

# Post-occupancy evaluation of non-domestic buildings



How to make non-domestic buildings green?

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OXFORD  
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## Structure of presentation

Background

Framework of POE studies of buildings

- Energy audits and energy surveys
- Environmental audits
- Assessing occupant satisfaction

Some case studies

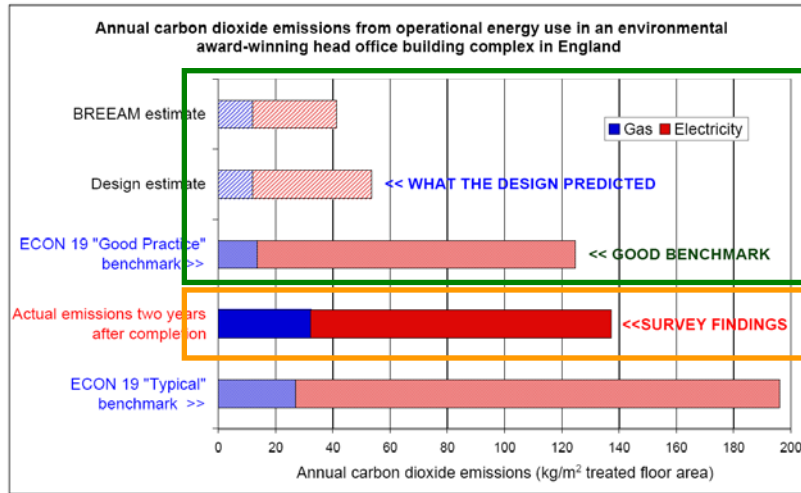
Conclusions

## Background

### First, a note about Building rating systems

- Rating tools provide a method of assessing the **environmental standard** of a proposed or existing building to:
  - Assist Architects and Building engineers in understanding what effect a design decision will have on the environment.
  - Appraise various options.
  - Identity potential shortcomings and to address problematic issues.
- There are various examples of rating tools. However, generally they fall into three categories:
  - Simulation models
  - Correlation tools
  - Scorecard rating tools

## Prediction and Actual: Credibility gap?



Source: Bill Bordass, 2005

## Prediction and Actual: Credibility gap?



Energy and Buildings 21 (1994) 121–131



### Two-to-one discrepancy between measured and predicted performance of a 'low-energy' office building: insights from a reconciliation based on the DOE-2 model

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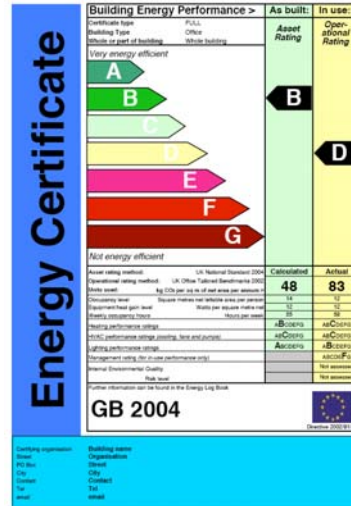
Received 1 February 1989; accepted in revised form 25 April 1994

#### Abstract

Computer models of building energy use, if calibrated with measured data, offer a means of assessing retrofit savings, optimizing HVAC operation (on- or off-line), and presenting energy-consumption feedback to building operators. The calibration process itself can pinpoint differences between how a building was designed to perform and how it is actually functioning. Our initial goal was to identify why the actual annual energy consumption of an office building was 325 kWh/m<sup>2</sup>, over twice the predicted value of 125 kWh/m<sup>2</sup>. Part of our effort to understand its performance involved calibrating a DOE-2 model prepared at the design stage. In the process, we formulated calibration guidelines and developed insights that may be of use to others. Of particular interest are the major sources of the wide discrepancy between predicted and actual energy use. Unanticipated tenant energy consumption, both during the day and the night, contributed 64% of the two-fold increase. Heating, ventilation and air-conditioning (HVAC) equipment operation beyond the expected 10 h per weekday contributed 24%. We attributed the remaining 12% to HVAC equipment not operating up to specification; building conductive heat loss in excess of the design-stage prediction; and minimum outdoor-air intake differing from the design value. The calibration process involved working on major input parameters independently of the others, then combining the results into one simulation. The calibrated model accounted for 94% of measured site energy for the building.

## Drivers for evidence-based evaluation

- Government looking to built environment to address climate change - hence 'zero carbon' aspiration by 2016 and 2019
- Building performance benchmarking is required to seriously address these
- Energy Performance Certificates mandatory - evidenced based feedback is essential and inevitable

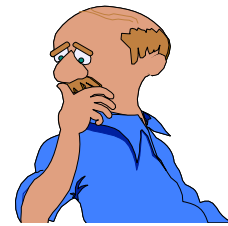


## So, what makes up measured consumption?

- The **theoretical potential** of the base building's fabric and services under standard assumptions.
- The **build quality** and **commissioning** of the above.
- The **fit out** by the occupant. THIS CAN UNDERMINE THE DESIGN INTENTIONS.
- The **equipment** added by the occupant.
- The **pattern** of use of the building & equipment.
- **Operation, control, maintenance, management** of all the above, by both landlord and tenant.

Source: Bill Bordass, 2005

## So, what is post-occupancy evaluation of buildings?



### What is POE?

- According to Adrian Leaman (Building Use Studies Ltd), POE of buildings tries to answer the following broad questions:
  - How is a building working?
  - Is this what was intended?
  - **How can it be improved?**

## What is POE?

- POE involves systematic **collection** and **evaluation** of information about the performance of a building in use.
  - Data collected can include
    - **measured information** such as energy consumption, temperatures, lighting levels, acoustic performance etc.,
    - **survey data** from the perspective of the occupants regarding issues such as comfort, aesthetics, occupant satisfaction, management, etc.
  - Most importantly, it identifies ways to improve building design, performance and fitness for purpose.
- 

## What are the benefits of POE?

- Reduces client's future costs
  - Reduces whole-life environmental impact
  - Maximises value of property portfolios
  - Reduces future liability of clients
  - Minimises maintenance costs
  - Increases occupants satisfaction
  - Increases design know-how
-

## POE and Architectural education

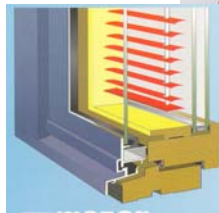
The reality is that students focus on:

- Design
- Technology
- Urban issues
- History



There is little focus on:

- People as users
- Change over time
- Assessing performance



(Adapted from: Gorgolewski, Windsor Conference, 2004)

## POE and Architectural education: Key benefits

Focus on the experiences of users

Develops an appreciation of "real" building performance

Develops an understanding of how buildings change over "time" as a design factor and how they can design buildings that are more adaptable to future change

Improves appreciation of how spaces work

Establishes the importance of clear brief & objectives

Understanding of importance of integrating appropriate technology

Establishes feedback loops

## Framework of POE studies

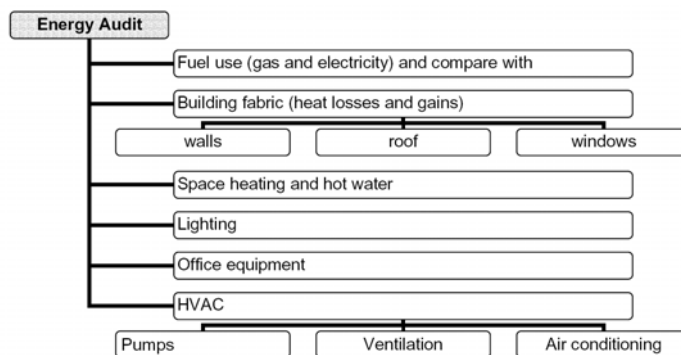
## Key techniques in POE

- resident questionnaires
- energy audit e.g. CIBSE TM22
- semi-structured interviews– design and build team, residents
- focus groups
- thermal imaging
- field observations of user behaviour
- monitoring of energy and water use
- meter readings

## Framework of the POE study: Energy Auditing and Energy Surveys

### Energy auditing

An **energy audit** is a study to establish the quantity and cost of each form of energy input to a building, site or organisation.



## Energy auditing: Stages

### 1. Preliminary audit: pre-survey calculations

Deals primarily with energy bills, and therefore does not involve a detailed site investigation.

### 2. Full audit: energy surveys

Breakdown energy use on service-by-service basis which involves measurement, analysis or direct assessment of energy consumption to indicate the proportions attributable to heating, lighting, air-conditioning etc.

Such information can only be obtained by performing a site survey.

## Preliminary audit: Benchmarking

Comparisons with simple benchmarks allow the standard of energy efficiency to be assessed and priority areas for action to be identified.

- Energy use Index
- Energy cost index
- Carbon dioxide emission index

KEY	
<span style="color: red;">■</span>	Heating and hot water
<span style="color: blue;">■</span>	Cooling
<span style="color: orange;">■</span>	Fans, pumps, controls
<span style="color: green;">■</span>	Humidification
<span style="color: yellow;">■</span>	Lighting
<span style="color: purple;">■</span>	Office equipment
<span style="color: cyan;">■</span>	Catering, gas
<span style="color: lightblue;">■</span>	Catering, electricity
<span style="color: brown;">■</span>	Other electricity
<span style="color: white;">■</span>	Computer room (where appropriate)

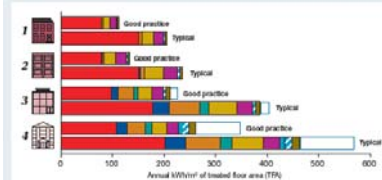


Figure 1 Energy use indices (EUI) for good practice and typical examples of the four office types

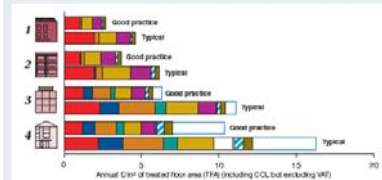


Figure 2 Energy cost indices (ECI) for good practice and typical examples of the four office types

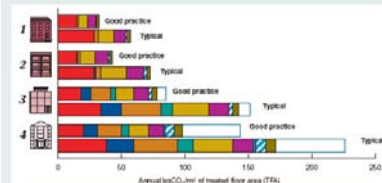


Figure 3 Carbon dioxide emission indices (CEI) for good practice and typical examples of the four office types

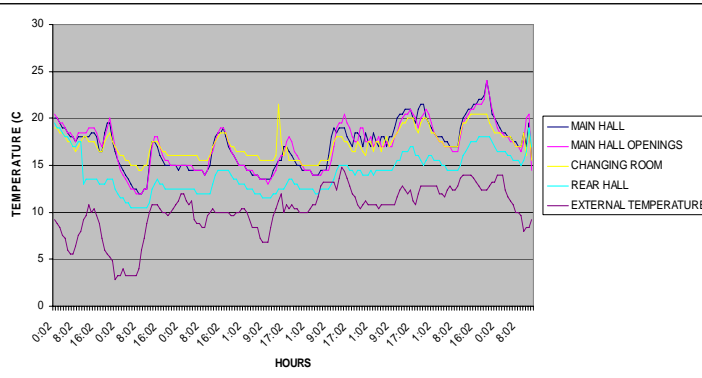
## Framework of the POE study: Environmental Auditing

### Environmental auditing

Tools for the evaluation of the building environmental impact include:

- Quantitative monitoring of the internal environment and analysing monitored information (temperature, humidity, lighting),
- Developing a qualitative credit-based approach (using evidence collected) to assess the various categories of transport, water, waste and material impact of the case studies.

## Environmental monitoring



Monitored average internal temperature over a week and comparison to external temperatures in a City Council building.

Internal temperatures in almost all buildings are inconsistent, with some spaces as cold as 17°C whilst others heated to over 25°C.

## Credit-based approach

Good	Pass	Indifferent	Poor	Fail
2	1	0	-1	-2

A summation of these scores will give an indicative environmental performance for the building.

Category	Score
Electricity consumption of 68.7kWh/m <sup>2</sup> is more than double the Carbon Trust's typical consumption benchmark for secondary schools of 30kWh/m <sup>2</sup> (These high electricity consumption rates may be attributed to on-going construction activities)	-2
Gas consumption of 120.7kWh/m <sup>2</sup> is well below the Carbon Trust's good practice consumption benchmark for secondary schools of 1.26 kWh/m <sup>2</sup>	2
Water consumption of about 8m <sup>3</sup> per pupil is well above the Carbon Trust's good practice consumption benchmark for secondary schools with no swimming pool of 5.8m <sup>3</sup> per pupil	-2
Education: There is very little visible education on local environmental issues.	-1
Waste Management: The school has no visible waste management policy in practice.	-2
Transport Policy: The school has a catchment radius of only 1500m, therefore, encouraging cycling and walking to school. The full cycle park and active encouragement of teachers driving in to work is evidence of this.	2
Rainwater harvesting and use a visible and effective symbol of natural resource management	2
The school website states: "The Charter School will be a community school fostering a social and environmental conscience". There is, however, no clear evidence of the application of this ethos.	0
Indoor air quality: Indoor air temperatures are too high and occupants complain of stuffy environments.	-1
Temperature controls and sensors excessively vandalised.	-2
Corridors and classrooms extensively littered, evidence of pupil's little concern for their environment's appearance and well-being.	-1
Lighting: There is adequate levels of natural light in the bays running along the external facades. This is not utilised instead blinds are drawn and lights switched on.	-1
Very limited use of air conditioning.	1
Over all awareness about environmental issues and reduction of energy consumption is low amongst staff as well as pupils.	0
<b>TOTAL</b>	<b>-5</b>

Good	15 to 30	-5 Poor
Pass	0 to 14	
Poor	-15 to -1	
Fail	-30 to -16	

Evidence from such qualitative monitoring, combined with personal observations by students, semi-structured interviews with the building manager, and questionnaire surveys of occupants, provide the evidence for allocating respective credits to questions for different categories.

Individual credits are then aggregated to give an overall score and rating for the environmental impact of the building.

Environmental score sheet

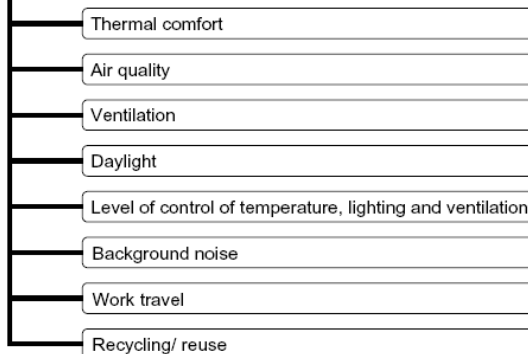
## Framework of the POE study: Occupant satisfaction

A questionnaire is developed to assess:

- Occupants' indoor environmental satisfaction.
- Current levels of environmental awareness.
- Use of controls.
- Gather information about staff habits such as recycling habits, paper consumption and driving distances etc.

### Occupant satisfaction

#### Occupant Satisfaction Survey



## Occupant satisfaction

Depending upon the use of the building, the questionnaire survey is either conducted face-to-face, drop and collect, or even electronically distributed to staff

The screenshot shows a Microsoft Excel spreadsheet titled "Questionnaire Answer". The survey questions and their corresponding answers are as follows:

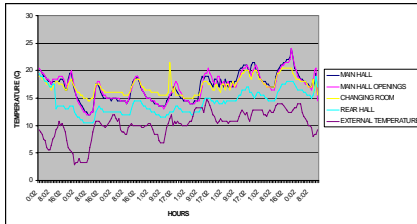
Question	Answer
<b>Air Quality</b>	
How do you find the air movement in your office?	Very stuffy
How do you find the air smell in your office?	Slightly smelly
How do you find the humidity in your office?	Just right
<b>Lighting</b>	
Is there adequate natural light to work during the day?	No
How often are you affected by glare?	Often
Does your office window have a blind?	Yes
If yes, how often do you use the blind?	Often
If yes, how effective do you find the blind?	Effective
Do you control the lights in your working area?	Yes
If yes, how effective do you find the lighting controls?	Very effective
How often do you turn the lights off when you leave your office?	Always
<b>Working Environment</b>	
Do the windows closest to your workspace overlook:	Town Hall
How often does your job involve being away from your desk?	Often
Do you have a pleasant view from your desk?	No view at all
Are you adversely affected by background noise level?	Sometimes
Do you enjoy working at the Blue Boar Street Office?	Yes
Please specify why:	
<b>Waste management</b>	
Does your office have a recycling policy?	Yes
How often do you recycle the paper or plastic that you use?	Always
How often do you turn your computer off when you leave your office?	Always
<b>Any other comments?</b>	

Electronically-administered occupant satisfaction survey for Blue Boar street office building. Received a very high response rate.

## Case studies

## 1. POE of public buildings

Energy audits of Oxford City Council-owned non-domestic buildings.  
Monitoring of building performance: temperature and humidity  
Environmental audit



Recommendations have been taken up!

## POE of public buildings: benchmarking

**Community centre buildings:** found to have a poor fabric performance in terms of heat loss, lack of insulation in the walls, and leaky fabric.

**Oxford Town Hall** performs extremely well against benchmarks, as it is a heavy thermal mass Victorian building, powered by green-tariff electricity.

Building Type	Energy use (fossil fuel + electricity) kWh/m <sup>2</sup> /year		
	Case Study	Typical	Good Practice
<b>COMMUNITY CENTRES</b>			
Blackbird Leys Community Centre	382	220	147
Donnington Community Centre	442	220	147
East Oxford Community Centre	405	220	147
Headington Community Centre	324	220	147
Bullingdon Community Centre	213	220	147
Regal Community Centre	234	220	147
Risinghurst Community Centre	258	220	147
<b>OFFICES</b>			
Ramsey House	175	203	115
Blue Boar Street Offices	225	236	133
<b>SPORTS BUILDINGS</b>			
Oxford Ice Rink	355	281	196
Temple Cowley Sports Centre	1157	1573	725
<b>TOWN HALL</b>			
	153	316	222

## Recommendations to improve building performance

No-cost measures	
<b>Raising awareness</b> Environmental policy Recycling Waste Public transport policy Switching off equipment	<b>Heating system</b> Re-programme boiler timings Change furniture placement (for natural lighting also).
Low cost measures (capital cost of £500-£1000)	
<b>Heating Systems</b> Insulate pipe-work Log books Foil behind radiators Thermostatic radiator valves	<b>Lighting</b> Energy efficient fixtures Internal blinds
Medium cost measure (capital cost up to £5000)	
<b>Built fabric</b> Wall insulation Roof insulation Floor insulation Double Glazing Draught proofing	<b>Heating Systems</b> Time sequence controls New high efficient boilers Replace electric heaters
<b>Lighting</b> Occupancy sensors Daylight Sensors Task Lighting Individual switches/group lights	<b>Miscellaneous</b> Plants in internal spaces Brighter paints
High cost measures (capital cost over £5000)	
<b>Renewable energy</b> Photovoltaics Solar water collectors	<b>Miscellaneous</b> Appointing energy manager Introducing roof lights Building cycle stands and shower rooms

Potentially about 30% of CO<sub>2</sub> emissions could be reduced cost-effectively using 'no-cost' and 'low cost' measures.

If the 'medium-cost' and 'high-cost' measures are also added, savings could technically increase above 50%.

## 2. City of London Academy

Secondary education institute awarded the Prime Minister's Public Building of the Year Award in 2006, for Public Partnership Contract (PPC).

School for 11-19 year old students  
 Offers ICT, finance, business and economics.

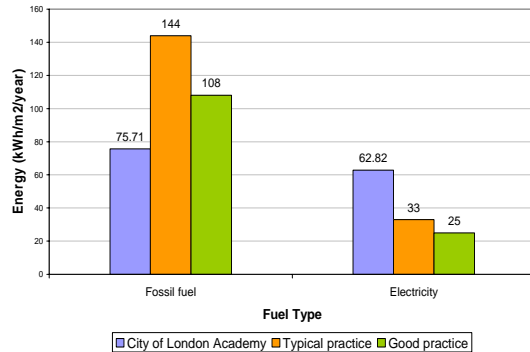
Two separate buildings – one for teaching and administrative areas, the other for sports.



Internal view of the atrium

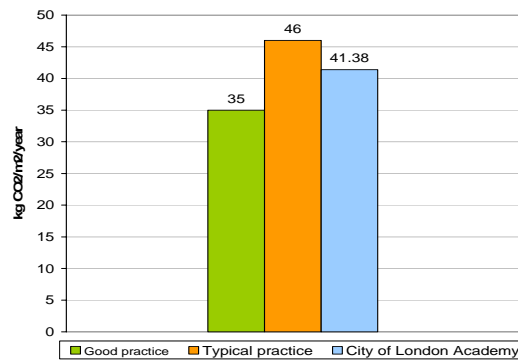
## Energy performance

Gas use is better than good practice benchmarks - shows a well-performing fabric and efficient heating system.



Electricity use is much higher than typical practice – increase in IT and other equipments for teaching, increased lighting load or wastage of electricity.

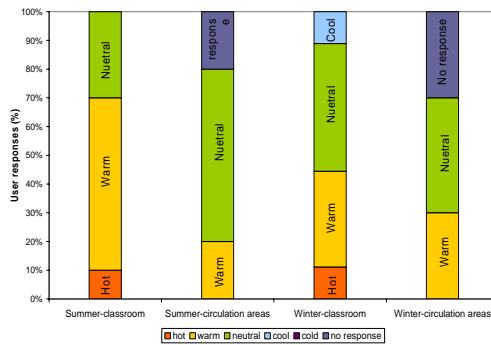
## CO<sub>2</sub> emissions



The total CO<sub>2</sub> emissions are mid - way between typical and good practice benchmarks - shows potential for fuel and cost savings.

## Occupant Satisfaction

Summer overheating specially in south-facing rooms - lack of any external shading strategies



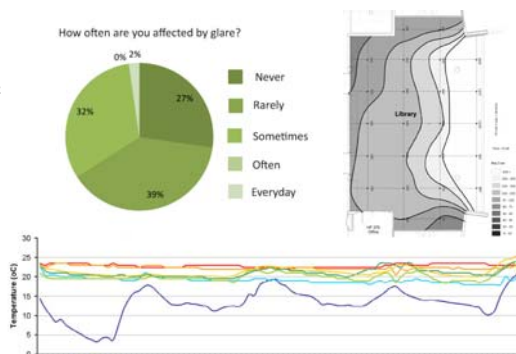
High temperatures in the atrium – central core which overheats frequently.

Noise of rain on the atrium roof requires attention to impact of construction materials.

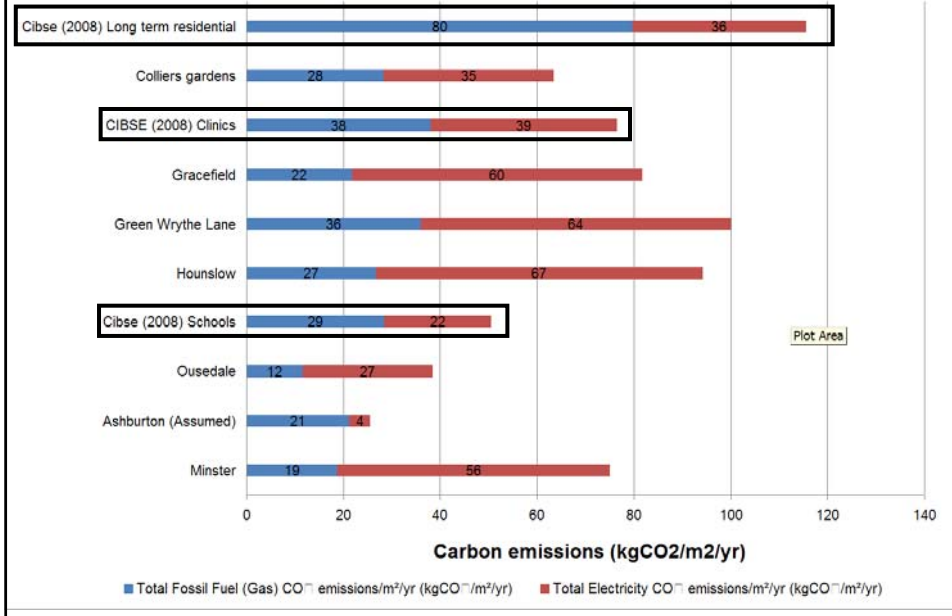
## 3. POE of sustainable education and healthcare buildings: informing future building design

Commissioned by Architects to undertake POE of 8 sustainable buildings as part of the 'post-occupancy building evaluation' module.

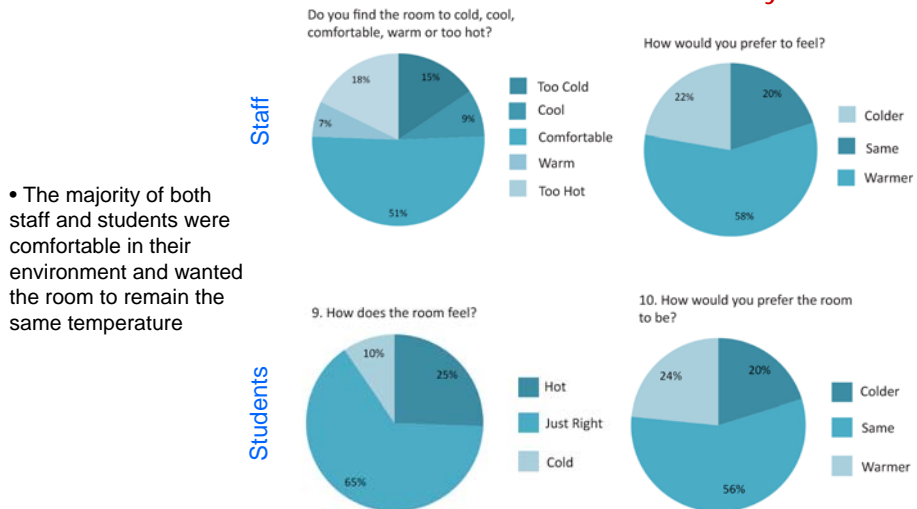
Provides valuable feedback to both architectural and building services firms to inform their subsequent building designs, specifications and performance.



## POE of sustainable education: comparative evaluation



## POE of sustainable education: thermal comfort survey



## Overall conclusions

Design in post-occupancy feedback...

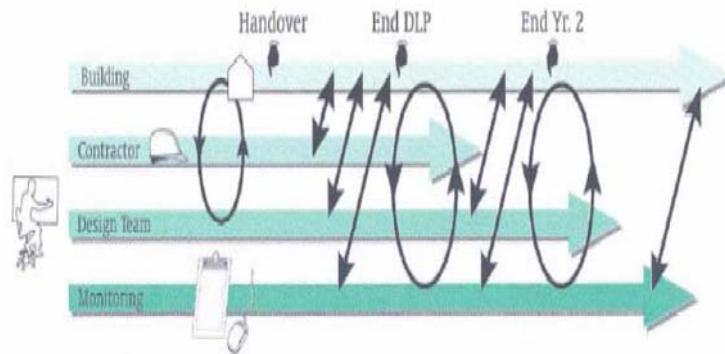


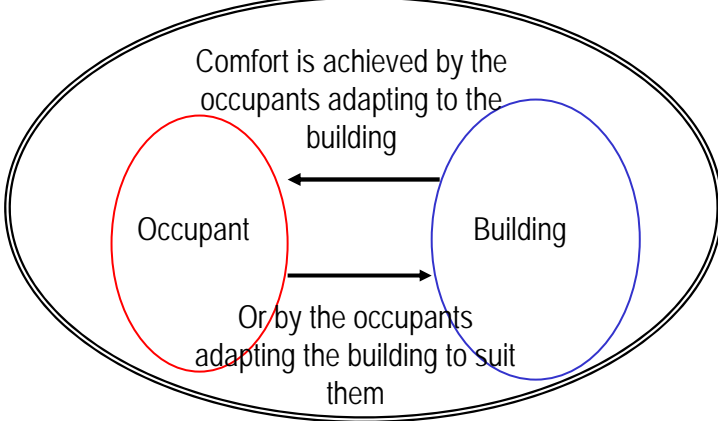
Diagram showing feedback loops required during all stages of a project.  
Source: Howard Liddell and Sandy Halliday

## Overall conclusions

Key lessons to learn from POE studies:

- Passive design - first step to a low energy building.
- Avoid overheating in summers: design atriums carefully.
- High electricity load leads to higher carbon emissions.
- Think of the user interface issues with new technologies.
- Provide control over immediate environment
- KEEP IT SIMPLE, DO IT WELL AND THEN BE CLEVER (Bill Bordass, 2008)

# Buildings, People and Temperature: Adaptive comfort model



This has to be done within the climatic, social, economic and cultural context of the whole system

(Source: Professor Fergus Nicol, 2007)

## LEARNING BY DOING: A POST-OCCUPANCY BUILDING EVALUATION MODEL FOR POSTGRADUATE ARCHITECTURE STUDENTS

Dr Rajat Gupta<sup>1</sup>

<sup>1</sup>United Institute of Sustainable Development, Oxford Brookes University, Oxford, United Kingdom

**ABSTRACT:** This paper describes the learning and making approach adopted in a postgraduate (post-occupancy) evaluation (POE) model for students at the United Institute of Sustainable Development (UISD), Oxford Brookes University. The model is based on the idea of 'learning by doing' and is designed to provide students with a practical understanding of the building process. The model is based on the idea of 'learning by doing' and is designed to provide students with a practical understanding of the building process. The model is based on the idea of 'learning by doing' and is designed to provide students with a practical understanding of the building process.

## Related Publications

A student-centred POE approach to provide evidence-based feedback on the sustainability performance of buildings

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<sup>1</sup>United Institute of Sustainable Development, Oxford Brookes University, Oxford, UK  
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