Professor Dennis Loveday, Loughborough University
Project Principal Investigator

Presentation to:
CIBSE Homes for the Future Group, 18 July 2013

Key Findings from the
CALEBRE Research Project
What is Project ‘CALEBRE’?

- **Consumer-Appealing Low Energy technologies for Building RETrofitting** (October 2008 – April 2013)

- Research project funded by E.ON / RCUK (£2million)

- Address challenges of UK domestic energy efficiency refurbishment
  - Principally solid wall, ‘hard to heat, hard to treat’
  - Selected current, medium and longer-term technologies
  - Householders’ perspectives at heart of our thinking

- Multi-disciplinary collaboration - laboratory testing; simulation modelling; test house field trials; user engagement methods

[www.calebre.org.uk](http://www.calebre.org.uk)
Project ‘CALEBRE’ – the Team

• A partnership of six leading UK Universities: Heriot-Watt, Loughborough, Nottingham, Oxford, Ulster and Warwick

• 24 research associates, doctoral students and academics

• 8 Advisory Board members: CIBSE, BRE, Edward Cullinan Architects, David Strong Consulting, Aachen and Loughborough universities, University College London, E.ON and RCUK
# CALEBRE - People and Expertise

<table>
<thead>
<tr>
<th>Expertise Area</th>
<th>CALEBRE Team Members and Universities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pumps</td>
<td>Bob Critoph, Steve Metcalf (Warwick)</td>
</tr>
<tr>
<td></td>
<td>Neil Hewitt, M S Khoushestani (Ulster)</td>
</tr>
<tr>
<td>Vacuum Glazing</td>
<td>Phil Eames, Saim Memon (Loughborough)</td>
</tr>
<tr>
<td></td>
<td>Trevor Hyde, Farid Arya (Ulster)</td>
</tr>
<tr>
<td>Field Trials</td>
<td>Mark Gillott, C Spataru (Nottingham)</td>
</tr>
<tr>
<td></td>
<td>Phil Griffiths (Ulster)</td>
</tr>
<tr>
<td>Modelling</td>
<td>Phil Banfill, Sophie Simpson, Andrew Peacock (Heriot Watt)</td>
</tr>
<tr>
<td>Householders</td>
<td>Vicky Haines, Val Mitchell, Becky Mallaband, Steve Bayer (Loughborough)</td>
</tr>
<tr>
<td>Advanced Materials</td>
<td>Matthew Hall, Sean Casey (Nottingham)</td>
</tr>
<tr>
<td></td>
<td>Edman Tsang, Abdullah Khan (Oxford)</td>
</tr>
<tr>
<td>Manufacturing &amp; Business Models</td>
<td>Svetan Ratchev, Rob Darlington, Kobby Agyapong-Kodua (Nottingham)</td>
</tr>
<tr>
<td>Project Leadership and Thermal Comfort</td>
<td>Dennis Loveday, Keyur Vadodaria (Loughborough)</td>
</tr>
</tbody>
</table>
CALEBRE and solid-wall housing: our approach

- 8.3 million solid wall properties
- 34% of UK housing stock
- 50% of domestic carbon emissions
- Refurbishment necessary, but challenging
- Limited choices for reducing wall heat loss
CALEBRE and solid-wall housing: our approach

So, we focussed on:

• Other means to reduce heat demand:
  – Airtightness
  – Mechanical ventilation with heat recovery
  – Advanced window treatments – vacuum glazing
  – Advanced surface treatments for moisture and temperature control

• Efficient heat supply:
  – Gas heat pump technology
  – Electric heat pump technology

• Householders and behaviour:
  – Attitudes to refurbishment
  – Retrofit practices
  – Personal energy tracking
  – Domestic thermal comfort
CALEBRE Briefing Notes

- Key findings summarised
- Handy format
- To assist the growing refurbishment industry
- To guide future policy
- To help further research
- Full set in booklet format for reference purposes available soon, and downloadable

www.calebre.org.uk
Key findings: Reducing heat demand - Airtightness, MVHR

Through practical trials in a test house, evidence for, and indication of:

- Airtightness values achievable in practical refurbishment…
- …challenging but practically realisable
- Levels of detailing required
- Quality of workmanship through training that is required
Key findings: Reducing heat demand - Airtightness, MVHR

And through dynamic thermal modelling of the test house:

- Airtightness levels needed for MVHR to save energy and carbon
- Install properly and balance, in a sufficiently airtight house
Key developments: Reducing heat demand - Vacuum Glazing technology

- Slimmer than standard double glazing
- New, lower-cost edge seals developed
- A step closer commercially
- U values of 0.26 Wm\(^{-2}\)K\(^{-1}\) achievable with triple vacuum glazing
- Can improve performance of solid-wall (and other) envelopes
- Supported by manufacturing business models
Key developments: Advanced surface material for moisture control

- Materials successfully engineered for rapid response humidity and temperature buffering
- Two orders of magnitude better than traditional interior building surface materials
- Expensive now – research for bulk manufacture needed
- Potential to control indoor moisture using relatively small surface areas
Key developments: Efficient heat supply - Heat Pumps technology

New technologies developed for air-source heat pumps:
- Designed for ease of retrofit
- Boiler replacement
- Operate with existing radiators (output at 60°C)
- Still give good performance
- Supported by manufacturing business models
The gas-fired air-source heat pump

- New technology – thermal compressor
- Box-for-box exchange for old boiler
- Split system, saves garden space
- 30% annual fuel savings
- Payback time < 3 years
- Commercial development continuing…
- …spin-out ‘Sorption Energy’ formed

www.calebre.org.uk
The electric air-source heat pump

- New technologies – economised vapour injection (EVI) and compressor-expander (CE)
- High temperature for direct retrofit
- In lab, CE gave COP (heating) of 4.31, but needs further development
- EVI is a viable product, competitive with cascade units
- Energy storage required to manage tariffs and electrical demand
Key developments: Business models for manufacture

- Requirement specifications developed for the heat pumps and vacuum glazing
- Systems design and manufacturing methodology defined
Key findings: Householders and Behaviour – Attitudes to refurbishment

Older properties - barriers and opportunities identified relating to:

- Motivation, timing & cost (e.g. repair and comfort are key drivers, not energy)
- Original house features (e.g. windows)
- The refurbishment process
- Issues of trust
- Attitudes to airtightness and ventilation
- Types of home improvers identified
Key findings: Householders and behaviour - Orders of Retrofit

Using dynamic thermal modelling of the test house:

- Sequences for retrofit of standard measures investigated
- Benefits and payback times of individual measures varies, depending on preceding measures installed
- Can impact upon the Green Deal and ‘Golden Rule’
- Early implementation of measures like wall insulation, double glazing, yield greatest cumulative savings

![Reduction in Annual Energy Consumption through Staged Improvement Measures](image-url)
Key findings: Orders of Retrofit

Reduction in Annual Energy Consumption through Staged Improvement Measures

- Base Case Order
- Experienced Installer Driven
- Affordability Driven
- Insulation Driven
Key developments: Householders and behaviour - Occupant energy tracking in real time

- Real-time location and energy tracking system developed
- Occupancy behaviour and energy use – personal carbon footprint
- Monitors space usage in response to indoor environmental conditions and interventions (e.g. retrofit)
- Can evaluate in-use performance of homes – a metric of occupants’ behaviour
Key developments: Householders and behaviour – Domestic thermal comfort

- Thermal comfort evaluation of technologies: vacuum glazing
- Review of indoor temperatures in UK dwellings, 1969 – present
- Development of a domestic thermal comfort model (on-going)
CALEBRE and solid-wall housing: bringing findings together

- **The effective retrofit**: Householders and trust, use of professionals, airtightness, MVHR, quality of installation, orders of retrofit

- **Fit with existing systems**: Heat pumps and existing radiators, slender vacuum glazing for period windows and envelope thermal improvement

- **Space efficiency**: split heat pumps in boiler space, saving small garden space, advanced surface treatments
CALEBRE and the Green Deal

GD Assessors:
• Order of retrofit, variable payback and ‘Golden Rule’
• Also if people go it alone

GD Installers:
• Training, quality of installation – closing the ‘gap’

GD Provision:
• Tailor to needs of different householders

GD Approval:
• Modified heat pumps, vacuum glazing – process?
Summary

• Householder perspectives in older properties
• Guidance on current refurbishment practice:
  – Airtightness, MVHR, installation quality & training
• Advances to technologies, near & longer terms:
  – Heat pumps, vacuum glazing, advanced materials
• Contributions to Green Deal, and solid-wall challenge
Summary

• CALEBRE Briefing Notes - booklet for referencing available soon
• Will be available for download at our website
• Visit us at: www.calebre.org.uk
• Thank you for listening….!