Tackling the performance gap between design intent and actual outcomes of new low/zero carbon housing

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Structure of presentation

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1. **Issue of performance gap**
2. **BPE as a tool to reveal (and tackle) the performance gap**
3. **Evaluation of 4 low carbon housing developments**
   - Design and construction audit
   - Fabric performance
   - Review of systems installation and commissioning
   - Review of control interfaces
   - Review of handover process and user guidance
   - Occupant survey, interviews and walkthroughs
4. **Lessons learnt**
5. **Recommendations**

Issue of performance gap in new housing

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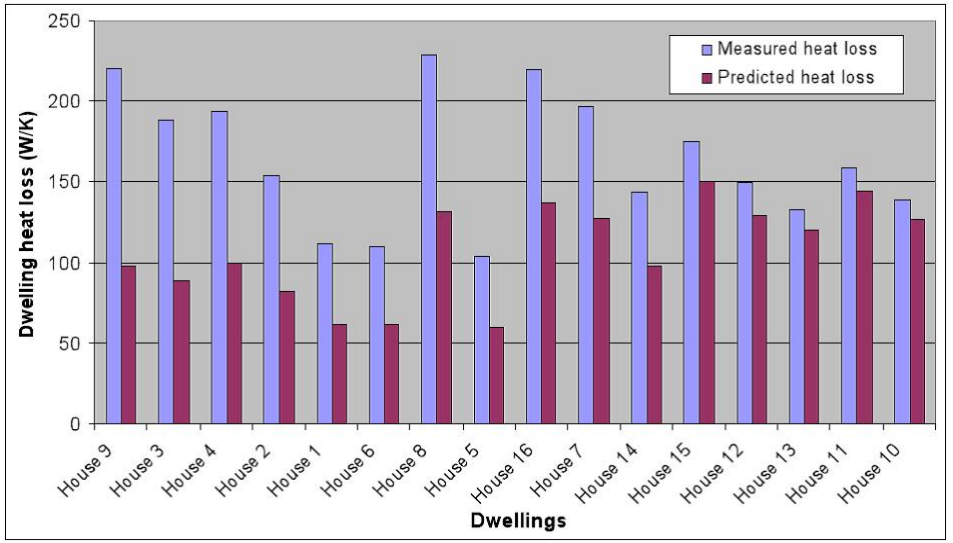
- UK Government has set target to achieve ‘zero carbon’ new housing from 2016
- Recent research shows growing **gap** between what is intended and what is achieved by fabric and services can be large, with some studies indicating, for example, that fabric heat loss can be 100% more than that predicted by design.
- Implications for the long term physical integrity of the building fabric of homes.
  - Missing insulation and high levels of air leakage could result in increased risk of damp and condensation which could contribute to a quicker deterioration of the property fabric.



Issue of performance gap in new housing

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- Widespread presence of such a gap would:
  - Potential to undermine zero carbon housing policy
  - Question the role of even new housing in the national carbon reduction plan
  - Higher energy bills for owners and occupants, undermining buyer confidence in new (low carbon) homes
  - For design and development team, fallout from underperforming new homes could be damaging to reputation and business



Measured versus predicted whole house heat loss for 16 dwellings (Source: Zero Carbon Hub, 2010)

Pressing need to **understand the reasons for the performance gap** and to put in place the **mechanisms and the support to address it**.

Emerging recognition of performance gap

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Carbon Buzz

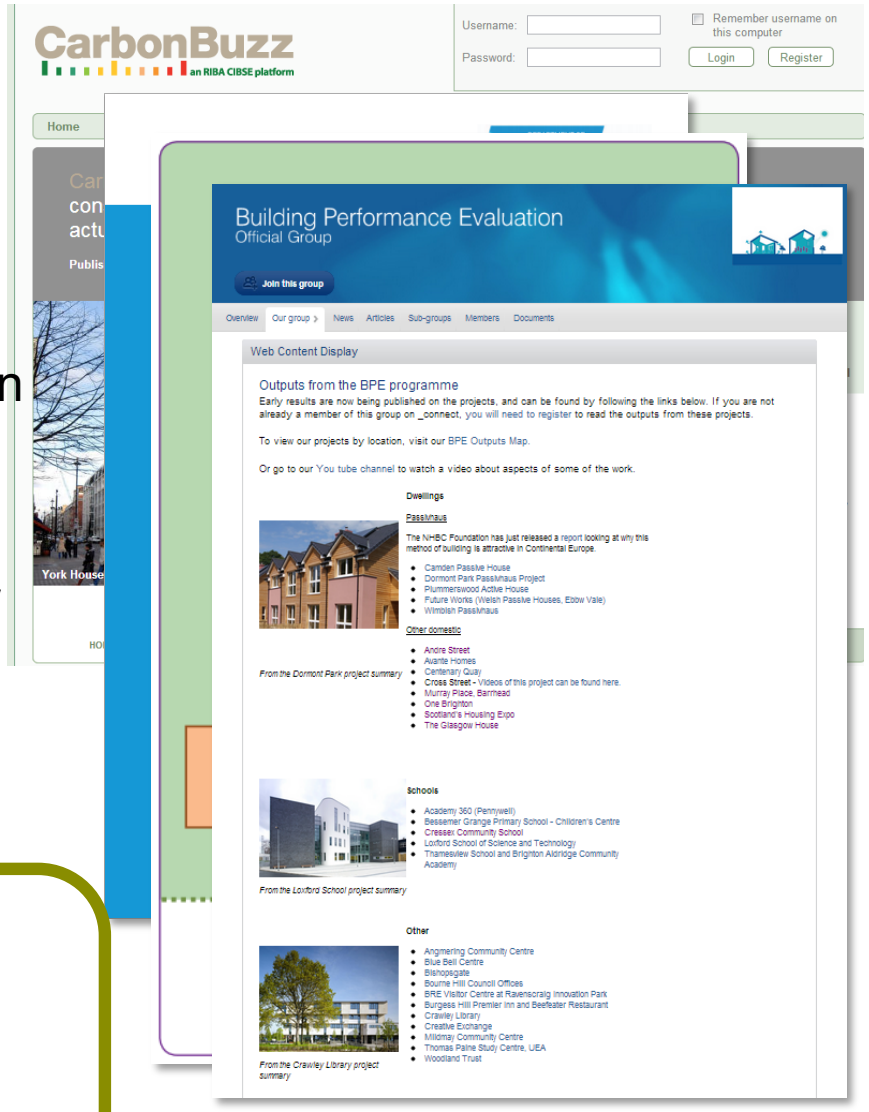
- Online platform for highlighting differences between design forecast and actual values

In-use factors – DECC

- Adjustments to reflect in-situ performance
- Avoid breaking of ‘Golden Rule’ within the Green Deal Programme.

Performance gap project (DCLG)

- Gathering evidence of areas where ‘Designed v As-Built’ ‘performance gap’ could occur.
- Considers construction process as a whole, from design and planning to testing and verification



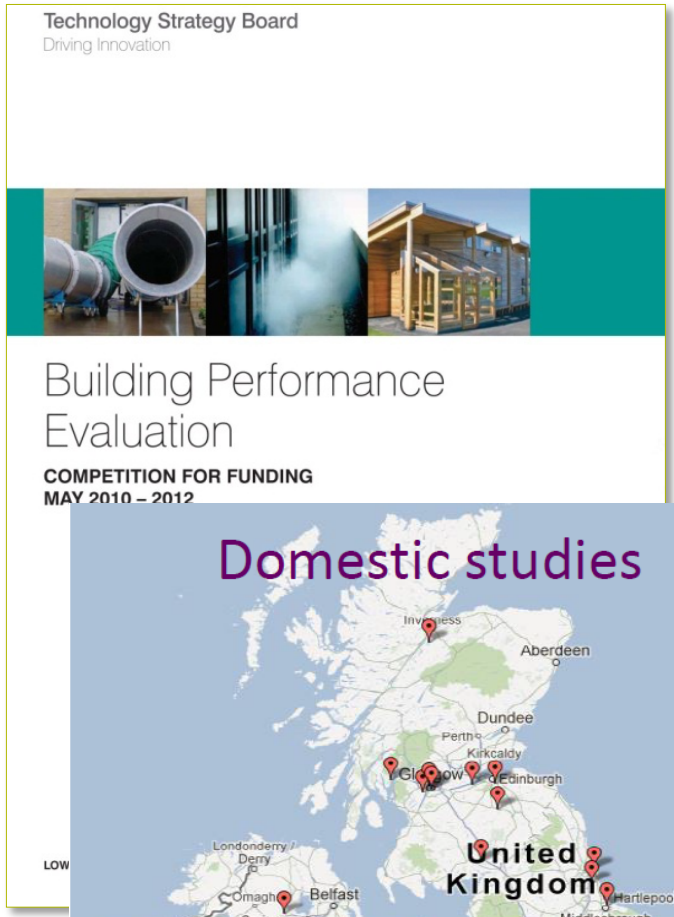
Technology Strategy Board’s National Building Performance Evaluation (BPE) Programme (4 years)

- £8m to fund the costs of BPE studies of case study domestic and non-domestic buildings.

BPE as a tool to address performance gap

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- **BPE:** process of identifying and locating the gap between *'as designed'* and *'as built'* or *'in use'* performance through a systematic collection and analysis of qualitative and quantitative information from a technical and occupants' perspective.



- **TSB BPE domestic studies:**

1. *Post construction and Early occupation 'as built'* performance of the building envelope and installed equipment, effectiveness of the handover process and occupants' initial reactions.

2. *In-use and post occupancy* - performance of the building over an extended period of time, after fabric and systems have stabilised and the occupant are more familiar with the dwelling



BPE case studies of four low carbon housing developments (UK)

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	Case study A	Case study B	Case study C	Case study D
Developer	Small private developer	Volume House builder	Volume House builder	Social housing / Local authority
Tenure	Freehold	Private homes ownership and Social rented	Private homes ownership and Social rented	Affordable housing rented, shared ownership
No. of bedrooms, house type	three bed, mid-terrace	two bed, semi-detached	three bed, end-terrace	three bed, end / mid-terrace
Construction type	Rendered, timber clad, timber frame	Rendered, structural insulated panels (SIP)	Brick, rendered block, cedar cladding on SIPs	Rendered hempcrete cast into timber frame
Target design rating	CSH Level 5	CSH Level 6	EcoHomes Excellent	CSH Level 6
Space heating and hot water system	Wood pellet burner with radiators and solar collectors and 300 litre thermal store	Communal gas CHP (hot water distributed through underground district heating network)	Gas boiler with conventional radiators	Exhaust Air Heat Pump (EAHP); under floor heating coils and 4m^2 vacuum tube heat pipe solar collectors
Target Air tightness ($m^3/h/m^2$ @50Pa)	5	1	5	2
Ventilation strategy	MEV	MVHR	MVHR	MEV through EAHP
Renewables	2 kW_pk Photovoltaic	-	-	4 kWpk Photovoltaics

BPE Methodology

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1. Design and construction audit

- Review of drawings, calculations, etc. to compare as-designed to as-built

2. Fabric performance

- Using a range of diagnostic field tests including: whole house heat loss, air permeability, in-situ U-value tests, and infrared thermography.

3. Review of systems installation and commissioning

- Installation and commissioning review; proper equipment operation

4. Evaluation of handover process and user guide

- Do owners/occupants receive appropriate training and guidance about operation, maintenance and usability?

5. Review of control interfaces

- Review of the usability, responsiveness and access of controls

6. Occupant survey, interviews and walkthroughs

- Comfort, satisfaction, habits and use of systems and building



1. Design and construction audit

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Case A

- Orientation of the case study dwelling changed!
- Mechanical engineer not involved with integration of space heating and ventilation strategy: *MEV duct runs have impacted layout and efficiency of the system.*

Case B

- During design stage the external envelope was simplified to ensure minimal thermal bridging and good airtightness: *House achieved superior airtightness and low heat loss predictions.*

Case C

- Changes on site made without full awareness of consequences (e.g. omission of radiators, omission of insulation to pipe work: *Change in designed heating prediction.*

Case D

- Lack of consistent communication and coordination between contractors, specialists and design team leading to improper sealing around service outlets in the external fabric: *Impact on overall airtightness, heat loss and energy use.*

Case A: small private developer, **Case B:** volume house builder, **Case C:** volume house builder, **Case D:** local authority – social housing

1. Design and construction audit:
Areas of concern

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	Case A	Case B	Case C	Case D
Construction changes as a result of inappropriate planning or incomplete design (impacts not always assessed)	X	X	X	
Construction changes as a result of developer decision resulting in sub-optimal conditions (impacts not always assessed)	X	X	X	
Mechanical, electrical and plumbing integration conflicts due to insufficient planning	X		X	X
Communication and/or support failure between design team, engineers, suppliers and construction team (lack of QC)	X		X	X
Lack of on-site knowledge and training (lead to changes, insufficient work, detailing and commissioning)	X	X	X	X

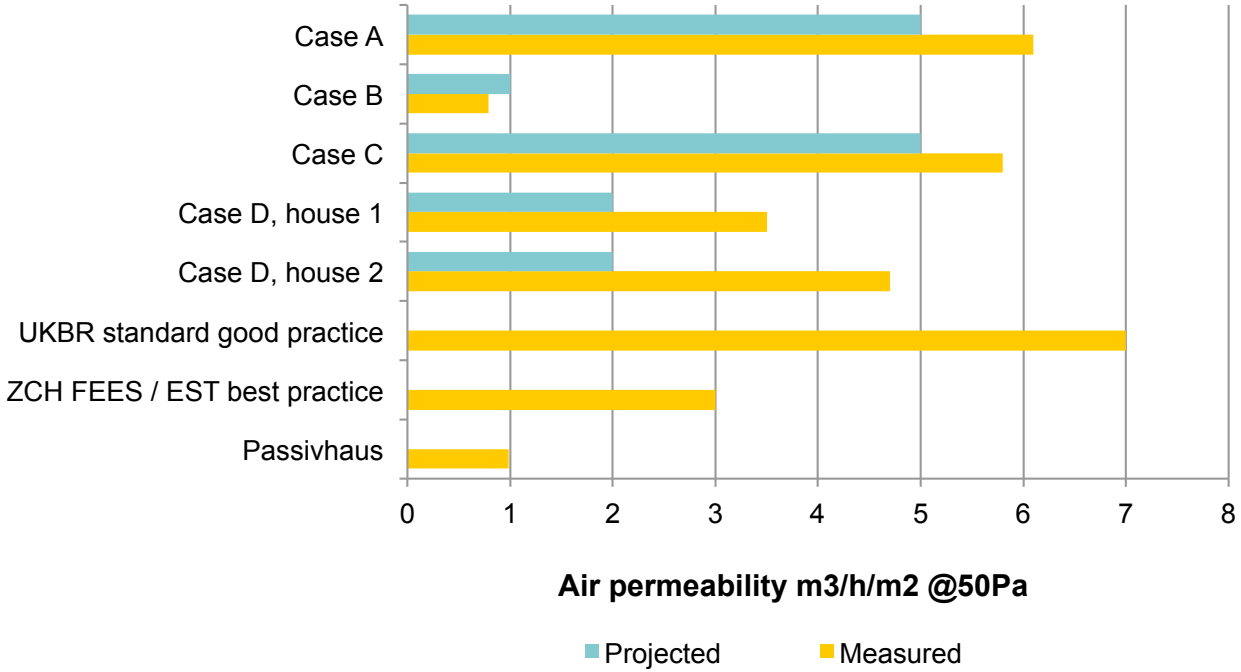
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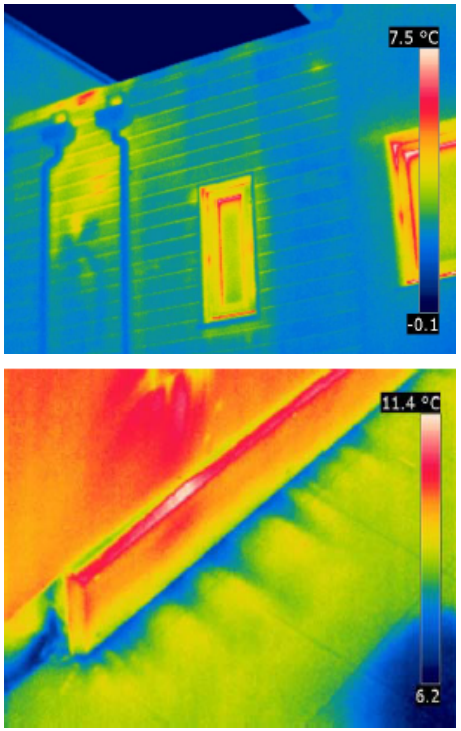
2. Fabric performance

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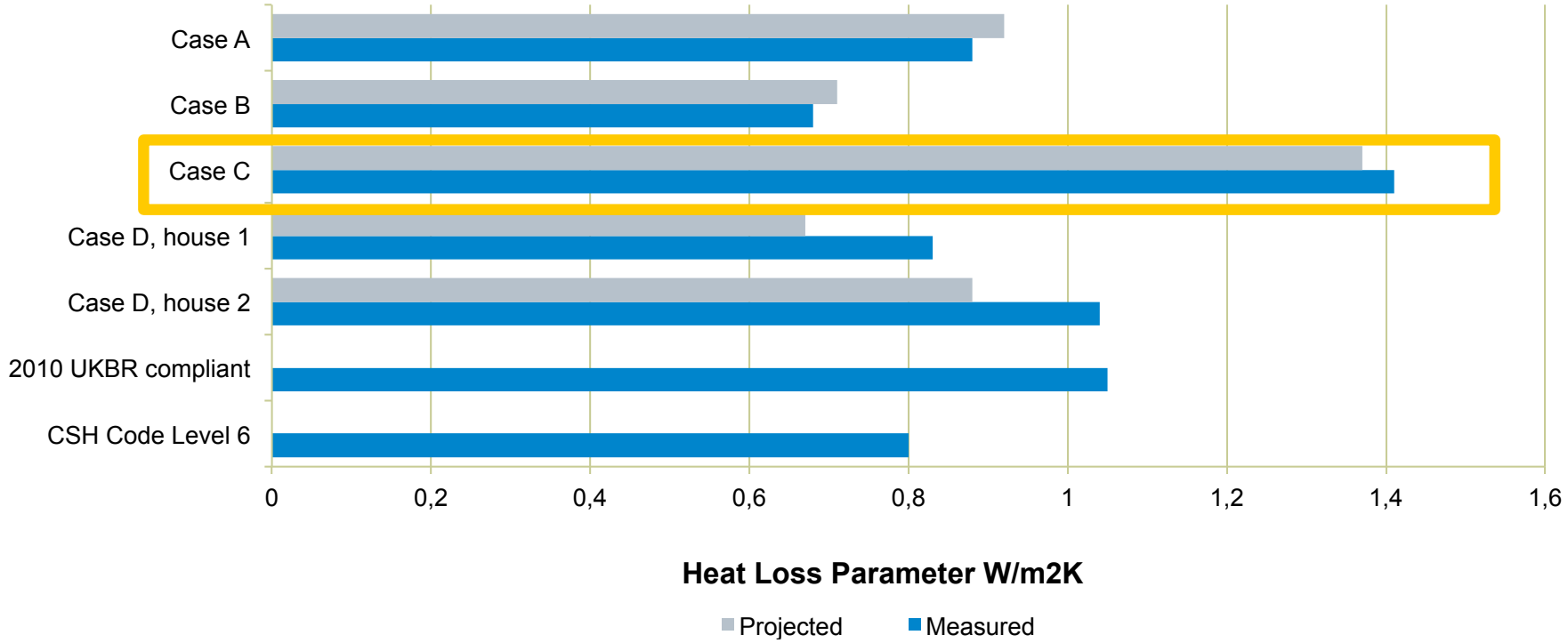
Common emerging issues

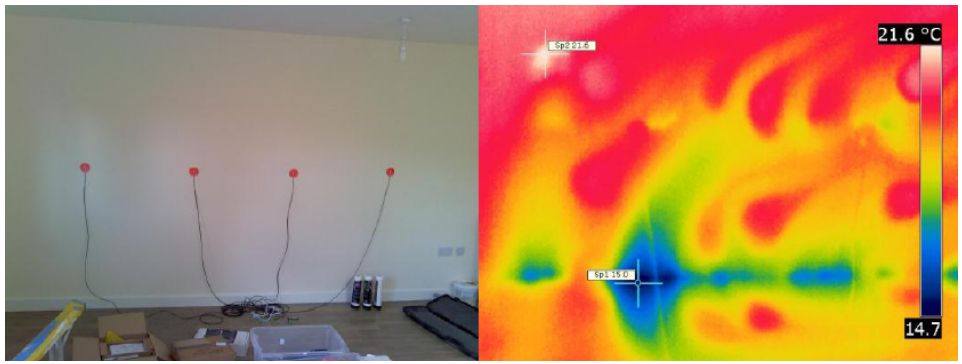
- Higher than projected air permeability
- Higher than expected heat loss through party walls
- Poor quality of insulation installation at junctions
- Gap between calculated (SAP) and predicted heat loss



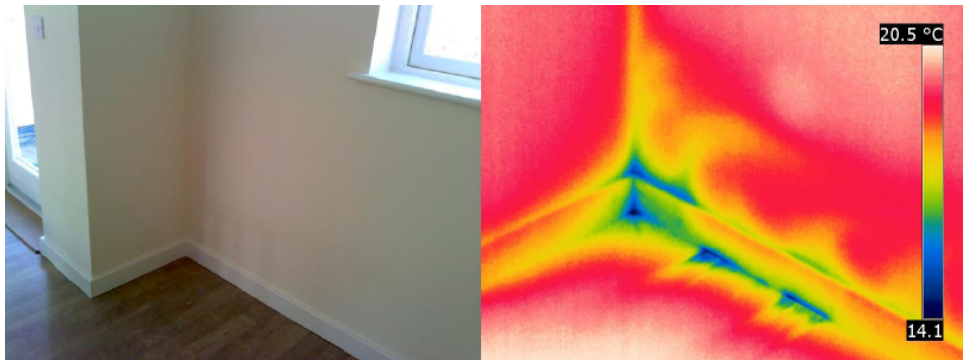


2. Fabric performance





Living room party wall heat flux sensors and heat loss



Heat loss around living room skirting board from junctions between floor and wall

3. Review of systems installation and commissioning: Areas of concern

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Case A

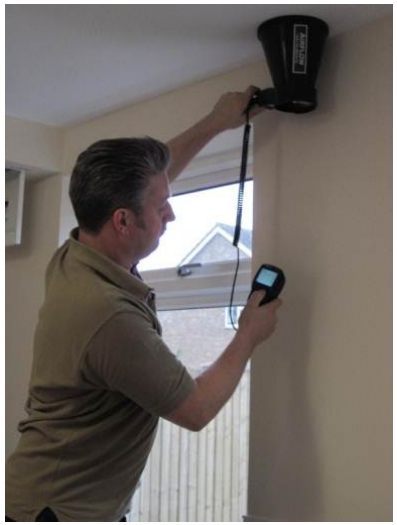
- Commissioning failure: MEV found to be delivering inadequate air flow rates (below regulations): *Negative impact on IAQ*

Case B

- MVHR found to have an imbalance between supply and extract of up to 30%: *Greater than predicted energy use*

Case C

- Ventilation flow rates are lower than recommended due to flexible ductwork and commissioning was incorrectly performed: *Negative impact on IAQ.*



Case D

- Heating controls and zone thermostats not connected, incorrectly installed (first floor heating inoperable): *Greater heating energy use than predicted due to attempt to compensate for unheated spaces.*

Case A: small private developer, **Case B:** volume house builder, **Case C:** volume house builder, **Case D:** local authority – social housing

3. Common issues with unfamiliar technologies: Mechanical ventilation systems

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- Inadequately planned ductwork with scarce insulation
- Additional offsets and bends in the ductwork potentially results in increased system resistance and noise.
- Inefficient ductwork in some cases resulted in MVHR efficiency reductions



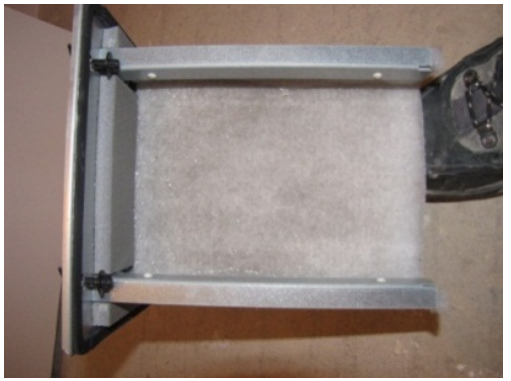
Poorly installed ductwork



Poorly insulated ducts



Super-insulated tank with non-insulated valves and pipes



Dirty filters of MVHR

4. Review of control interfaces

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Case A

- No control for changing ventilation rates: *Increased heat loss and energy consumption, possible impact on IAQ*

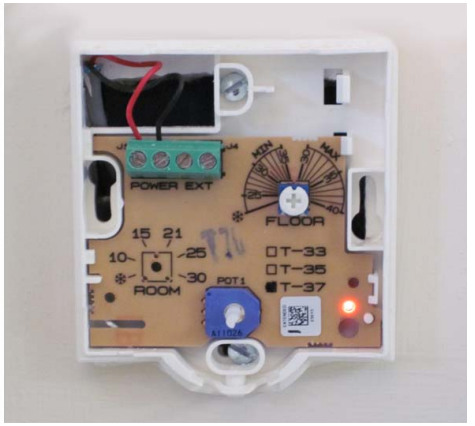


Case B

- MVHR controls unclear and difficult to operate; little indication of system response: *Compromises on the user's ability to control the systems for optimal comfort and energy consumption*

Case C

- Location of MVHR boost switch inaccessible and non-compliant with Building Regulations: *Negative impact on indoor air quality and user satisfaction*



Oversimplified room thermostat

Case D

- Oversimplified heating interface lacking clear labelling and indication of system's response: *Potential negative impact on energy use.*

Case A: small private developer, **Case B:** volume house builder, **Case C:** volume house builder, **Case D:** local authority – social housing

4. Common emerging issues with controls: access and usability

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- Lack of provision of clearly labelled, understandable and accessible controls was the common leading issue
- Room thermostats tend to either oversimplified or over-engineered.
- Lack of provision of usable controls (including boost function) for mechanical ventilation systems
- Poor serviceability access for MVHR (e.g. filter replacement).







Usability criteria	Poor	Excellent
Clarity of purpose		
Intuitive switching		
Labelling and annotation		
Ease of use		
Indication of system response		
Degree of fine control		

Comments

MVHR booster switch located in cupboard – difficult access, not labelled for purpose, no indication of responsiveness

5. Evaluation of handover process and user guidance

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Case A

- One sided handover (no interaction with occupants); guidance documents lacked diagrams and clear, simple explanations of the heating and ventilation systems, emergency cut off points, etc.: *Impact on comfort and energy consumption*

Case B

- Not occupied

Case C

- Well-presented and informative master manual and home user guide; charismatic demonstrators: *Positive impact on confidence of buyers and trust between developer and occupants.*

Case D

- Group induction tours conducted before occupation; individually after occupation. Repeat training: *Occupants found combination of induction tour and training day very useful.*

Case A: small private developer, **Case B:** volume house builder, **Case C:** volume house builder, **Case D:** local authority – social housing

5. Evaluation of handover process and user guidance: key messages

	Case A	Case C	Case D
Guidance and handover needed to be more comprehensive	x		
Home user guide should be concise, clear and highly visual	x	x	x
Handover lacked demonstrational and operational hands-on experience	x	x	x
Handover held at inappropriate time for occupant thereby sacrificing full comprehension	x		





6. Occupant survey, interviews and walkthroughs: Areas of concern

	Case A	Case C	Case D
Noise and summer overheating problems reported	x	x	x
Occupants do not have a sense of control	x	x	
Lack of understanding of using equipment / systems	x	x	x
Lack of adequate storage	x	x	x



- **Green triangles** represent mean values significantly better or higher than both the benchmark
- **Amber circles** are mean values no different from the benchmark.
- **Red diamonds** are mean values worse or lower than benchmark.

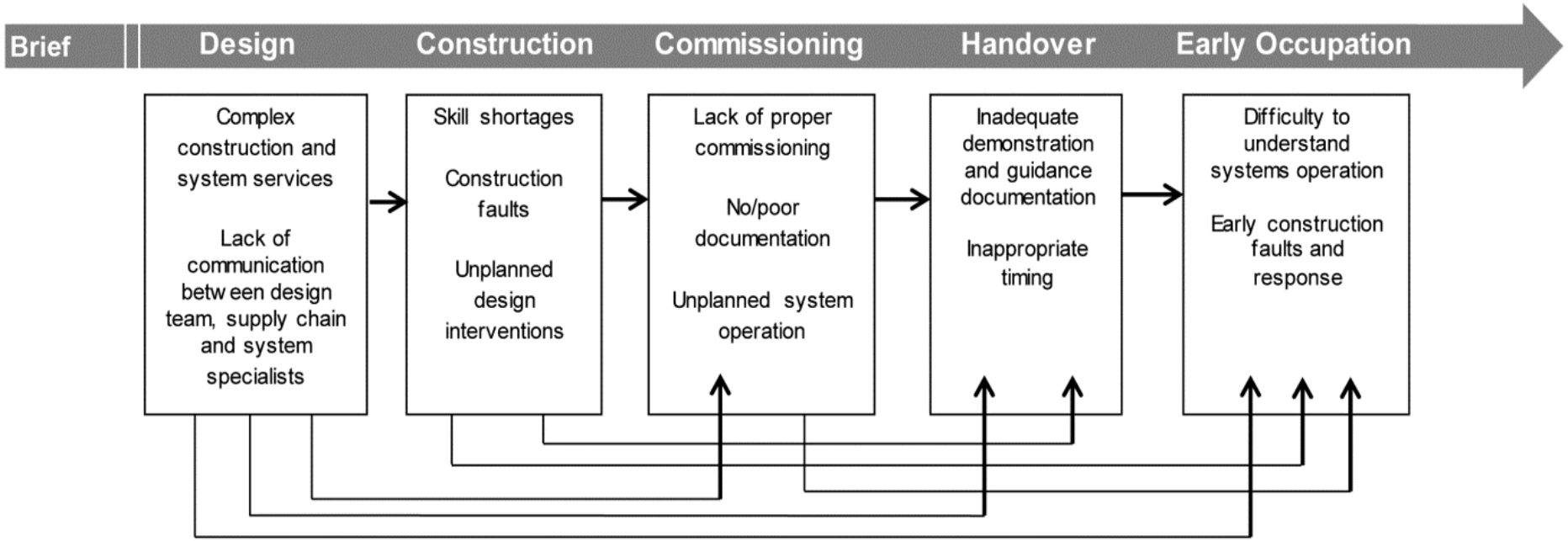
Lessons learnt from the BPE studies

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- Impact of changes to construction details (during the construction process) or furnishings are not always assessed
- Energy systems not always well integrated into the design from an early stage
- Inadequate or poorly detailed insulation and air tightness at junctions. Greater heat loss through party walls than predicted
    - Physical mock-ups of innovative or unconventional solutions: prototype testing
- Communication is essential across all parties throughout design and build stages
    - Utilisation of a mentor to advise and check work of contractors will help
- Inadequate installation and commissioning of systems.
    - Mechanical ventilation systems - poorly understood, installed, commissioned, operated and maintained (leads to excessive energy use)
- Active involvement of occupants essential during handover and demonstration. Repeat training of occupants is vital.
- Home user guide needs to be concise, highly visual and easily available
- Accessibility and usability of controls are important. Occupants are empowered through sense of control.
- Occupant dissatisfaction with provision for storage needs to be addressed through innovative design.

Way forward: Soft-landings based approach

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Soft Landings approach

Stage 1
Inception and briefing
Communication of intention (targets), past experience, responsibilities, measurement of success, appropriate response to shortcomings

Stage 2
Design development
In depth review of past failures and successes, reviewing the design with all stakeholders (communication), establishing the knowledge of the contractor, sub-contractors and suppliers in expectations and acceptance

Stage 3
Pre-handover
Training of maintenance staff, commissioning completion, occupant guidance

Stage 4
Aftercare
Ensuring the building operations continue smoothly

Stage 5
Extended aftercare (1-3 years)
Quarterly – bi-yearly review meetings, logging of environmental and energy performance, fine-tuning of systems, interviews and walkthroughs

Recommendations

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Policymakers

- **Soft landings, and BPE** should be incentivised – lead to **evidence gathering**
- **Diagnostics be mandatory.** E.g., a sample of homes in new low carbon housing developments undergo co-heating tests & commissioning checks. All homes have thermography
- Sustainability certification (e.g. CSH) should be limited to homes that have had **BPE/diagnostics**
- **Performance driven targets** set in Building Regulations
- Regulatory modelling to be informed by empirical evidence

Developers

- Developers **share and seek** experience
- Take the lead on initiating and **ensuring communication** between all stakeholders
- Ensure capability and experience of all stakeholders involved
- Create comprehensive and highly visual user guides (input from Design team) for occupants
- **Incentivise prototype testing** and BPE to future occupants

Building industry

- **Simplify external envelope** - minimal thermal bridging and optimised airtightness
- **Communication** and involvement of all parties through all stages
- Use experienced contractors and check their work.
- Improve commissioning process.
- Consider accessibility of controls and usability of control interfaces
- Close attention to overheating risk

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Thank you for listening!