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Approaches and challenges in monitoring and evaluating low energy housing refurbishments

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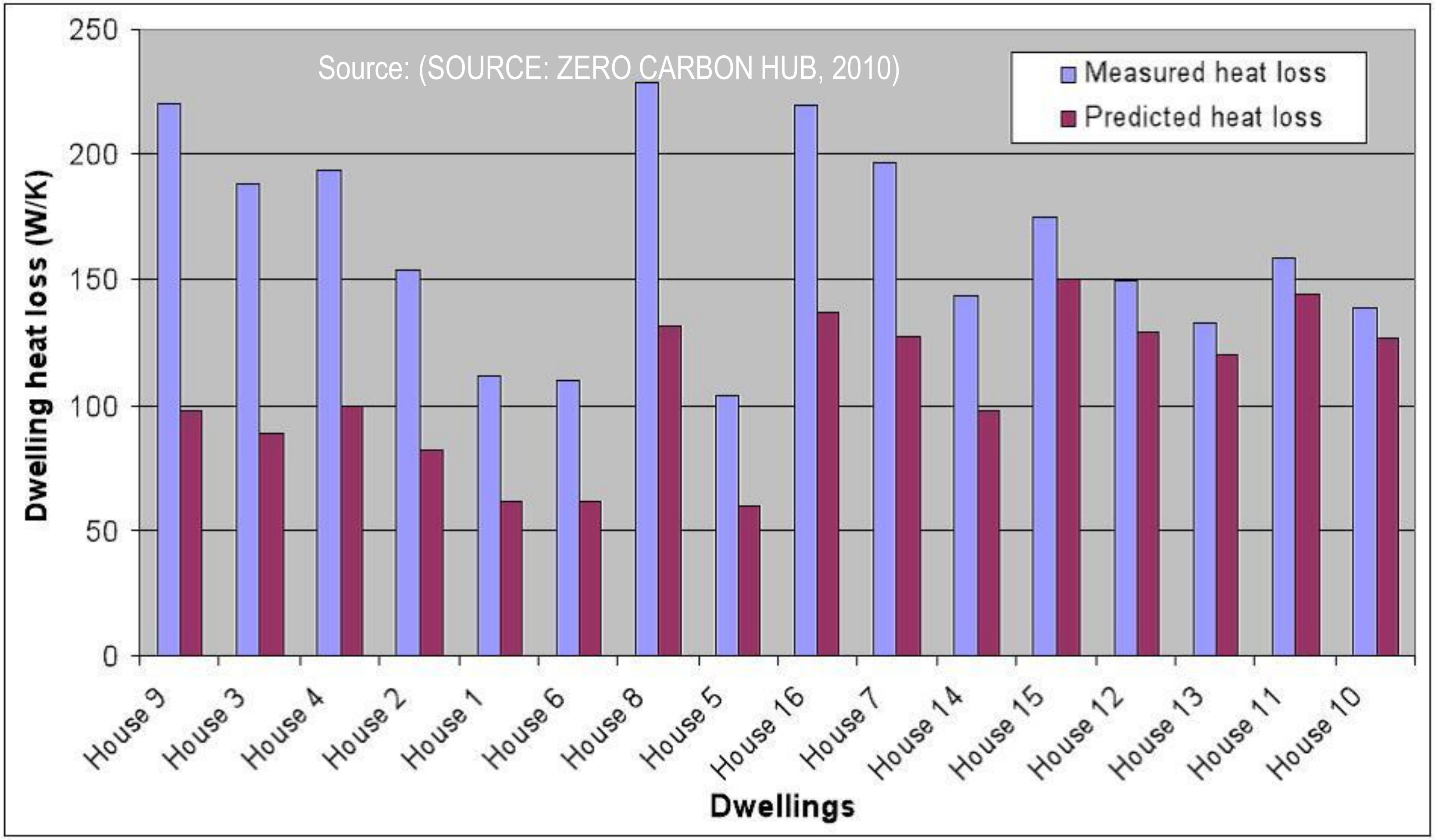
Structure of Presentation

1. Background: Significance of M&E for low carbon refurbishment
2. Approaches and Techniques of M&E
3. Oxford Whole House Low Carbon Refurbishment Project: using an integrated M&E approach
4. Final thoughts: future challenges

Background and context

Credibility gap between predicted and actual performance

'As designed' and 'As built'



'As designed' and 'in use'

Our approach

Key elements of an M&E study

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1. Post-construction fabric testing
2. Evaluation of handover process, user guide and review of commissioning of systems
3. Energy assessment and benchmarking
4. In-use measurement and monitoring of the physical environment
5. Occupant feedback survey

Post-construction and early occupation: ‘As designed’ and ‘As built’

In-use stage:
‘As designed’ and ‘in use’

M&E techniques: Pre- and Post-Refurbishment

Building performance evaluation	Technique	Pre-refurbishment	Post-refurbishment
Post-construction fabric testing	Infrared thermography (external façade, openings, corners, junctions)		
	Co-heating test		
	Air-pressure testing (air permeability rate and pathways of air leakage)		
	Photographic survey		
Energy assessment and benchmarking	CIBSE TM22 Energy Assessment approach		
	Degree day analysis, control charts		
	Benchmarking energy use and CO_2 emissions		
	Detailed energy survey		
In-use measurement and monitoring of the physical environment	Delivered energy (gas, electricity)- weekly/10-minute/smart metering		
	Detailed metering-appliance energy using plug-in meters/whole-house kit		
	Detailed metering-domestic hot water using heat meter / whole-house kit		
	Water consumption		
	Internal temperature, lighting and humidity – living rooms / bedrooms / hall		
	External temperature, lighting and humidity		
	CO2 levels (internal air quality)		
	Daylight factor measurements using lux meter		
	MVHR system – electricity use of pump and air flow rate		
	Performance of low/zero carbon technologies - heat pump, micro-CHP, solar PV, solar thermal, micro-wind,		
Occupant feedback survey	Questionnaire surveys		
	Open-ended semi-structured interviews - occupants		
	Open-ended semi-structured interviews – design and build team		
	Activity log sheets of occupants – logging occupants activities		
	Heating schedule diary		
	Thermal comfort diary		
	Appliance energy usage questionnaire		
	Field observations of user behaviour		
	Occupants' video diaries		
	Focus groups		

Exemplar deep whole-house refurbishment

TSB Retrofit for Future programme:
Deep whole-house low-carbon refurbishment

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22 August 2011 Last updated at 14:53

Oxford retrofit cuts energy consumption by 85%

Two council tenants in Oxford have had their home turned into a showcase for energy efficient technology.

Steve and Shirley Bishop are taking part in a research project looking at the best ways to reduce CO2 emissions in existing UK housing stock.

The couple have seen their energy consumption cut by 85% and hope to see bills drop from £600 a year to £150.

The Victorian property on Nelson Street has been retrofitted with a number of energy-saving measures

Project leader, Prof Rajat Gupta, from Oxford Brookes University said findings would inform future government policy.

The Victorian terraced property on Nelson Street has been fitted with a number of energy-saving measures and will be studied over a two-year period.

Mrs Bishop, who has lived there for 21 years, said the changes had improved her quality of life and even helped with her asthma.

She said: "It's bright warm, no draughts... the air quality is amazing, it's somehow fresher."

Optimum technologies

There are 86 other houses across the country taking part in the government's Retrofit for the Future programme.

The information will be used to decide on the most cost effective ways of reducing carbon emissions.

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…nitoring and occupant feedback

…ow-carbon retrofit strategies to achieve 80%

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…ntation followed by 2-years of monitoring/…

…rovement and then low carbon/zero carbon

…d for energy by 60-75% using energy efficie…

…w-maintenance 'fit and forget' approach

…, comfort, well-being of occupants

- User-centred solutions

Winner of 2011 AJ Retrofit award (Penoyre and Prasad)

Whole House Retrofit – Oxford, TSB RfF

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2-bedroom 19th century end-terrace, Oxford

Area : 76.9m^2
House Orientation: South-West (front facade)
Walls: solid brick
Roof: timber trussed slate roofed
Ground floor: Concrete ground floor slab
Windows: uPVC Double Glazed
Extensions: Two cavity brick walled extensions with flat roof and some refurbishment work


CO2 CUT: Eco-renovation for research project

IN BRIEF

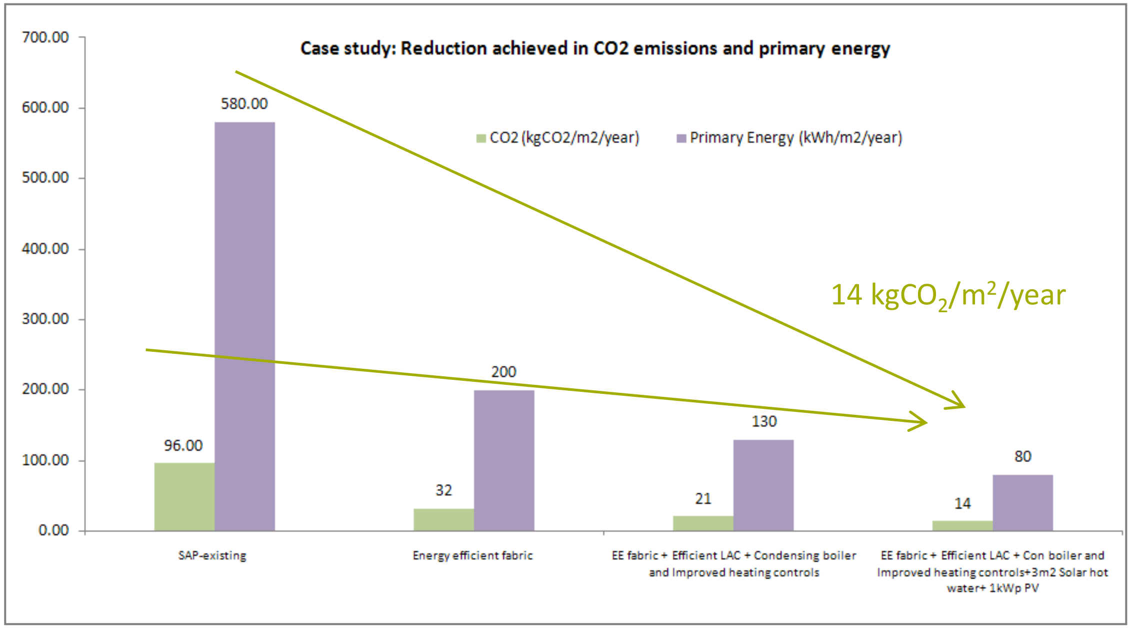
Victorian terrace's big eco makeover

JUST SOME OF THE 'GREEN' RENOVATIONS

A lifeline for animals

Our M&E approach

- **Pre-refurbishment M&E: helped to identify low carbon interventions for refurbishment**
- **Post-construction and early occupancy: to address the gap between 'as designed' and as 'built performance'**
- **In-use stage: to address the gap between 'as designed' and 'in use' performance**



What did the *Pre-refurbishment* M&E reveal?

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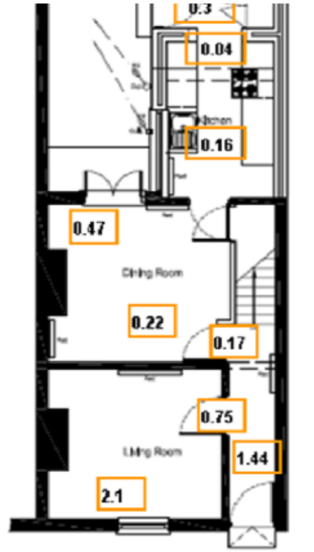
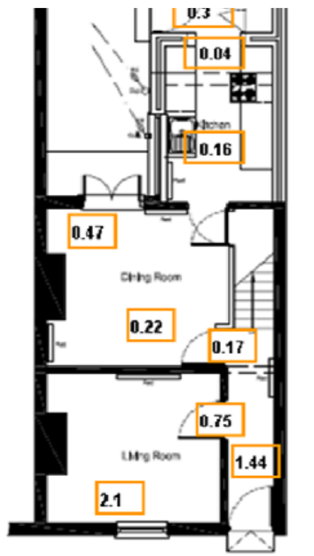


EXISTING GROUND FLOOR PLAN

SAP model	Total consumption (kWh)
Gas	24,139.14
Electricity (Lighting +fans/ pumps)	802.52
Total energy	**24,941.66**



EXISTING GROUND FLOOR PLAN

Bills	Total consumption (kWh)
Gas (29 Jan 08-28 Jan 09)	9465.16
Electricity (Lighting + fans/ pumps + appliances)	2481.00
Total (energy only)	**11946.14**

What did the *Pre-refurbishment* M&E reveal?

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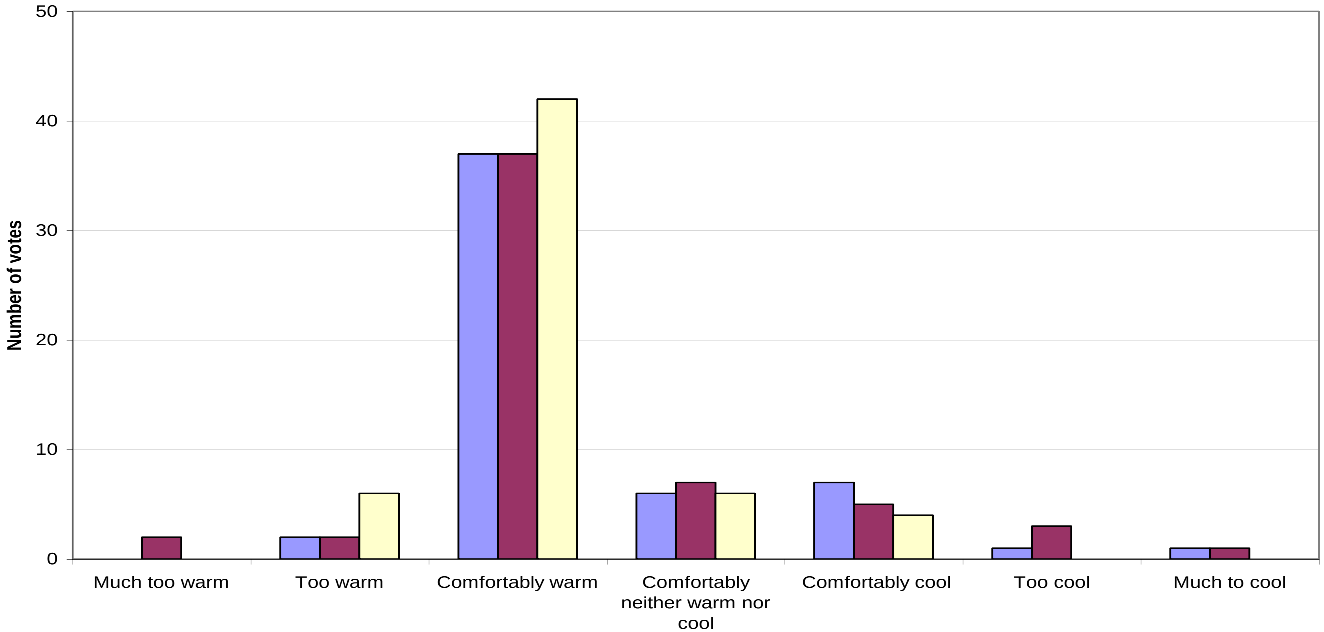
Oxford Average temperatures (Degree Celsius)				
	External	Living room	Master bedroom	Rear bedroom
October	11.0	18.4	16.8	17.9
November	8.05	17.05	14.35	16.20



- High CO_2 levels: averaging at 1380ppm
- Low light levels: Daylight factor 0.2-0.4%
- Low internal temperatures: 14 -18 deg C
- High forgiveness factor
- SAP predictions were double actual consumption
- Occupants complained about a 'cold' house which was difficult to heat due to lack of insulation and rising fuel costs.

How did this impact the effectiveness of the refurbishment?

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Oxford: Key results	Interventions
• Poor levels of daylight in most rooms, • Average daylight factors of less than 1, except the master bedroom and living room.	Roof lights incorporated in design with good low U-values to minimise heat loss
• Poor indoor air-quality in the house • Windows were monitored for 28 days and found to be opened on an average for only 4 days.	Incorporate mechanical ventilation in the house to maintain indoor air quality levels, Retrofit will lead to a well-sealed house further reducing natural air/ventilation pathways. The effectiveness of the MVHR system will be monitored technically (air flow and electricity use of the pump).
• Un-insulated fabric • Difficult to heat house to comfortable temperatures • Lower than average gas bills as the occupants are very careful with the use of heating system, given the rising costs of gas.	Highly-insulated fabric, Triple-glazed passivhaus windows and, Efficient heating system

Post-construction and early occupancy

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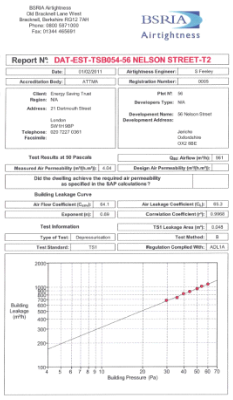
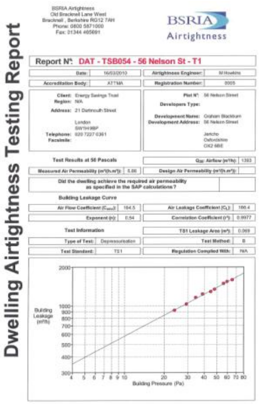
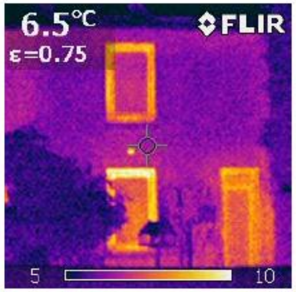
1. Observation and Review of Handover process

Dwelling Airtightness Testing Report



Dwelling Airtightness Testing Report





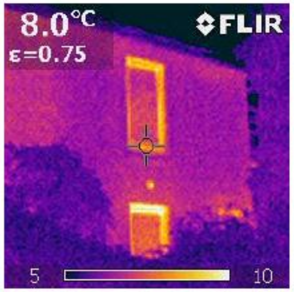
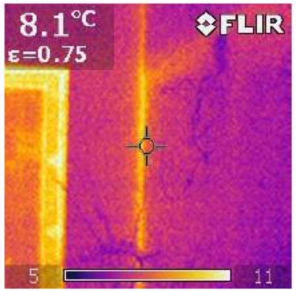
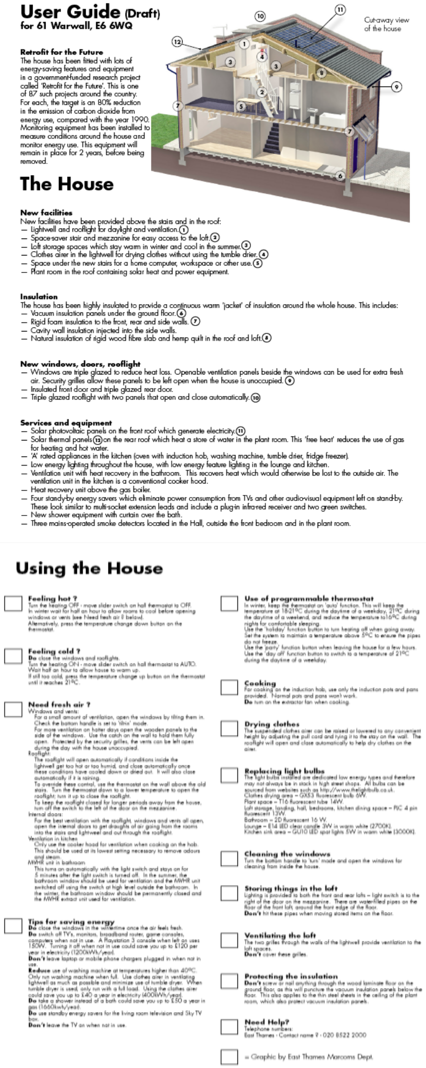


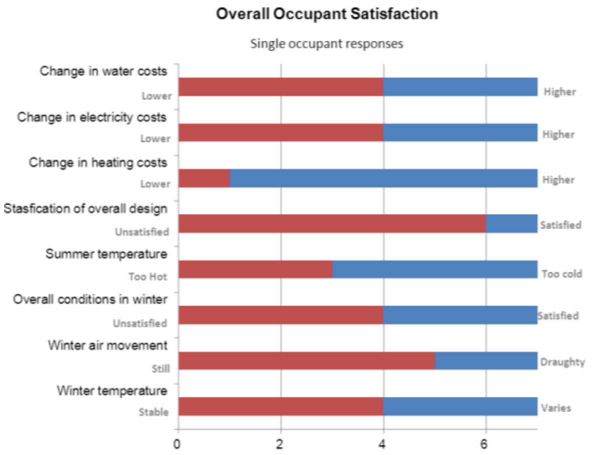
Figure 1 and Figure 2: Heat loss from window frames on front facade



2.Evaluation of Home User Guide

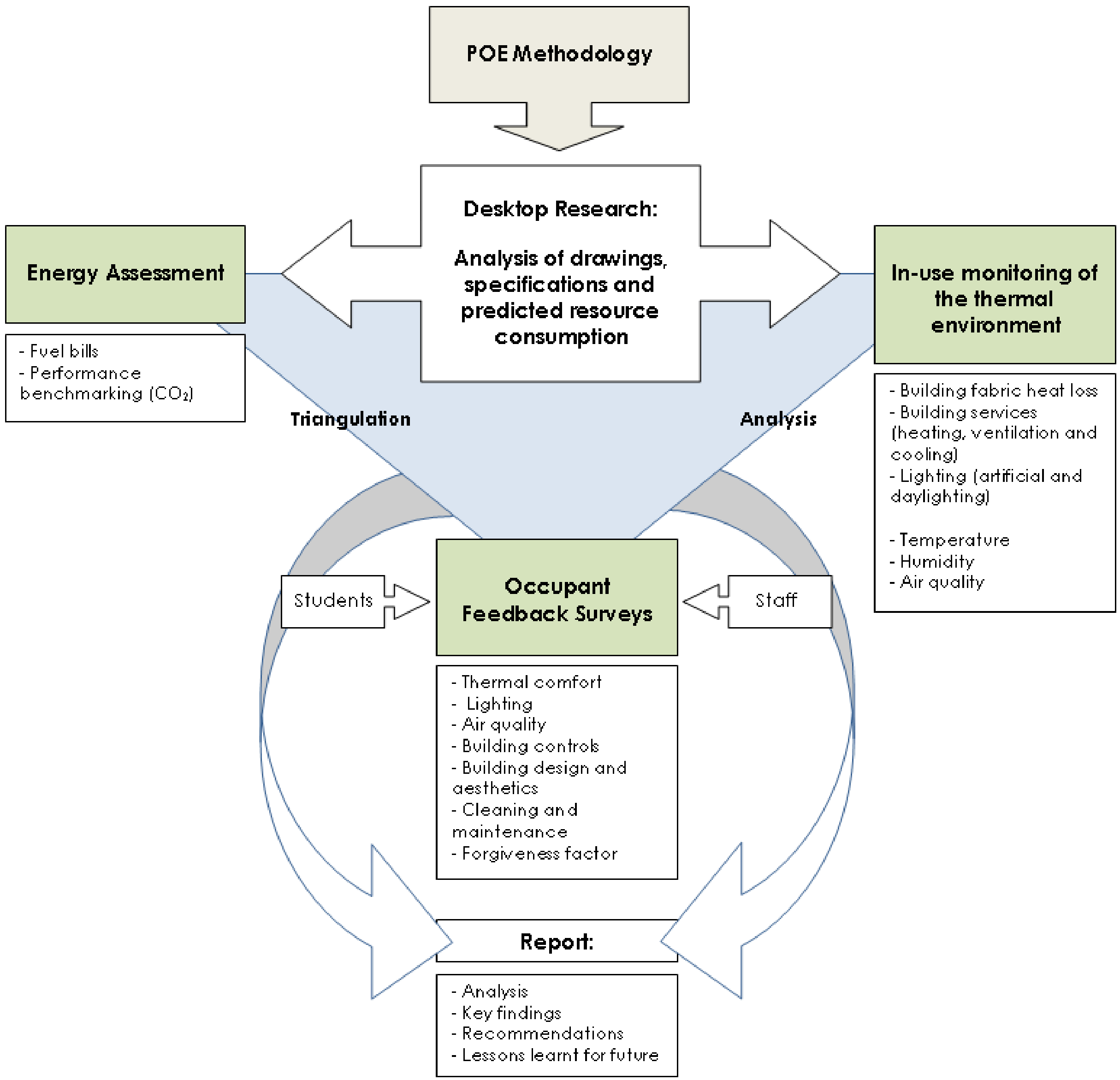


3.Building User Survey Questionnaire



4.Home User Interview and Walkthrough

Post-refurbishment user guide and monitoring



On going monitoring & feedback

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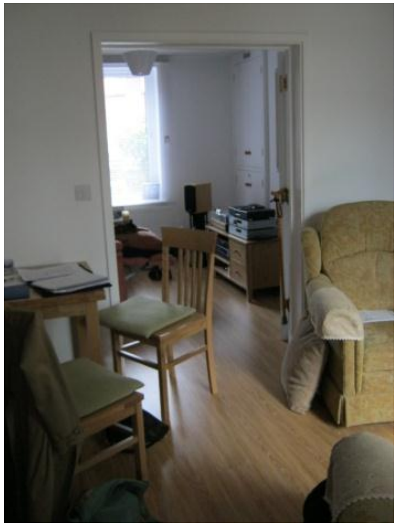
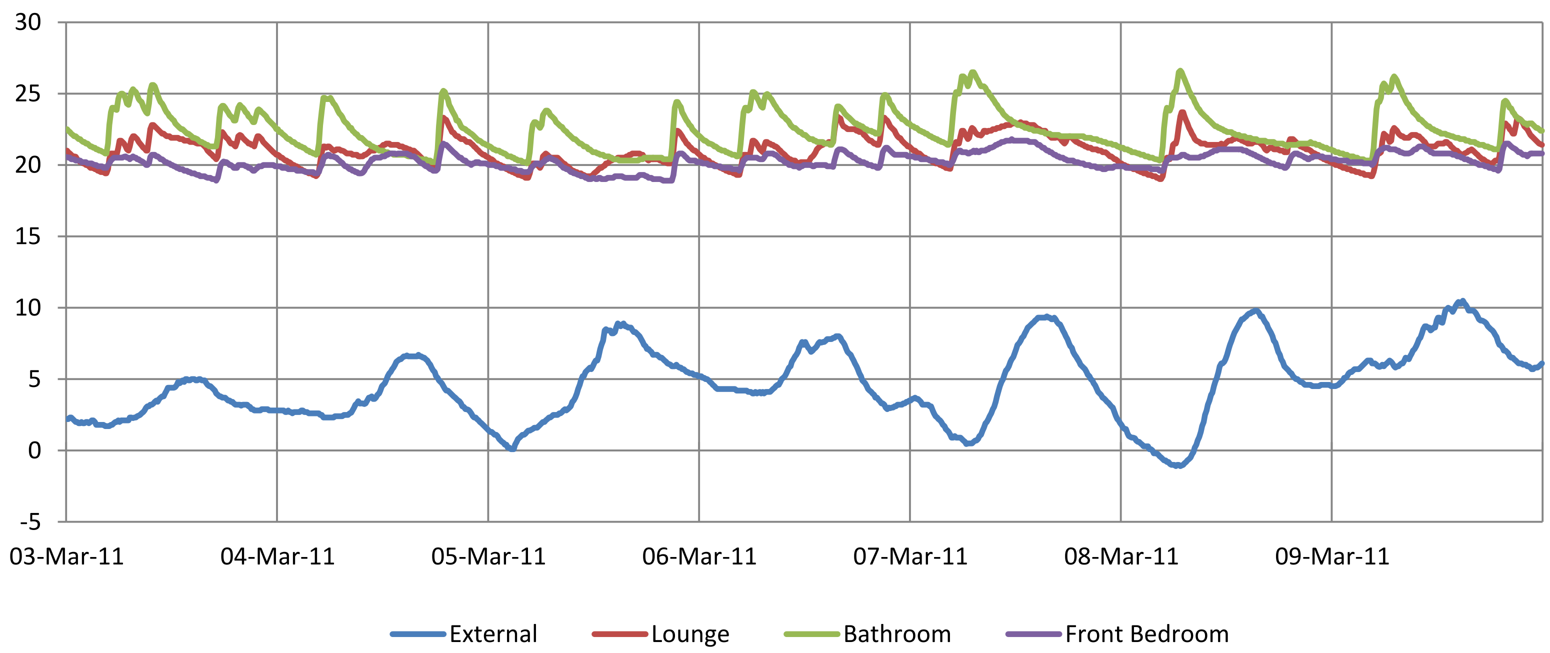
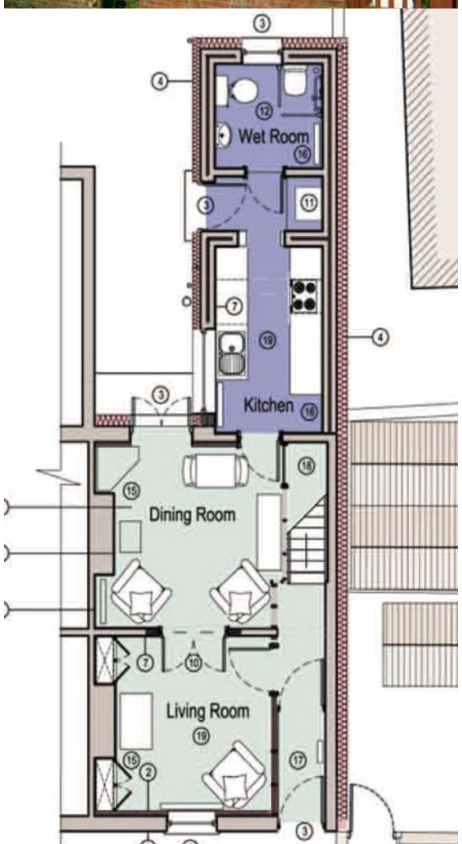




Post-refurbishment monitoring and post-occupancy evaluation



What are the best aspects of the house?

- Extra daylight
- No draughts
- Temperature control and responsiveness
- Noise reduction
- Less dusty

What are the worst aspects of the house?

- Lost storage space: spare bedroom replaced the attic as a storage place.
- Upstairs shower not working.
- Water temperature of the bath is too low.

"We are generally very delighted."

Overall conclusions: lessons and challenges

- M&E as a tool for continuous learning and improvement
- Helps to reduce the performance gaps between 'as designed', 'as built' and 'in-use performance
- Differentiate between **'need to know'** versus **'nice to have'** when doing BPE
- Avoid **overcomplicating** monitoring & evaluation requirements
- Build **intelligent feedback** from monitoring - avoid information overload
- Think of the user interface issues with new technologies.

Key challenges for M&E for housing refurbishment:

- Issues related to privacy
- Accounting for the increasing use of appliances by occupants.