~~-~~£~~~~£~~
Regulations	SAP calculations are required to produce the EPC
Specific considerations for timber construction	None.
What to do with the results? i.e. how to interpret results & identify next steps	Compare energy calculation results with targets. Review where improvements might be possible. Ensure performance factors are reflected in the design and communicated throughout the build. Consider how energy performance will be validated in use. **Possible detailed BPE alongside or as next step:** thermal bridge analysis; heat and moisture analysis.