Building performance feedback for UK homes

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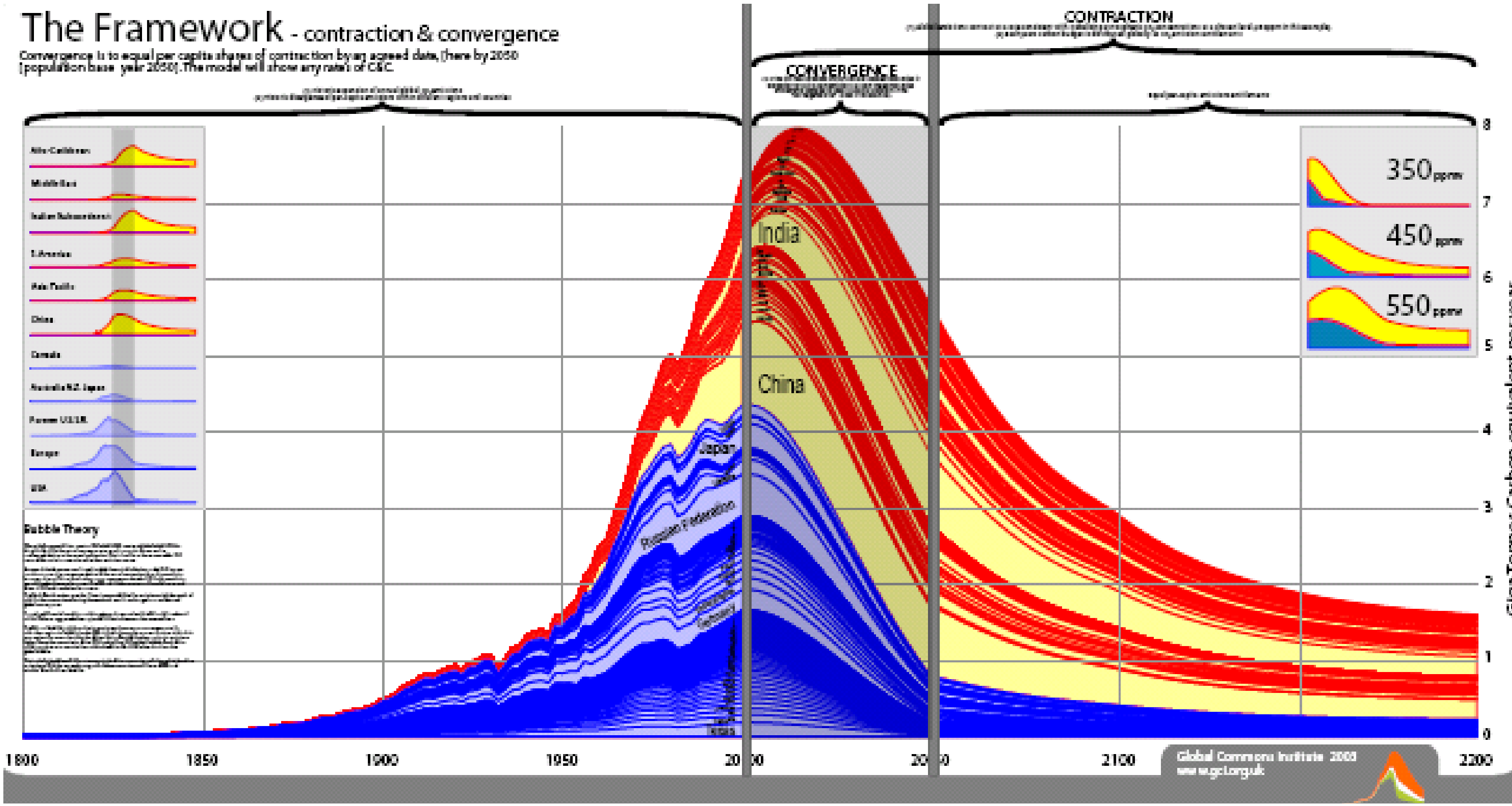
The big question:

Can we improve the performance of our housing in time to save the planet?

Oxford Institute for Sustainable Development (OISD)

- 50 researchers in the built environment + 50 PhD students
- Recognised as key institution for sustainable development research in UK
- OISD has research staff dedicated to POE and monitoring, who also teach this as CPD on MSc. Sustainable Building: Performance and Design
- Current monitoring and POE projects include: British Council of Offices, Stewart Milne Homes, Kingerlee Homes, Architype Architects, Oxford City Council (23 buildings to date, ongoing), Portsmouth library

The challenge: 90% reduction on 1990 CO2 levels needed for UK by 2050



drivers for evidence-based evaluation

- government looking to built environment to address climate change – hence 'zero carbon' aspiration by 2016
- Code for Sustainable Homes has specific new targets to be met now
- housing performance benchmarking is required to seriously address these
- Energy Performance Certificates mandatory – evidenced based feedback is essential and inevitable
- RIBA has set up 'anonymous' register for carbon dioxide emissions from buildings to overcome confidentiality problems

current situation with housing performance

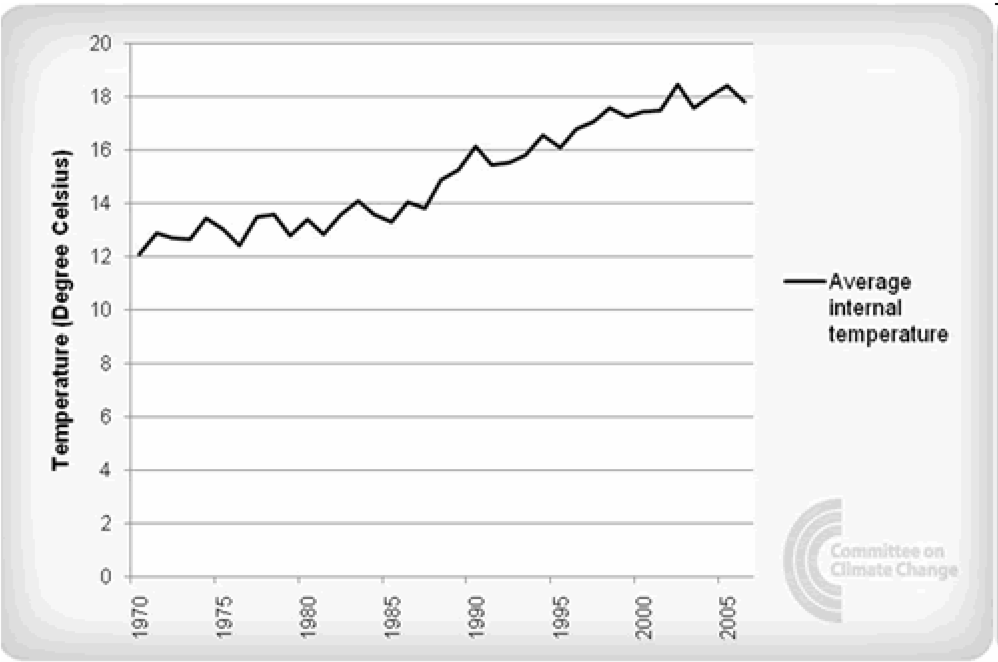
- 40% of buildings tested during a recent BRE study failed their airtightness test
- flagship CSH5 and 6 demonstration houses on the BRE Innovation Park initially failed their airtightness tests also
- major gap between predicted performance and actual performance
- very little hard evidence of housing performance

heating in homes

housing responsible for around 27% of UK Carbon emissions.

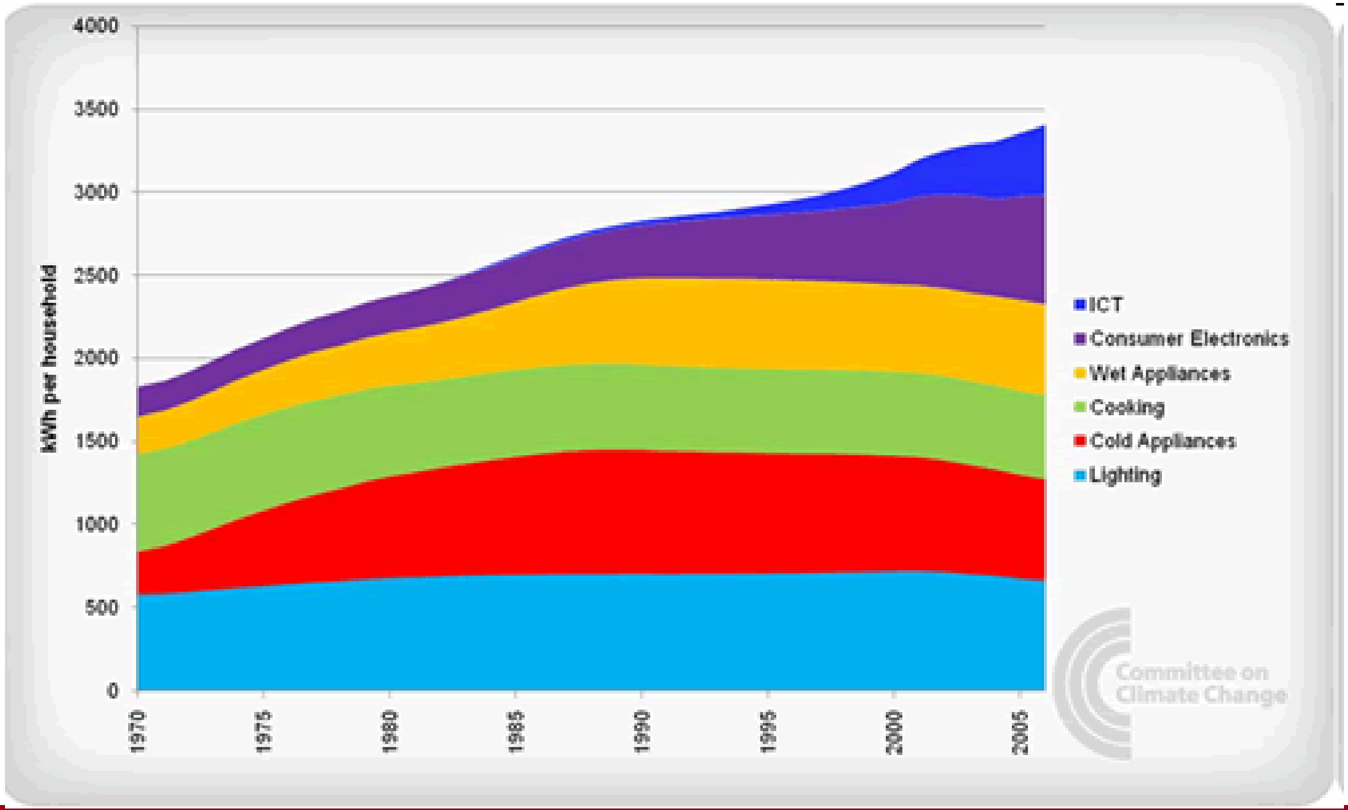
Just over half comes from direct combustion of fossil fuels – mainly for heating.

Despite improvements in efficiency, emissions broadly flat as people heat their homes to a higher standard.



electricity consumption in homes

consumption per household has increased by 8% since 1990 -growth of computers, consumer electronics and number of homes.



the real problem….

- Big gap between prediction and observation
- Only half the predicted savings achieved from energy interventions - **why is this happening?**

We need better understanding of:

1. modelling of buildings at design stage
2. how buildings work in practice (building physics)
3. how people use buildings to create comfort
4. fabric, technology, control systems & occupant interactions

(D.Shipworth, UCL, 2009)

the solution...design in feedback at all stages

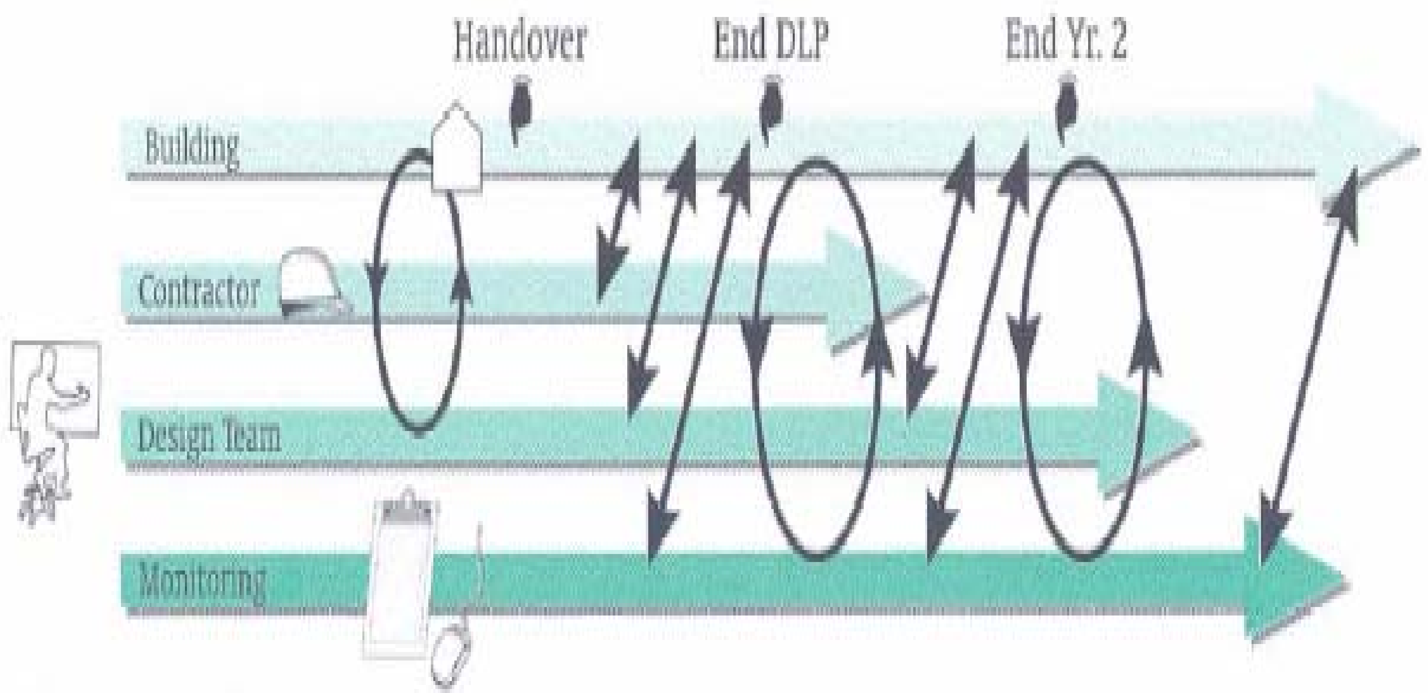


Diagram showing feedback loops required during all stages of a project.
Source: Howard Liddell and Sandy Halliday

Some quick feedback definitions...

Satisfaction survey = are people happy in the building?

Monitoring = did it measure up physically?

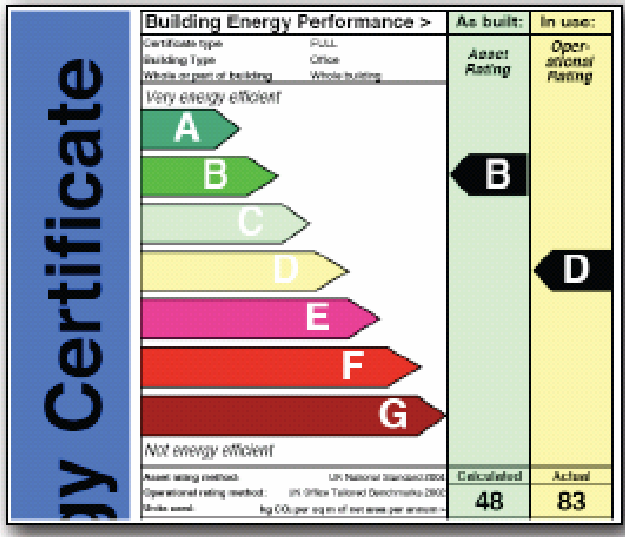
Post completion evaluation = how did the construction process go?

Post occupancy evaluation = are people happy and did the building measure up?

Soft Landings = how do we build all this into the brief ?

The economic advantages of feedback

- reduces future costs
- reduces environmental impact
- maximises value of property portfolios
- reduces future liability
- minimises maintenance costs
- increases design know-how



3 key questions for evaluating housing performance

1. How is the building performing?

2. How satisfied are the residents?

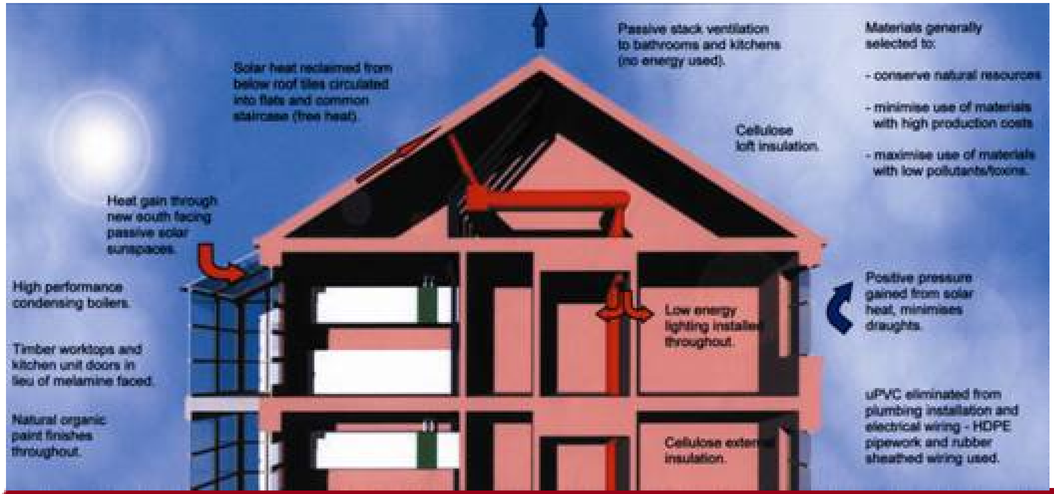
3. What is the relationship between building performance and residents' perceptions/actions?

key techniques in housing feedback

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

longitudinal feedback study in Scotland

- assess performance of key low energy features used in affordable housing
- evaluate from the perspective of the different actors involved: development officers, housing managers, and tenants
- study over a long period of time and from a multiple perspective to triangulate results and learn lessons

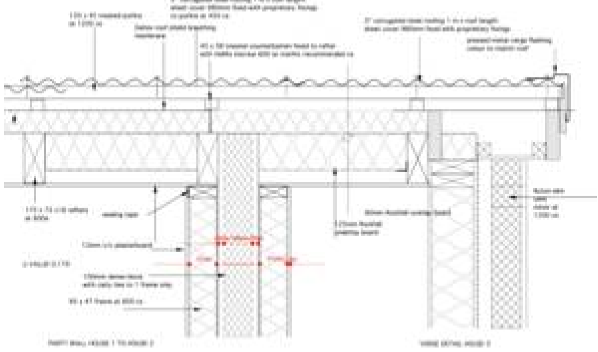


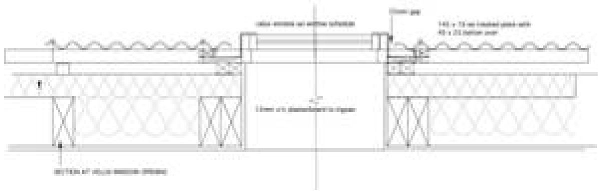
identification of projects

- Questionnaire sent to 150 social housing providers in Scotland
- 51 responded - response rate of 32%.

- 13 case studies selected in 2000
- 10 further case studies in 2007 (+ follow up of original 13 studies) = 23 in total
- 8 refurbishment, 15 new build –mostly urban (5 – 120 housing units)

methods





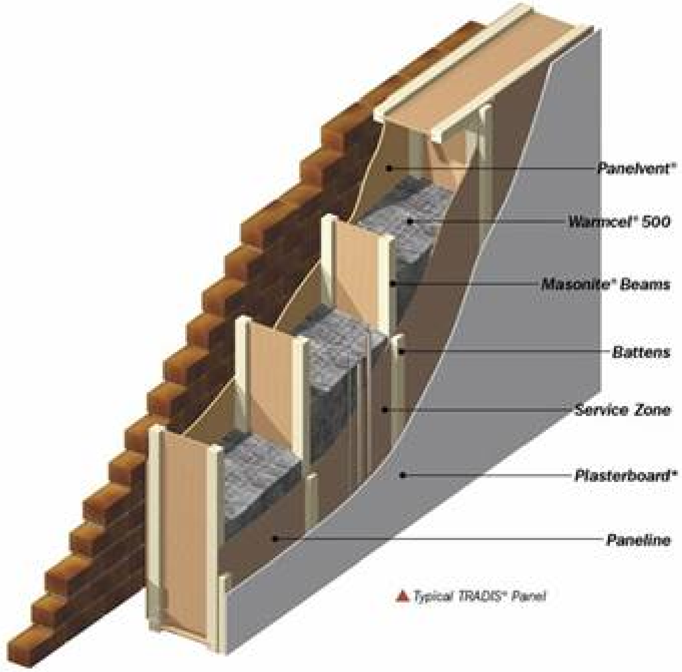
- multi-modal method

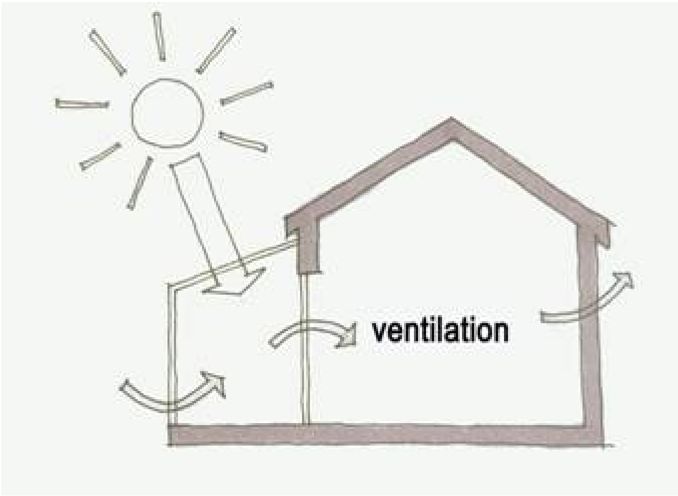
- pre-visit questionnaires
- technical data pro-forma to establish construction
- semi-structured interviews with key actors

- field observations during walk-through visits
- predicted and actual energy costs identified where possible

results – features used

low energy feature/ nos. of cases	initial cases 1999	additional cases 2006	Total	% of all
high insulation	9	9	18	78
passive ventilation	5	5	10	43
breathing wall	4	4	8	35
sunspaces	6	2	8	35
communal heating	3	4	7	30
thermal mass	0	3	3	13
solar panels (water)	2	1	3	13
ground source heat pumps	1	1	2	9
dynamic insulation	0	1	1	4
biomass energy/Combin-ed Heat and Power (CHP)	0	1	1	4
Mechanical Heat and Ventilation Recovery (MVHR)	1	0	1	4





results –overall acceptance of features over time

low energy features 1999 revisited	Would provider use feature again?	% providers who would use again
high insulation	yes, if affordable	100
passive ventilation	yes	100
breathing wall	yes	100
sunspaces	yes, amenity only	66
communal heating	yes	66
solar panels (water)	yes, if affordable	100
ground source heat pumps	yes	100
MVHR	no	0

post-occupancy evaluation (POE) studies

Only 7 out of the 23 case studies carried out full POE

- 2 POE studies ‘lost’
- 1 focussed only on health issues -omitted
- 4 used widely different methodologies
- two shared indicators: thermal monitoring and basic overall energy use

post-occupancy evaluation –shared indicators

Project/ shared POE indicators	Thermal monitoring	Energy use	
1.	x	x	
2.	x	x	
3.	x	x	
4.	x	x	
Project/ other POE indicators	Humidity	User survey	Thermographic imaging
1.		x	
2.	x	x	
3.	x	x	x
4.			x

dealing with emerging issues

emergent problems due to:

- lack of precedent
- change in use and management
- changing technology
- poor information management
- design failure
- climate change

Solutions= passive features and systems which are self-managing

= embedding POE in housing procurement

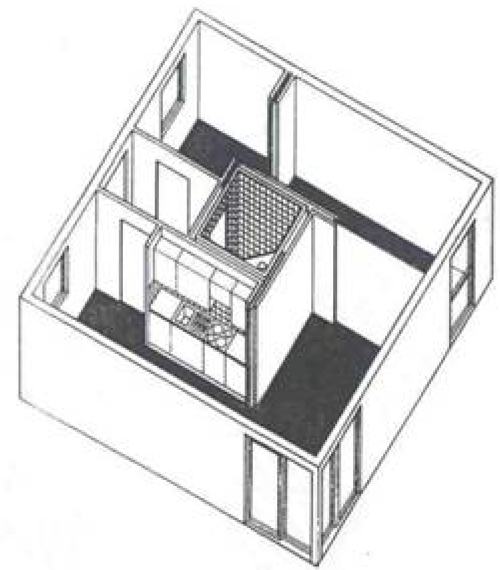
= preserving tacit knowledge through archiving - electronic and paper

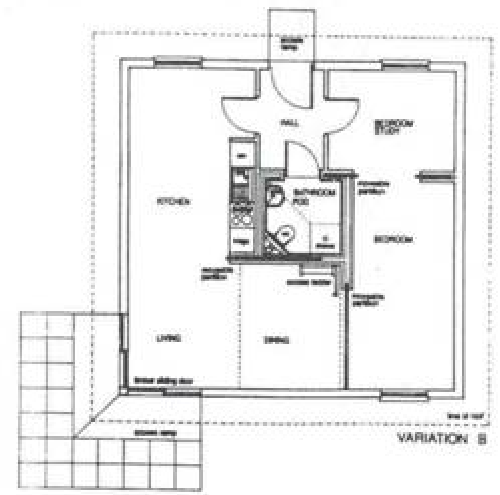
barriers and opportunities....

- organisations more focussed on the next development than evaluating the one just completed
- uneconomic to undertake POEs for buildings if physical monitoring is required
- Using POEs which aim to identify only what is abnormal, rather than monitoring normality continuously, can significantly reduce costs
- cost of a ‘snapshot’ POE factored in as a quinquennial maintenance item can quickly recoup themselves through problem-identification

Case study 1: Kincardine O'Neil, Aberdeenshire

- environmental audit
- energy costs measured
- walkthrough
- resident, management and design build team interviews after 2 and 7 years





findings....

- undersized mechanical ventilation
- high energy use
- overheating in summer and low heating in winter
- conflict between thermal mass and heating controls

Case study 2: Dalguise, Perthshire

innovative material -unfired clay bricks

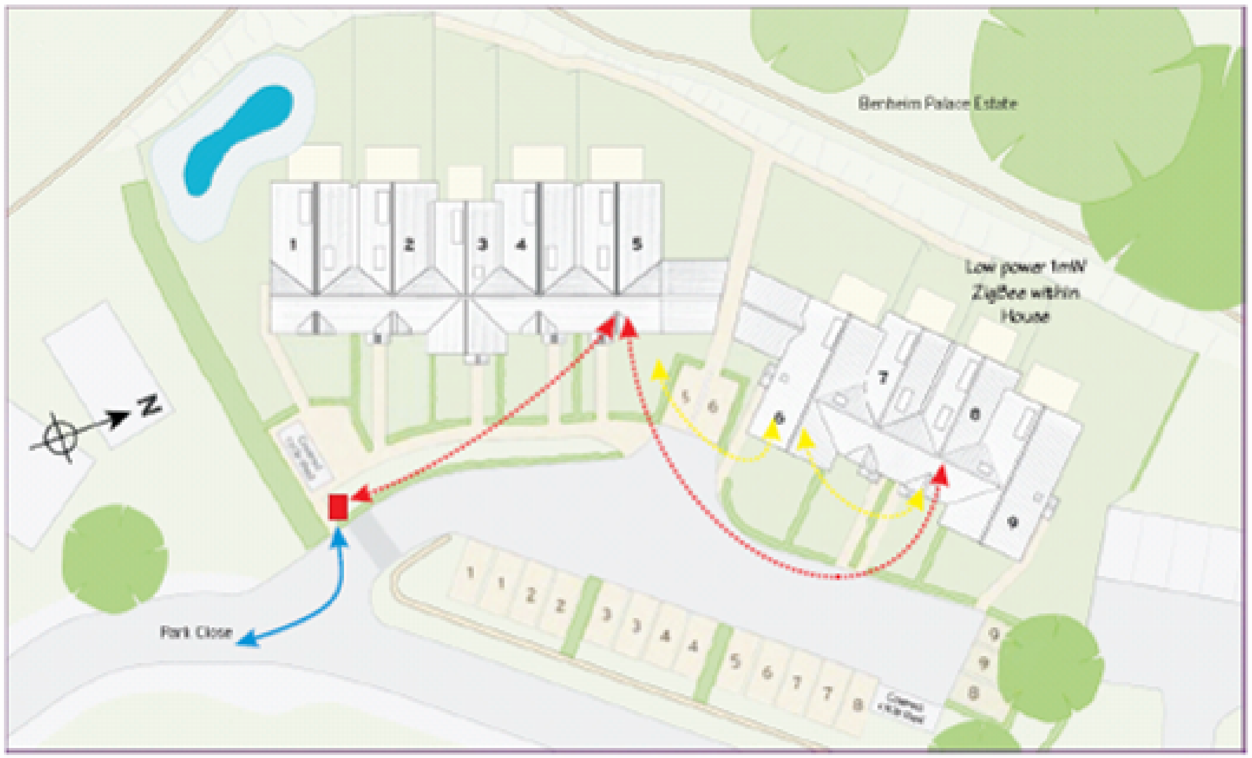
evaluated:

- buildability + durability
- temp + relative humidity
- Acoustics
- maintenance
- residents response

Key lessons…….

- weekly logsheets very useful for monitoring but….
  need to remind residents weekly!
- monitoring equipment needs to be unobtrusive
- difficult to screen out variables in field testing

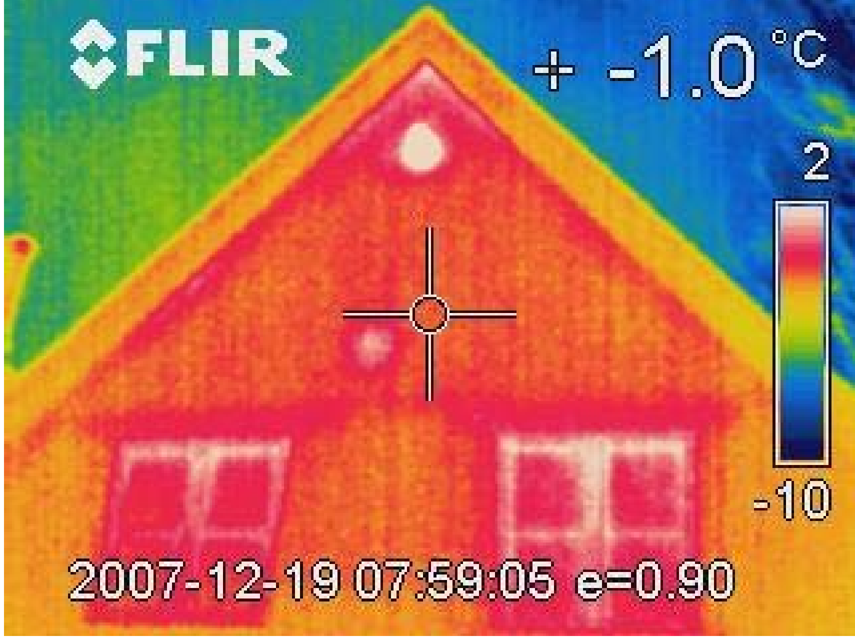
Case study 3: Bladon, Oxfordshire



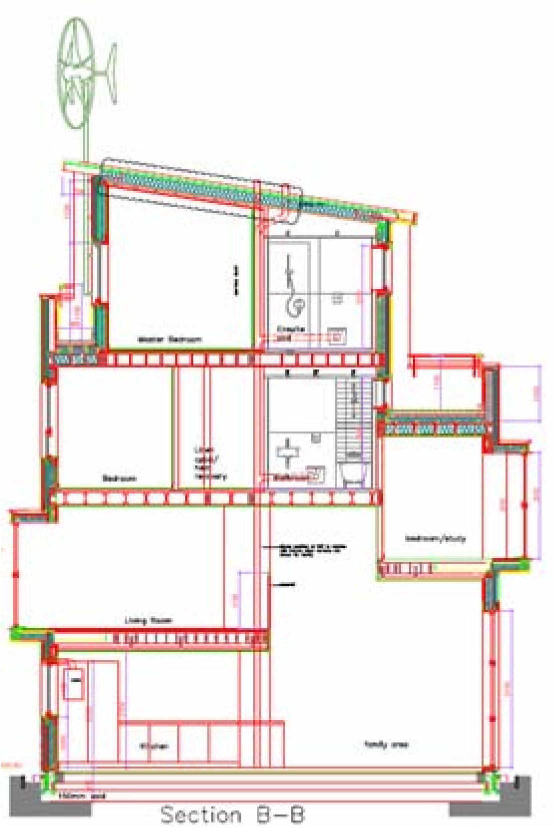
= Coordinator in IP65 housing + ADSL modem (or GPRS)
Red = Radio Links (ZigBee 100mW) from 8 to ??5 (or other) then to Coordinator box
Yellow = Alternative if signal of above too week
Blue = ADSL modem link to internet (alternative is GPRS)

initial findings...

- higher humidity due to construction
- thermal bridging at key junctions
- minimal use of appliances by occupant –low energy use

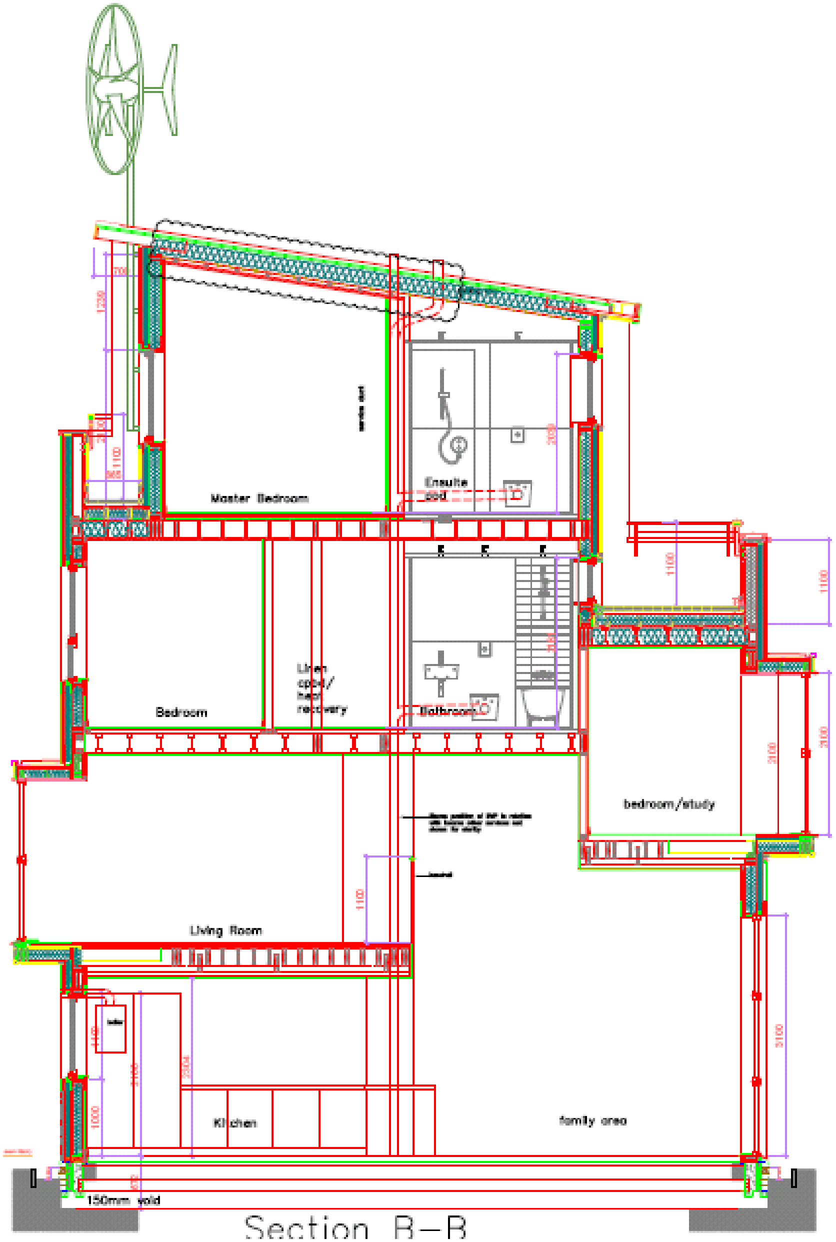


Case study 4 : Sigma Home CSH level 5, BRE



aims

- Assess performance of timber frame prototype house
- Triangulate perceptions and actions of residents with physical monitoring
- Improve design of home prior to mass production offsite



background to Sigma Home

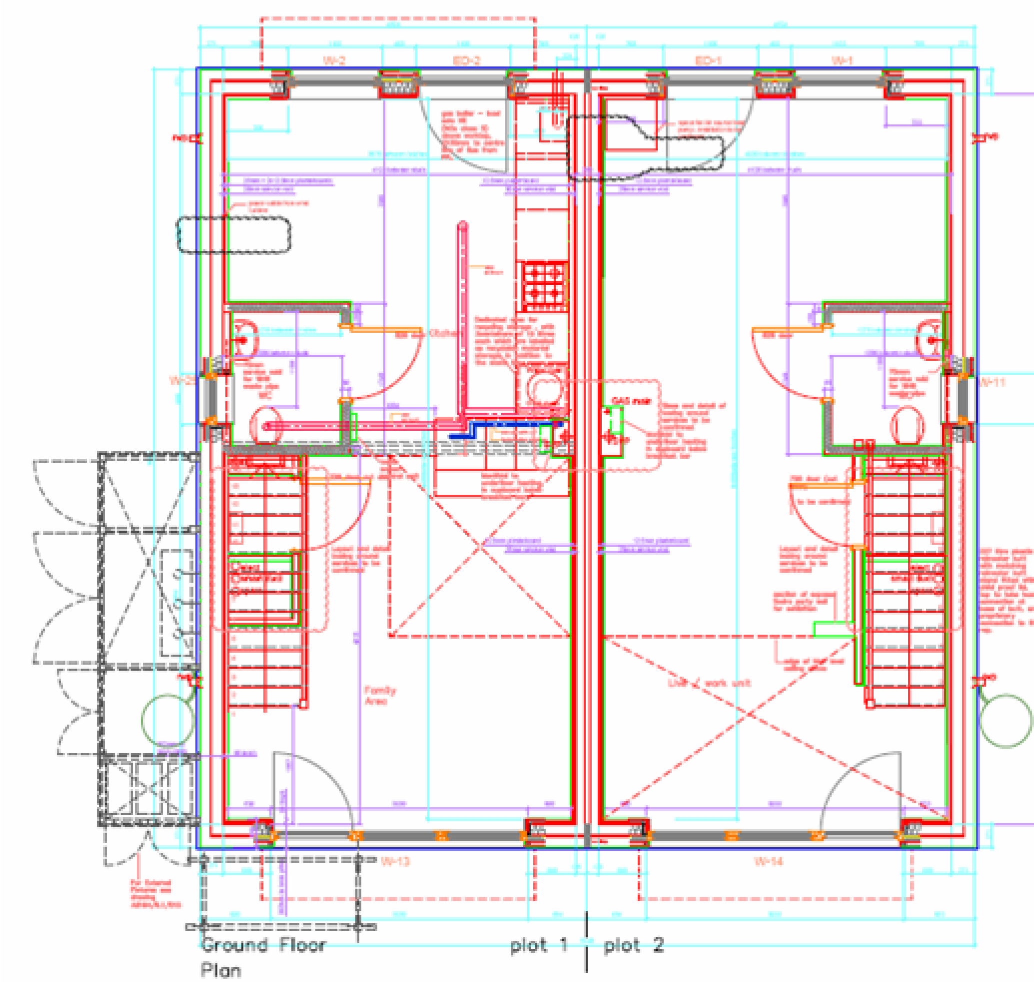
Built in 8 weeks as exhibition house

Site is just north of London, UK

Semi-detached, 4 storey

116m^2 floor area

Built to Code for Sustainable Homes
Level 5 = zero carbon for heating and lighting (but not appliances)



feedback methods used

- 2 week occupation periods for each season over a year
- Pre-selected family of 4 : 2 adults, 2 children age 7 and 12
- Combination of wireless monitoring, interviews, video and logging
- Logging = thermal comfort survey, activity sheets
- Field observations during walk-through visits
- predicted and actual electricity, gas and water use

co-heating test

1. Seal whole building completely
2. Set temperature against a varying outside temperature over 7 days
3. Establish actual heat-loss of the external fabric against predicted
4. Needs significant temperature difference :15 degrees ideally

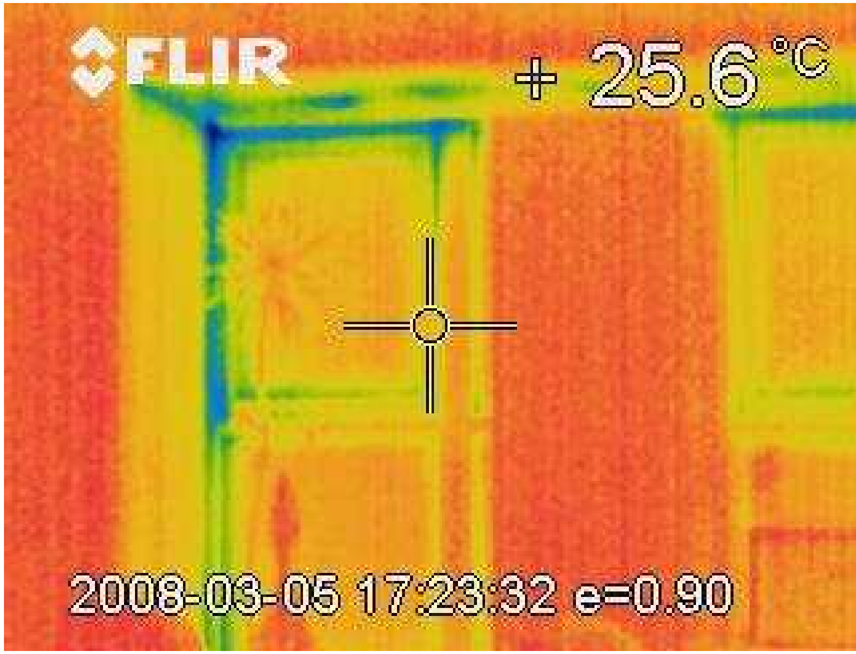
co-heating test - results

Predicted heat loss coefficient = 98 W/K
Actual heat loss coefficient = 144 W/K

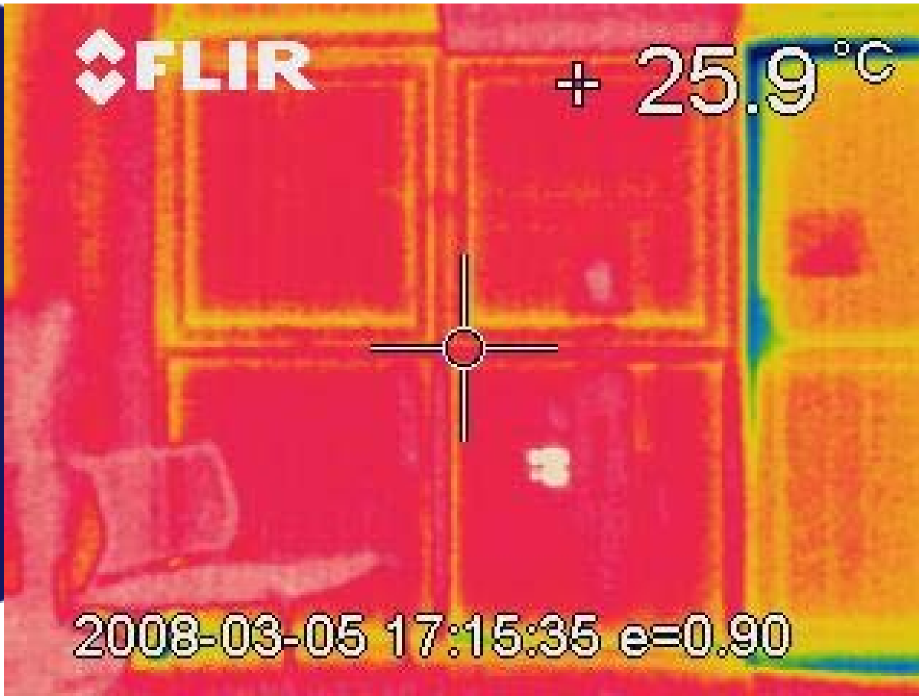
Airtightness =2.72 m3/(h.m2) @ 50 Pa

Thermal imaging revealed key problems:

- Overly complicated envelope
- Air leakage at junctions
- Compromised specifications



thermal imaging = x-ray vision for homes



Reveals what you see is not what you get !

wireless monitoring technology- set up

24 individual window sensors

7 Humidity + temperature sensors

Carbon dioxide sensor

Air movement sensor

Electrical circuit sensors

55 monitoring circuits in total

results

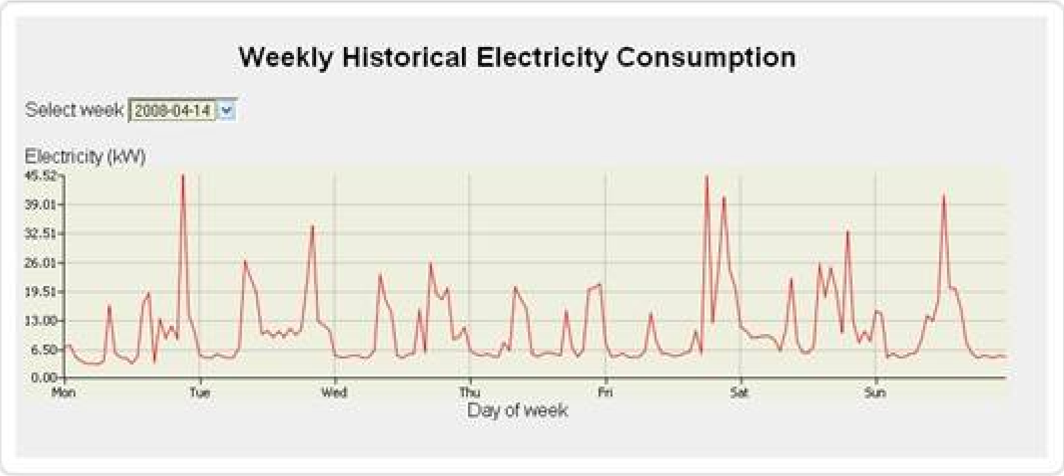
Energy use =140 kWh/m2/year
= 4.176 tonnes/co2/year

water use = 80 litre pp/day

Av. temperature = 19.3 - 21.7oC
(design temperature = 18.5oC)

Av. relative humidity = 40 -47%,

indoor carbon dioxide levels =479 ppm



water –results compared to national average

	Frequency per day	Litres per event	Annual water use
Power shower	1	84	30,660
Power shower	0.3	84	9,198
Electric shower	1	27	9,855
Bath	0.3	73	7,994
Electric shower	0.3	27	2,956

Assumes 7 minutes for all showers: actually people spend longer in power showers than in electric ones – each extra minute of daily power showering adds 4,380 litres per year.

thermal comfort –occupant results

- 1000+ samples over 4 x 2 week periods
- Residents 'comfortably warm'
- Findings contradicted interview feelings
- Interview only records extremes

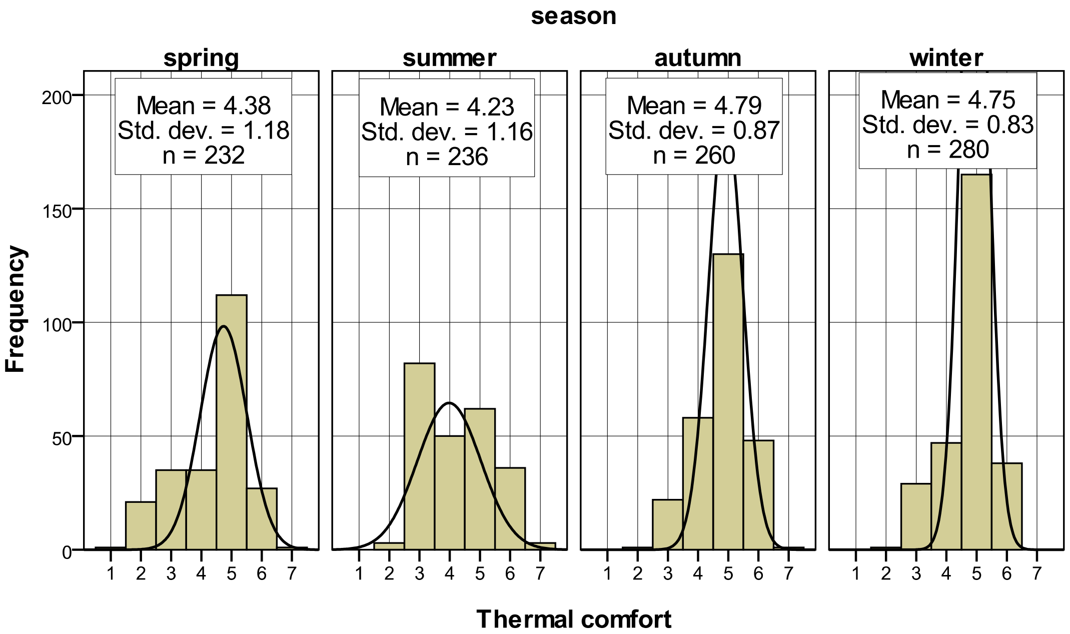
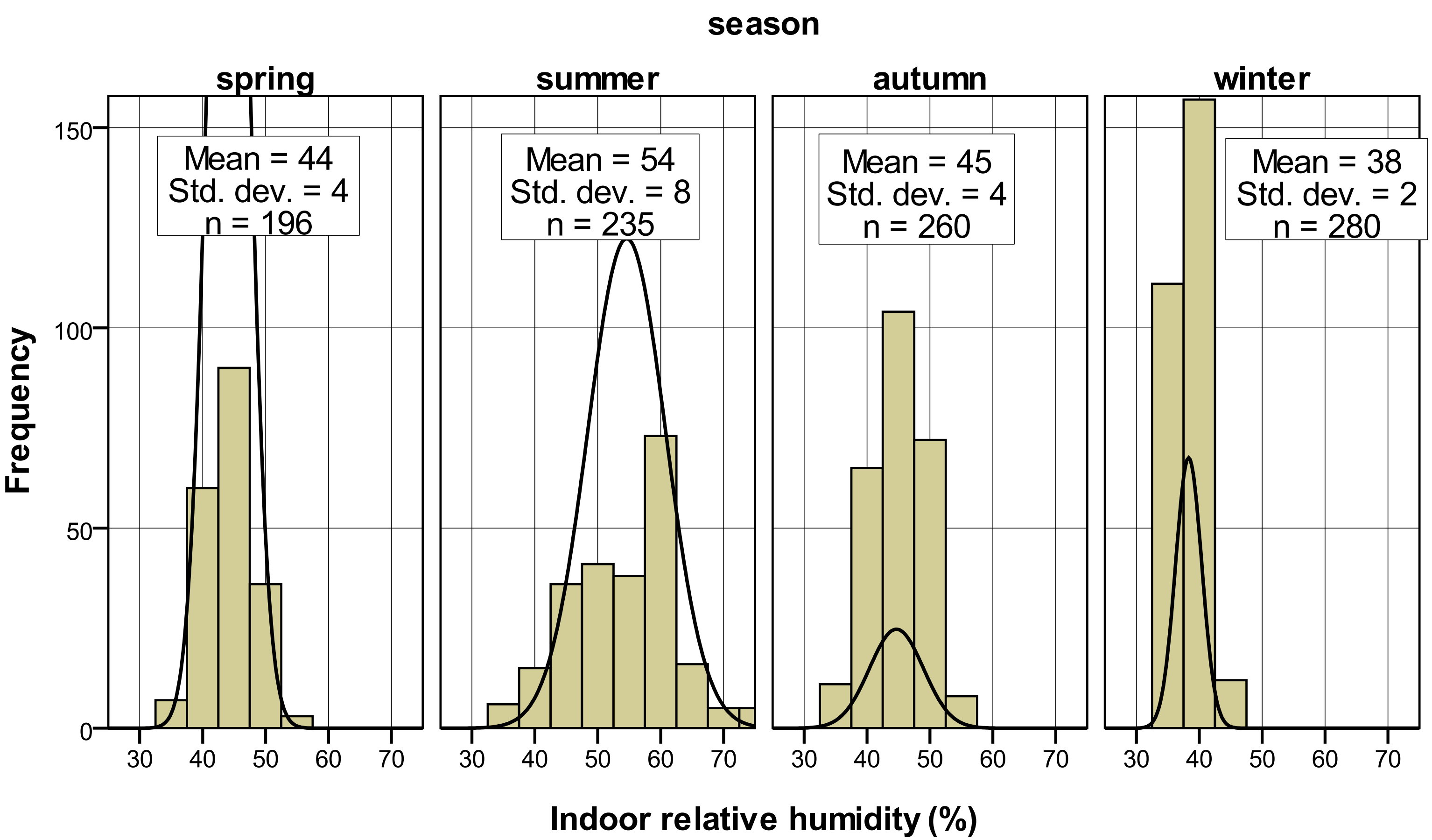


Fig.4 Occupants thermal comfort level (1. Much too cool, 2. Too cool, 3 . Comfortably cool, 4. Comfortably neither warm nor cool, 5. Comfortably warm, 6. Too warm, 7. Much too warm)

thermal comfort –humidity results

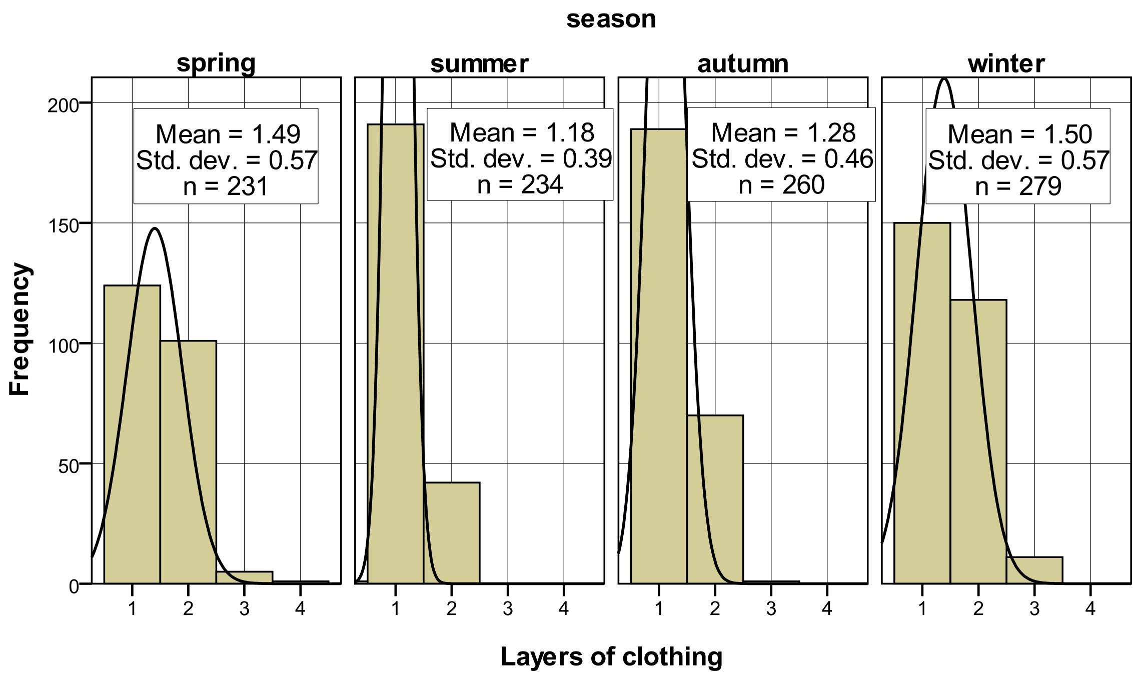


thermal comfort survey -behaviour

Residents adjusted to warmer temperatures

1 layer of clothing predominant

Experienced 'stack effect' = Temperature variation in home



wireless monitoring technology -issues

- Datalogger connection to web failure
- Wireless transmitters reset themselves
- Strength of signal depends on construction

…….Technology for housing is not mature

lifestyle findings

- Exceptional use of the washing machine
- Opened the windows much more often than they usually did in their own home
- Very little understanding of heating and ventilation controls
- Use of video camera by family revealed hidden failures such as detailing
- Family in control of investigatory process

window/ MVHR use

- windows open often in summer
- windows open little in winter
- windows also open in spring and autumn – wasting energy
- MVHR.v. windows = problem?

…..is MVHR really the answer?

induction process = part of feedback loop

- Initial user manual issued –very poor
- Users need to understand how to use home *prior* to occupation
- Developer representative not knowledge when demonstrating home features
- Need to customise generic manufacturing information

Monitoring .v. POE in housing

- Lack of user understanding contributed significantly to energy use
- Heating, lighting and ventilation controls are key issues
- Users adapted to heat rather than turning down thermostats
- Physical monitoring alone does not explain influence of user on performance

Plasma tv screen is major energy issue

Proto-type .v. post-occupancy evaluation

- Analogy with car manufacturing now holds good
- Prototype ‘road testing’ is essential - with users
- Tease out operational issues which cannot be identified by modelling or precedent
- Difficulties include: bias, temporary nature of occupation, significant additional costs

Refining research design for feedback - prototypes

Need to redefine the essentials:

•Co-heating test

•Basic monitoring of resource use, temperature and humdity and IAQ

•Questionnaire/Interview

•Thermal Comfort survey/logging activity

•Video

…….but avoid data overload

3 prototype houses at BRE Innovation Park, UK

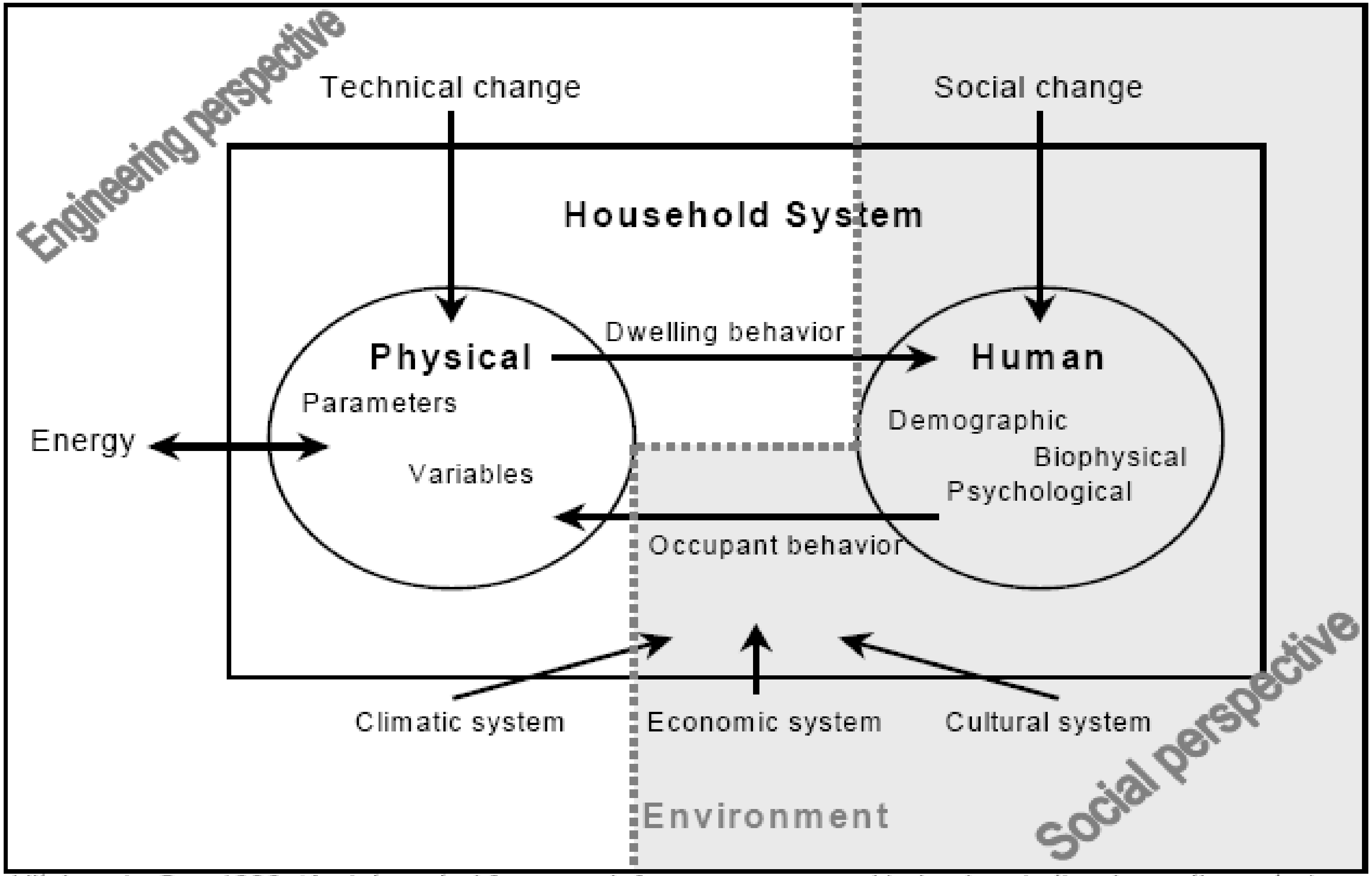
Ethics in housing feedback– is it an issue?

- Prototype testing = recruiting users
- Family in the limelight
- Need to preserve dignity and privacy
- Post publicity also an issue
- Sound ethics procedures needed

Conclusion: cost effective feedback

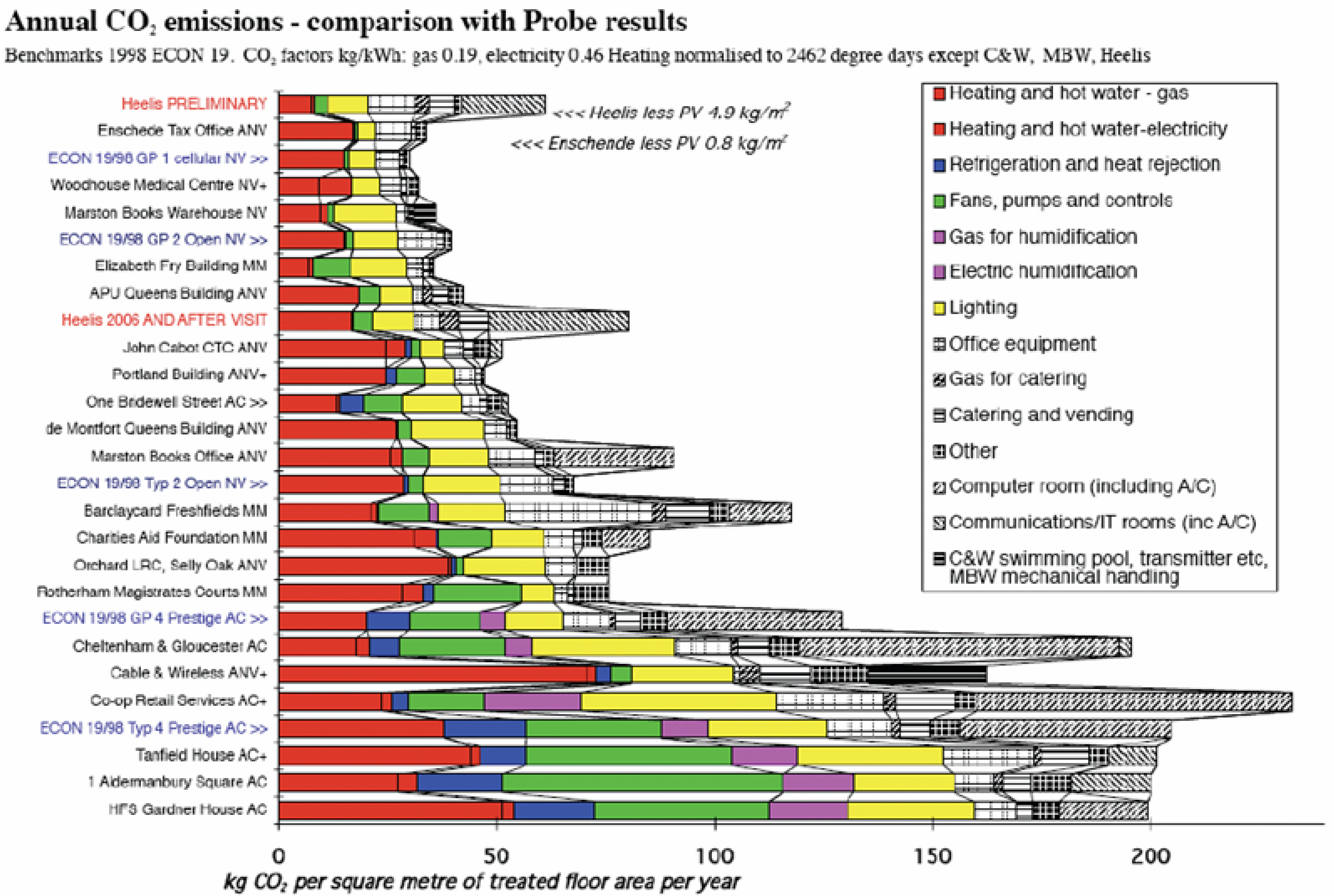
- 9 months minimum monitoring
- Use 3 season spot checks
- Use prototype as exhibition home
- Two week periods with users work well –one to settle in, one to use as normal

more socio-technical research needed!



Hitchcock, Guy 1993, 'An integrated framework for energy use and behaviour in the domestic sector', *Energy and Buildings*, Vol. 20, pp.151-157.

Where we would like to get to with housing...



Thank you for listening to this.....

For more information on post-occupancy evaluation visit:

www.usablebuildings.co.uk