BPE Case Studies
Non-domestic

Estover Community College
National Composites Centre

15th February 2016

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Regional Director, AECOM
Building Performance Evaluation

- £8 million Innovate UK funding – four year programme 2010 – 2014

Aims

- to help designers & constructors to deliver more efficient, better performing buildings.
- to assemble substantial body of data to draw generic conclusions on performance

Findings

- Specific findings immediate benefit for participants
- Generic findings being widely disseminated across industry & academia
Building Performance Evaluation

- Projects are a mix of domestic and non-domestic
- 44 domestic, 48 non-domestic projects
- New build or major refurbishment
- Either under construction, or within 3 years post completion
AECOM BPE Projects

• Non-Domestic Buildings, Phase 1: Buildings In Use:
  - Eli Lilly Research Office Building (completed February 2013)
  - Stevenage Bioscience Catalyst (completed June 2013)

• Non-Domestic Buildings, Phase 2: Buildings In Use:
  - National Composites Centre (completed August 2014)
  - Estover Community College (completed July 2014)

• Domestic Buildings, Phase 2: In-use performance and post occupancy evaluation:
  - Seager Distillery Site Housing Development (completed August 2014)
Estover Community College (Tor Bridge High)

National Composites Centre
Overview

- May 2012 – April 2014
- Occupant satisfaction
- Energy performance
- Renewable / low carbon technologies performance
- Internal conditions
- Lessons for industry
<table>
<thead>
<tr>
<th>Project Value</th>
<th>~£28m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completion</td>
<td>August 2012</td>
</tr>
<tr>
<td>Client</td>
<td>Plymouth City Council</td>
</tr>
<tr>
<td>Architect</td>
<td>Feilden Clegg Bradley Studios</td>
</tr>
<tr>
<td>Structural Engineer</td>
<td>Jenkins &amp; Potter</td>
</tr>
<tr>
<td>M&amp;E Consultant</td>
<td>AECOM</td>
</tr>
<tr>
<td>Project Manager</td>
<td>EC Harris</td>
</tr>
<tr>
<td>Contractor</td>
<td>Kier Western</td>
</tr>
</tbody>
</table>
Tor Bridge High, Plymouth

- Approx 1,600 pupils on site ranging from 4-18 years old
- 11 buildings
- 16,900m²
- 500kW Biomass boiler
- Mini district heat network
- 2x gas boilers (516kW and 452kW)
- Mainly naturally ventilated
Occupant satisfaction survey

- Only one survey carried out
- Response rate relatively low - 44%
- Positive
  - Design of building
  - Effect on behaviour of pupils
- Negative
  - Lighting controls
  - Noise
  - Storage
Occupant Satisfaction

- Air in summer: overall
- Air in winter overall
- Comfort: overall
- Design
- Health (perceived)
- Image to visitors
- Lighting: overall
- Needs
- Noise: overall
- Productivity (perceived)
- Temperature in summer: overall
- Temperature in winter: overall
Wind vortex
Occupants like natural ventilation

...but can leave night vents open in winter
PIRs are not always as effective as we anticipate.
Biomass boiler

• FM and the Finance team lost confidence in the biomass boiler
• Perceived added maintenance burden, disposal of ash, and high moisture content
• Fuel supply contract provided no means of ensuring fuel quality
• Ineligible for RHI as gas boilers are unmetered for heat so distribution losses cannot be determined
• Shape of fuel pit caused problems
Heat consumption

Total heat consumption
kWh (primary axis), Regional Degree Days (secondary axis)
Comparison against EPC

- EPC
- Actual

kWh/m²

- Heat
- Electricity
Electricity consumption

- Energy centre: 4%
- Austen: 5%
- Faraday: 9%
- CADE North: 9%
- CADE South: 5%
- Sports Hall: 13%
- Tenzing: 5%
- Graham Brown: 0%
- Kitchen: 7%
- Cann: 5%
- Bridge: 6%
- Primary school: 8%
- Sound House: 11%
- CADE Plant room: 8%
- Server: 6%
- External lights: 1%
- Sprinkler house: 2%
- Unknown: 2%
- Floodlighting: 1%
- Sprinkler house: 2%
- Energy centre: 4%
- CADE North: 9%
- CADE South: 5%
- Sports Hall: 13%
- Tenzing: 5%
- Graham Brown: 0%
- Kitchen: 7%
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- Sprinkler house: 2%
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Comparison to benchmarks

Annual electricity benchmark comparison by block

<table>
<thead>
<tr>
<th>Blocks</th>
<th>kWh/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graham Brown</td>
<td>10</td>
</tr>
<tr>
<td>Austen</td>
<td>20</td>
</tr>
<tr>
<td>Primary school</td>
<td>30</td>
</tr>
<tr>
<td>Tenzing</td>
<td>40</td>
</tr>
<tr>
<td>Faraday</td>
<td>50</td>
</tr>
<tr>
<td>CADE North</td>
<td>60</td>
</tr>
<tr>
<td>CADE South</td>
<td>70</td>
</tr>
<tr>
<td>Cann Bridge</td>
<td>80</td>
</tr>
<tr>
<td>Sound House</td>
<td></td>
</tr>
<tr>
<td>Sports Hall</td>
<td></td>
</tr>
<tr>
<td>Typical</td>
<td></td>
</tr>
<tr>
<td>Good practice</td>
<td></td>
</tr>
<tr>
<td>Typical</td>
<td></td>
</tr>
</tbody>
</table>

- Retained Block
- New build
- SEN Teaching

Guide F - Secondary School
TM46
Comparison to benchmarks

![TBH total annual fossil fuel benchmark comparison](chart1)

![TBH total annual electricity benchmark comparison](chart2)
Lessons for industry

• Ensure high level sub-meter reconciliation shortly after handover

• If renewable / low carbon generation is utilised, make sure adequate metering is in place otherwise funding opportunities may be missed.

• Natural ventilation strategy is highly dependent on occupants. More effective ways to indicate appropriate use to occupants are required.

• Manual control can lead to high occupant satisfaction, but also to inappropriate use and energy consumption.

• Suitability of biomass for schools needs careful consideration

• Out of term time use for schools can be problematic

• Occupant satisfaction possibly a missed opportunity
### National Composites Centre

<table>
<thead>
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<th>Project Value</th>
<th>~£25m</th>
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<tr>
<td>Completion</td>
<td>2011</td>
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<tr>
<td>Client</td>
<td>University of Bristol &amp; South West RDA</td>
</tr>
<tr>
<td>Architect</td>
<td>Stride Treglown</td>
</tr>
<tr>
<td>Structural Engineer</td>
<td>Halcrow</td>
</tr>
<tr>
<td>M&amp;E Consultant</td>
<td>AECOM</td>
</tr>
<tr>
<td>Surveyor</td>
<td>Cyril Sweett</td>
</tr>
<tr>
<td>Contractor</td>
<td>Kier Group</td>
</tr>
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</table>
National Composites Centre

- 8,500 m² state-of-the-art industrial research facility
- Rapid build time – 10 months
- Mixture of office, workshop, and specialised lab spaces
- BREEAM Excellent
- Large 138kWp PV array
- Rainwater harvesting
- Heating via 5 gas boilers
General layout
Ventilation

• Displacement ventilation in workshop
  – Low level fresh air
  – Internal heat gains in winter

• Mixed mode for office areas
  – Automatic windows
  – Night cooling
  – Squirrel infiltration

• Air tightness
  – Part L – 6 m³/(h.m²) @ 50 Pa
  – Achieved - 4 m³/(h.m²) @ 50 Pa
  – BER ~10% better than TER
Key findings

• The NCC has proved a commercial successful – second NCC building (NCC2).

• NCC2 designed by largely the same team as NCC, providing a rare opportunity to directly feedback information from the BPE study.

• Occupants largely satisfied with the building. However, indications that on occasion too hot in summer in office areas.

• Dynamic space - alterations made to space and services since completion (particularly within the Main Workshop space) to accommodate different functions.

• Benchmarking shows while energy consumption for fossil fuel is comparable to other (possibly) relevant benchmark datasets, electricity consumption is much greater.

• Significant opportunities for energy savings identified and fed-back
Comparison against EPC
Benchmarking

• Benchmarking difficult as very unique building

Total carbon intensity for NCC against raw and constructed benchmarks

- **Fossil Fuel**
- **Electricity**

<table>
<thead>
<tr>
<th>Category</th>
<th>CO₂/kg/m²/pa.</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCC Actual (FF TM46 adjusted)</td>
<td>150</td>
</tr>
<tr>
<td>Constructed TM46</td>
<td>60</td>
</tr>
<tr>
<td>Raw TM46 (Workshop)</td>
<td>40</td>
</tr>
</tbody>
</table>
PV array
PV performance

Annual comparison of PV generation

~3% more than predicted
PV performance

PV Array Year 1 performance

Design Actual Design output Actual output
kWh

On-site use Export Total generated

47% 6%
Electricity consumption

- MCC PLT Space East: 21%
- Nitrogen Plant: 11%
- Centre BusBar: 6%
- Manufacturing Lighting total: 6%
- West BusBar: 5%
- Clean RM Chiller: 5%
- Spec Gases DB: 5%
- Office Power: 5%
- Office lighting: 4%
- Clean Room P&L: 3%
- Ext Lighting: 2%
- Mech PLT West: 2%
- PTRM: 2%
- East Freezer 1 & 2: 2%
- ATL/AFB Rapid depo P&L: 1%
- Robot 1&2: 1%
- Autoclave 1 Chiller: 1%
- Liquid resin cell: 1%
- Ply Cutter P&L: 1%
- UPS total: 3%
- Other: 9%
- Not connected to BMS: 10%

Total electricity consumption: 2,370,000 kWh p.a.
Metering issues

- Timestamps incorrect
- BMS truncates exported meter data at 1,000,000 units
NCC sub meter reconciliation Fri 08/09/13
Gas consumption

- Autoclave: 6%
- HWS: 5%
- Boilers: 89%

Total gas consumption: 1,560,000 kWh p.a.
Workshop AHU temperature Thursday 19/12/13 to Friday 20/12/13

Supply Temperature (°C)  Extract Temperature (°C)  Setpoint
Occupant satisfaction

• Two surveys carried out using BUS method roughly a year apart.
• Achieved response rates of 78% and 73%
• Fed results back to design of NCC2
• Statistical comparison of qualitative answers conducted
Occupant satisfaction

Positive

• Collaborative environment
• Lots of natural light
• Breakout areas
• Being close to manufacturing facility can be very motivational

Negative

• Lack of men’s WCs
• Distracting noise from rainwater down pipe in office areas
• Varying temperatures throughout the day from automatic windows opening and closing
• Frustration with automatic lights going on/off while people are still in the office or meeting room.
• Lack of storage space for desk areas, lockers for cyclists, and workshop materials and tools.
Automated windows frustrating occupants
Occupant satisfaction

Summary (Overall variables)

- Air in summer: overall
  - Unsatisfactory: 1
- Air in winter overall
  - Unsatisfactory: 1
- Comfort: overall
  - Unsatisfactory: 1
- Design
  - Unsatisfactory: 1
- Health (perceived)
  - Less healthy: 1
- Image to visitors
  - Poor: 1
- Lighting: overall
  - Unsatisfactory: 1
- Needs
  - Very poorly: 1
- Noise: overall
  - Unsatisfactory: 1
- Productivity (perceived)
  - Decreased: -40%
  - Increased: +40%
- Temperature in summer: overall
  - Uncomfortable: 1
- Temperature in winter: overall
  - Uncomfortable: 1
Influence of the BPE study on the NCC2 design

- PV array electrical design - arrangement caused negative readings on associated meter. Through feedback to NCC2, PV array feeds directly into the main switch panel.

- Rain water pipes through offices. Noise issue highlighted by BUS. For NCC2, rain water collection pipes will not run through office spaces.

- Allocation of male/female toilets. NCC2 will have proportionally more male than female toilets available for staff to better reflect demographic.

- Screens are being provided on high level automated windows to prevent entry of squirrels.
Lesson for industry

- High level meter reconciliation during aftercare following commissioning
- Unsuitability of standard BMS for long term energy monitoring
- Ownership of energy data throughout the building life cycle
- Communication of metering strategy between design team and installers
- PV design export assumptions should be made on regulated and unregulated energy consumption
- Fully consider rain noise during design
Lessons for industry - Estover

• Excellent feedback from building users
• Users seem to appreciate having control over their environment
• Fulfils the primary function of providing a great place to teach and learn

Lessons for industry - NCC

• Significant commercial success
• Development of NCC2 allowed feedback from BPE directly to design team
• Fulfils the primary function of providing first class facilities for ground breaking research
Thank you!

Questions later…