The benefits of a holistic approach to building performance data

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Outline

• Introduction to TOP project
• Overview of the case studies
• Available data
• Building diagnostics and improvement opportunities
• Relevance to Level(s)
Total Performance of Low Carbon Buildings in China and the UK (TOP)

WP1: Contextual review
- Review of UK & China’s context for building design, construction & operation – issues such as:
  - Policy
    - Regulations
    - Statutory requirements
    - Future policy
  - Standards
    - Industry accreditation
    - Construction
    - Building performance
  - Targets
    - Development
    - Skills & education
    - Workforce
    - Emissions
    - Performance
  - Building techniques
    - Construction
    - Equipment
  - Climate

WP2: Energy / Carbon / IEQ performance
- Phase 1: Monitoring
  - Preliminary monitoring of: energy & IEQ of buildings (residential, office, schools, hospitals)
  - UK: 8 buildings
  - China: 16 buildings
- Phase 2: Integration
  - Integration of monitoring & modding with development of:
    - Integration data schema
    - Calibration process
    - Performance indicators
  - Detailed monitoring of: building systems, observational, energy IEQ (essential and in-depth), subjective evaluations of buildings (residential, office, schools, hospitals)

WP3: Development of guidance
- Using a participatory system dynamics approach to develop robust advice for policy and regulation development. The process will include workshops with stakeholders in China and the UK

WP4: Developing impact
- Developing impact for relevant stakeholder groups e.g.:
  - Building & system designers
  - Construction industry
  - Product manufacturers
  - Policymakers
  - Inspectors
  - Industry bodies

Informs participatory workshops

Knowledge transfer
Unintended consequences of energy efficiency policies

Unintended IEQ consequences

- energy efficiency of buildings
  - energy efficiency improvements
  - total building performance shortfall

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TOP case studies in the UK

- TOP focus is large scale building projects
- Where modest improvements in building procurement & management could bring significant environmental benefits
- Offices, educational buildings, and hospitals account for around 65% of the UK non-domestic building stock & 32% of its carbon emissions
- Apartment blocks account for 12% of the UK residential floor area
- Eight case studies are covered in the UK (two from each sector)
Energy performance of the non-domestic cases against Good Practice (GP) benchmarks

GP benchmarks: 25% of DEC dataset, ECG72 benchmarks for hospitals

Ambitious ‘energy budgets’ set out by designers; the building is subject to Soft Landings & performance contracting
Can performance contracting close the gap?
The target was to achieve DEC-A rating by the second year of operation.
Energy performance: Office 1

Net electrical demand: Office 1
IEQ Performance: Air Quality

- Indoor CO$_2$ concentration (reproduced from BMS data)
- Indoor PM$_{2.5}$ concentration
Out of range values: thermal comfort
Low-energy buildings

Source: Abadie et al., 2016. IEA EBC Annex 68 – Indoor Air Quality Design and Control in Low-energy Residential Buildings, SUBTASK 1: Defining the metrics
Towards ‘total’ performance: Energy + IAQ

Source: Abadie et al., 2016. IEA EBC Annex 68 – Indoor Air Quality Design and Control in Low-energy Residential Buildings, SUBTASK 1: Defining the metrics
TOP Case Study (Office 1): Natural ventilation strategy
Monitoring of indoor/outdoor air quality

Trade-offs between CO₂ levels (ventilation rate) and NO₂/PM2.5
TOP Case Study (Hospital 1)

- Hospital in Bristol City Centre
- Inpatient services for surgery and medicine (two operating theatres)
- Full mechanical ventilation (10-12 ACH)
- Sealed envelope
Monitoring of indoor/outdoor air quality: CO₂

CO₂ concentration levels are usually lower than 750 ppm.
(IDA Class 4 Ventilation in BS EN 13779)
Monitoring of indoor/outdoor air quality: PM2.5

Indoor concentration levels are significantly lower than outdoor.
(F9/HEPA filtration in air handling units)
Monitoring of indoor/outdoor air quality: NO$_2$

Indoor NO$_2$ closely follows outdoor NO$_2$!
(Activated carbon filter or other measures required)
**NO₂ concentrations in non-domestic case studies**

<table>
<thead>
<tr>
<th>Location</th>
<th>Office 1</th>
<th>Hospital 1</th>
<th>School 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O</td>
<td>0.99</td>
<td>0.42</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>0.39</td>
<td>0.42</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>0.59</td>
<td>0.30</td>
<td>0.80</td>
</tr>
</tbody>
</table>

**WHO guideline limits:**

- **Annual mean (chronic health effects):** 40 µg/m³ (21 ppb)
- **Hourly mean (acute health effects):** 200 µg/m³ (105 ppb)
Internal sources of pollution

- Formaldehyde in all apartments 3xs ELV’s after 3 and a half years.
- Perceived wisdom of 2 years to off-gas is questionable. Boost ventilation mode on MVHR required to be used?
- No notable formaldehyde in one school possibly due to low-emission material specification for fixtures and fittings.
Passive sampling of VOCs: heating season

<table>
<thead>
<tr>
<th>VOC concentration (µg/m³) &amp; Air Change rates per Hour for each zone</th>
<th>APT. 3 (Block A, 9th Floor)</th>
<th>APT. 4 (Block B, Ground Floor)</th>
<th>IEA EBC Annex 68 Long Term ELV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Living room</td>
<td>Kitchen</td>
<td>Sample bedroom</td>
</tr>
<tr>
<td>Benzene</td>
<td>1.3</td>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>29.25</td>
<td>26.87</td>
<td>29.53</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Styrene</td>
<td>1.5</td>
<td>2.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Naphthalene</td>
<td>5.4</td>
<td>5.4</td>
<td>5.0</td>
</tr>
<tr>
<td>Toluene</td>
<td>2.7</td>
<td>2.9</td>
<td>3.1</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>0.6</td>
<td>&lt;0.6</td>
<td>&lt;0.6</td>
</tr>
<tr>
<td>ACH (PFT measurements)</td>
<td>0.50</td>
<td>0.52</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Concentration levels of benzene and formaldehyde are significantly higher than long-term/chronic exposure limit values (ELVs) in both apartments 3 years after completion!
Conclusions

• Energy Performance Contracting & Soft Landings are quite effective in closing the performance gap

• However, IEQ must also be included (Towards EEPC)

• Collated data point to improvement opportunities in control strategies in both naturally & mechanically ventilated buildings

• Standards for VOC source control of construction material should be improved

Relevance to Level(s):

Design targets and operational data for energy, thermal comfort and IAQ available for 4 UK case studies with high granularity + calibrated computer models for scenario analysis: LEVEL 3

One building registered for Level(s) pilot study: the office building subject to EPC & Soft Landings
Available Data for Level(s)

- Active monitoring results for four buildings (weekly blocks in heating season & summer): PM1-10, NO₂, TVOC, CO, CO₂, T, RH

- Passive sampling results (weekly blocks in heating season & summer): concentrations of all critical pollutants identified for low energy dwellings in Subtask 1 of IEA EBC Annex 68

- PFT measurements in apartments (air exchanges in all zones)

- Contextual information: occupancy level & pattern, occupant behaviour (self-reported + site observations)

- Energy performance data

- Occupant satisfaction surveys (thermal comfort & IAQ)

- Design information (energy targets and IEQ standard limiting values)
Towards ‘total’ energy & environmental performance

Any questions?

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Source: Evening Standard, 8 May 2017