Energy performance of heritage buildings : predictions and performance

Some examples of recent research by BRE

Presentation at

"Improving Thermal Performance in Traditional Buildings"

Greenwich

Tim Yates, BRE

15th November 2011

Context – Refurbishment

- Construction & performance
- Climate Change
- Legislation

Context – Demolish or refurbish?

Context - The scale of the problem

Context - Historical value vs energy efficiency targets - Conservation Limit

- At some point the extent of the work will mean that a 'Conservation Limit' will be reached.
- This is defined as the point beyond which conservation principles and good practice will become compromised if further changes are made to the building
  - *for example the replacement of windows in a conservation area*
  - *the replacement of an historic roof with Photovoltaic panels*
  - *the application of an external rendering system.*
- If the building is listed there may also be limits on internal alterations, for example the dry lining of the walls to improve thermal performance.
- The Green Deal

bre

Context - "The Sustainability Limit"

- Balancing social and environmental needs as well as economics drivers
  - *Important to meet the needs and/or wishes of society, particularly those most closely associated with the building or its immediate environs.*
  - *The amount of investment required to achieve a certain improvement – liveability, energy efficiency, appearance – may not be justified in terms of the likely returns.*
- This is more likely to be a problem in areas where there is limited demand for this type of housing.

bre

Context - Barriers and disincentives

- **Research points to refurbishment as the more sustainable option**
  - *But developers and their advisers currently see more drawbacks than incentives to housing refurbishment over demolition and new build.*
- **Refurbishment projects tend to be smaller and can be cost effective where the original stock is in good condition and is capable of relatively quick, simple conversion**
  - *Significant improvements in energy performance through refurbishment but these are not highly rated by developers and their advisers as a driver for retaining existing housing.*
- **Refurbishment is viewed as more risky and costly than new build housing.**
  - *Particularly where the existing stock is in poor condition.*
  - *Standard refurbishment solutions are needed but are perceived to be unattainable because every project is unique.*

(Based on research by CEM University of Reading)

Context - Barriers and disincentives – social

Theory - Sequential Improvements

Achieve Higher Bands

Element	% Improvement	EPC (start D60)	CO_2 Emissions Start 49.40 kg/m²/per year
Low energy lighting	2.9%	D60	47.97
Insulation to roof [1]	14.1%	D63	40.98
Insulation to solid walls to 2.24 to 0.31 W/m²K	16.1%	C74	33.05
Gable wall [2], currently at 0.45	0.3%	C74	32.89
Windows from BFRC rating G to C [3] or Windows from BFRC rating G to A [4]	4.9% or 5.4%	C76 or C76	30.46 or 30.23
Doors [5] to gable PVCu half glazed, U value =1.5 to front door solid front PVCu U value 1.0	1.3% 2.4%	C76 C76	29.82 29.27
Ground floor insulation [6] 1/3 suspended upgrade to building regs. 2/3 solid floor, long term insulate to accept overlay under floor heating	5.1% 8.4%	C79 C80	26.76 25.14
Heating [7] Install TRVs or Programmable timer and Weather compensation	2.7% or 4.2% and 5.1%	C80 C80 B81	25.45 24.70 24.22
Air tightness and Natural ventilation [8]	7.1%	B83	20.69
Mechanical Ventilation Heat Recovery (MVHR) [9]	9.4%	B83	19.57

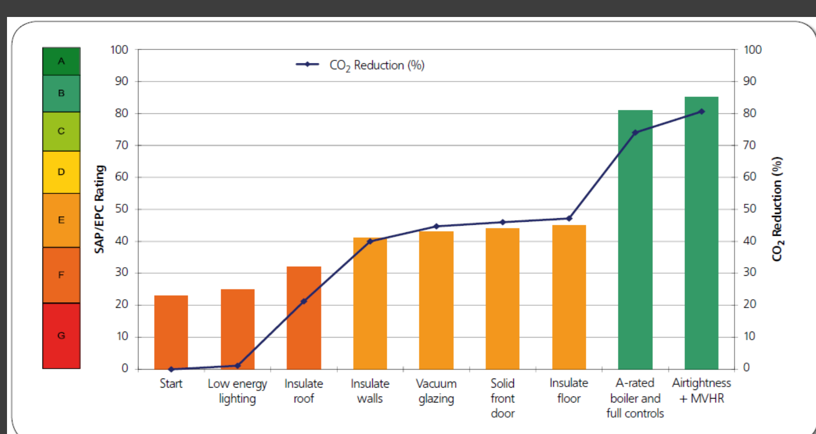
Floor area 97m² inc cellar. 90m² excluding cellar.

Start: CO_2 emissions at 90m² x 49.40kg/m² per year = 4.446 tonnes per year

Potential: CO_2 emissions at 90m² x 19.57kg/m² per year = 1.761 tonnes per year

bre

Theory - Step wise approach to refurbishment

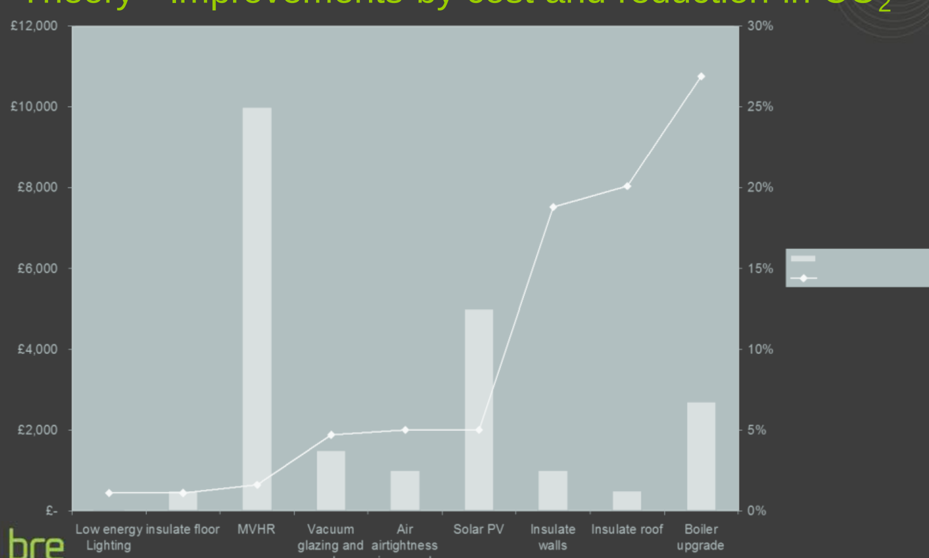


bre

Theory - Aim is tiered refurbishment

Wall construction	Heating system	Glazing type	Base case: fuel cost (£/yr)	Base case: SAP rating	Base case: CO_2 (t/yr)	60% target	High cost package: fuel cost (£/yr)	High cost package: cost saving (£/yr)	High cost package: SAP rating	High cost package: CO_2 (t/yr)	High cost package: CO_2 saving (t/yr)	Improvements	Cost
Insulated cavity	gas boiler	double glazing	257	73	2.4	1.0	105	152	91	0.8	1.6	dedicated low energy lighting, draught proofing throughout dwelling, new door, new boiler and controls, full external insulation, floor insulation, new windows, 1.4kWp PV	£20,200
Insulated cavity	gas boiler	single glazing	266	72	2.6	1.0	105	161	91	0.8	1.8	dedicated low energy lighting, draught proofing throughout dwelling, new door, new boiler and controls, full external insulation, floor insulation, new windows, 1.4kWp PV	£20,200
Insulated cavity	gas boiler, electric secondary	double glazing	286	70	2.5	1.0	105	181	91	0.8	1.7	dedicated low energy lighting, draught proofing throughout dwelling, new door, new boiler and controls, full external insulation, floor insulation, new windows, 1.4kWp PV	£20,200
Insulated cavity	gas boiler, electric secondary	single glazing	298	68	2.7	1.1	105	193	91	0.8	1.9	dedicated low energy lighting, draught proofing throughout dwelling, new door, new boiler and controls, full external insulation, floor insulation, new windows, 1.4kWp PV	£20,200
Insulated cavity	storage heaters	double glazing	368	60	4.0	1.6	215	153	78	1.2	2.8	dedicated low energy lighting, draught proofing throughout dwelling, new door, full external insulation, floor insulation, new windows, air source heat pump, 0.4kWp PV	£18,200
Insulated cavity	storage heaters	single glazing	386	58	4.2	1.7	215	171	78	1.2	3.0	dedicated low energy lighting, draught proofing throughout dwelling, new door, full external insulation, floor insulation, new windows, air source heat pump, 0.4kWp PV	£18,200

Theory - Improvements by cost and reduction in CO_2



Theory - How much can we save?

Measure	Cavity Wall Insulation	Internal Wall Insulation[1]	External wall Insulation[2]	Double glazing
Annual saving (£/yr)	£90	£300	£300	£90
Installed cost £	Around £500	From £40/m2	From £1,900	
Installed payback	Around 5 years		From 6 years	
DIY cost				
DIY payback				
Annual CO_2 saving	750kg	2.4 tonnes	2.5 tonnes	740kg

bre

Practice - Case study 1 : Ecohome, Nottingham

- Private refurbishment project by the owners
- Demonstrating that our older houses can be made energy efficient
- Eco retrofit, with every element as good as could be achieve using low impact materials.

bre

Practice - Case study 2 : Flagship Project, RBKC

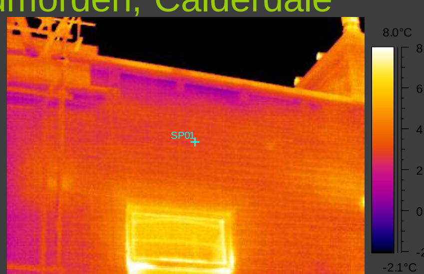
- To demonstrate and promote practicable, cost effective, energy efficiency measures to private landlords.
- To target older, solid walled properties in conservation areas that have been ignored by national and regional campaigns.
- To demonstrate how older properties can make a positive contribution to a low carbon economy through the use of innovative methods used in conjunction with traditional sustainable green materials.

Case study 3 -Todmorden, Calderdale

Todmorden, Calderdale

- Back to Back property
- No garden
- 2 Bedroom
- Stone fronted Heritage property
- EPC rating D, 59
- Old windows
- Solid wall
- Cellar

Todmorden, Calderdale



- Upper bedroom window Air Leakage around opening casement
- Mortar joints visible, so porous and leaking air
- Front door very poor

Practice - Case Study 5 : BRE Solid Wall Research in Wales

Using the work and research undertaken in the Susref Project and other field trials in Wales

The principles have been taken and used on historic and listed buildings in Wales

Working with Cadw, National Trust and others to deliver a realistic improvement without compromising the breathability of the structure.

bre

Projects being worked on

- Merthyr Town Hall – Grade 2* Civic Centre being converted for use as an Arts and Learning Centre. Solid brick wall ranging from 225mm – 500mm, pulverised ash and slag mortar. On site measurement of existing u values
- Need to retain existing features at the front of the building, not so important towards the rear.
- Exposed frontage with wind driven rain and severe winds.

bre

Calculations – Steady state to 2D

Variety of calculations – Sensitivity analysis on results

Colin King
BRE

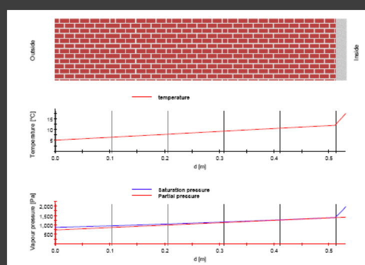
Documentation of the component
Calculation according BS EN ISO 13788
Source: own catalogue
Component: New external wall

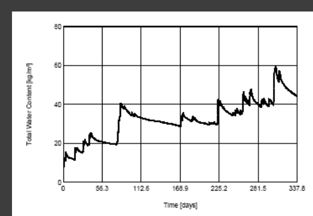
24. June 2011
Page 4/30

Surface temperature to avoid critical surface humidity
Calculation according BS EN ISO 13788

Location: Cardiff. Wales; Humidity class according BS EN ISO 13788 annex A: Dwellings with low occupancy

		1	2	3	4	5	6	7	8	9	10	11	12
	Month	Te [°C]	phi_e ---	Ti [°C]	phi_i ---	pe [Pa]	delta p [Pa]	pi [Pa]	ps(Tsi) [Pa]	Tsi,min [°C]	fRsi ---	Tsi [°C]	Tse [°C]
•	January	4.8	0.870	20.0	0.610	748	677	1425	1781	15.7	0.716	17.4	5.2
	February	4.4	0.840	20.0	0.598	702	695	1397	1747	15.4	0.704	17.4	4.8
	March	6.2	0.820	20.0	0.596	777	615	1392	1740	15.3	0.661	17.7	6.6
	April	7.9	0.760	20.0	0.577	809	539	1348	1685	14.8	0.572	18.0	8.2
	May	11.2	0.760	20.0	0.600	1010	392	1403	1753	15.4	0.482	18.5	11.4
	June	13.9	0.780	20.0	0.646	1238	272	1510	1887	16.6	0.442	19.0	14.1
	July	16.1	0.780	20.0	0.685	1427	174	1600	2000	17.5	0.362	19.3	16.2
	August	16.0	0.780	20.0	0.683	1417	178	1596	1995	17.5	0.367	19.3	16.1
	September	13.8	0.810	20.0	0.665	1277	276	1554	1942	17.0	0.523	19.0	14.0
	October	10.7	0.850	20.0	0.645	1093	414	1507	1884	16.6	0.631	18.4	11.0
	November	7.6	0.850	20.0	0.616	887	552	1439	1799	15.8	0.665	17.9	7.9
	December	6.0	0.870	20.0	0.615	813	624	1437	1796	15.8	0.701	17.6	6.4





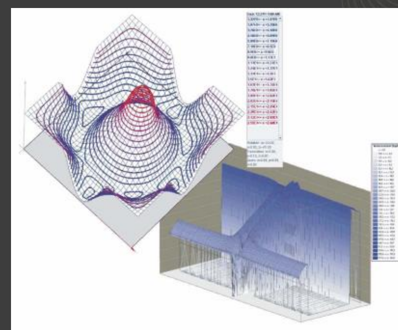
Zoned Approach

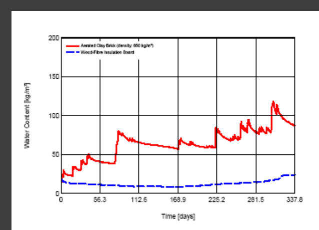
Where possible drive the fabric harder, heritage importance / high risk – do what you can

Range of Improvements

Range of u values and insulation thickness

- 0.74 W/m2 - 0.35W/m2
- Woodfibre insulation used. Lime plaster finish
- Others considered, flax and insulated lime etc





bre

Practice - How much can we save?

- Estimates of carbon dioxide emissions for a typical refurbishment indicates that a value of around 55kg/m2/year can be achieved (equivalent to around 5 tonnes for a 3 bedroom semi-detached house).
- External or internal insulation could reduce this by 20kg/m2/year
- Houses refurbished by Adactus in Nelson, Lancashire achieve a similar figure (around 32 kg/m2/year).

bre

Practice - How much can we save?

- A value of 32 kg/m2/year is a considerable improvement over an unimproved house (where values can be in excess of 100kg/m2/year)
- Part L 2006 target of 24 kg/m2/year and the best practice target (now Part L 2010 target) of less than 18 kg/m2/year.
- The 'Ecohome' refurbishment in Nottingham is recorded as achieving a value of 16kg/m2/year

bre

Practice - How much can we save? - Ecohome, Nottingham

Table 7 Energy and costs at the Nottingham Ecohome*

	Heating	Hot water	Cooking	Lights and appliances	Total
Original specification (before windows were replaced)					
£/year	2513	538	31	424	3569
GJ/year	113.4	24.3	6.3	19.1	163
CO_2 t/year	13.0	2.8	0.3	2.2	18.9
Actual figures (May 2005)					
£/year	250	122	79	388	867
GJ/year	49.4	24.1	3.6	17.5	94.6
CO_2 t/year	0.3	0.2	0.4	2.0	2.9
Aspirational (airtightness complete and windows upgraded)					
£/year	163	122	79	387	780
GJ/year	32.2	24.1	3.6	17.5	77.3
CO_2 t/year	0.2	0.2	0.4	2.0	2.8

* Figures based on NHER energy modelling and taken from www.sustainablehousing.org.uk/documents/NottinghamRefurbishment.pdf.

bre

From: recycling vernacular: an eco refurbishment by Gil Schalom and Penney Poyzer

Theory into Practice : Rethinking Refurbishment

BRE's flagship refurbishment project

bre

Theory into practice - Centre of Refurbishment Excellence (Core)

- A new iconic building for Stoke
- A national showcase for sustainable refurbishment
- Training and skills
- Centre of Excellence
- Business incubator hub
- Knowledge Transfer
- Refurbishment Portal

bre

Theory into practice and practice into theory – Where next?

- BRE Trust funded project with the aim to produce guidance that will:
  - ***Be applicable to a wide range of buildings***
  - ***Emphasise the importance of considering how the building was intended to function***
  - ***Help in deciding which interventions are appropriate to improve sustainability***
  - ***Provide best practice guidance based on previous successes and failures***

bre

Theory into practice and practice into theory – Where next?

- BRE Trust funded project with the aim to produce guidance that will:
  - *Challenge assumptions on the implementation of sustainability principles and practices in historic buildings.*
  - *Identify limitations and opportunities and devise a methodology to guide and encourage owners to scope out the possible opportunities for their building.*

bre

Theory into practice and practice into theory – Where next?

- Identify case studies.
  Identify a short list of representational projects – completed or under development covering a range of scales and uses.
- Initial stakeholder consultation.
  Consult with key stakeholders to select the final list of 10-15 case studies and guide the development of the methodology and key outputs to ensure relevance and value

bre

Theory into practice and practice into theory – Where next?

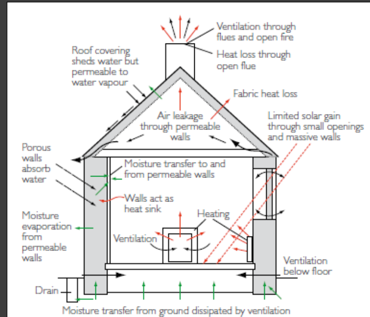
- Develop case studies. Review the agreed case studies to establish:
  - *current status;*
  - *historic development/operation;*
  - *external influences;*
  - *actions taken and decision processes adopted/rejected with reasoning;*
  - *benefits achieved/projected;*
  - *opportunities for improvement.*

Element	**Product**	**U value** W/m^2K
Roof-existing lath and plaster	Sheep wool 250mm	0.16 (2.30)
Roof light & roof light shaft		1.75(5.9) & 2.3(1.6)
First floor walls - injected insulation behind existing lath and plaster	Bonded plaster beads(L) and blown cellulose(R)	0.86 (1.15)
Ground floor walls – fibre boards	Wood /hemp with clay plaster board and clay plaster skim coat	0.86(1.25)
Ground floor-solid	Limecrete on expanded clay aggregate	3.6(0.32)
Suspended timber floor	Hemp board laid under existing floor boards	3.6(0.2)
Windows	Existing sash an case with new slim double glazed & draft stripped	1.8(5.5)
Door (north)	Highly insulated timber door	1.85(2.75)

bre

Theory into practice and practice into theory – Where next?

- Define underlying principles and limitations.
  Prepare a case study summary including a specific roadmap for each project.
- Develop a roadmap both for this project and for future initiatives.
  Develop generic principles and roadmap for development/operation including the impacts and consequences for individual, organisations and regulators.
- Draft an outline methodology.
  Develop generic methodology including appropriate options/priorities.



Moisture, air movement & thermal behaviour of a traditional building
© Crown Copyright, image reproduced courtesy of Historic Scotland

bre

Theory into practice and practice into theory – Where next?

We need your help to make sure we're going the right way!

If you'd like to comment on our 'roadmap' and case studies let me know

Tim Yates yatest@bre.co.uk

Thank you for your attention

bre