Bridging the gap between predicted and actual energy performance in schools

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Introduction

• **Problem:**
  - Discrepancy between predicted and actual energy consumption in schools becoming more evident
  - Designers requested to accurately estimate energy use in schools

• **Aim:**
  - Investigate factors affecting energy use in schools
  - Enable design team to provide likely range in energy use and advice on most influential factors
Factors contributing towards discrepancy:

- Model simplifications
- Changes between making predictions and final building
- Occupants
- Commissioning, controls, management and maintenance
Methodology 1: School Visits

- Visits to 15 schools across UK
  - Interview
  - Walk-around
  - Utility bills
Results 1: School Visits

Energy use

- kWh/m²/yr

Schools A to O and CIBSE TM46 energy consumption data is shown, with two categories: Gas and Elec.
Results 1: School Visits

Building days of use per year

Days of use per year

School
Results 1: School Visits

Temperature set point in classrooms

Temperature set point (degC)

School
Methodology 2: Simulation

• Sensitivity Analysis:
  - analyse relationship between inputs and outputs
  - find out how a change in each input affects the output

- Example: heating temperature set point

<table>
<thead>
<tr>
<th>Temperature set point</th>
<th>Annual gas consumption for different heating set points</th>
<th>Gas consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C (design value)</td>
<td>+88%</td>
<td>Design estimate</td>
</tr>
<tr>
<td>16°C</td>
<td>-50%</td>
<td></td>
</tr>
</tbody>
</table>
Methodology 2: Simulation

• **Differential Sensitivity Analysis:**

1. Base case building – design assumptions
2. Identify inputs (e.g. Fabric U-values, hours of heating, equipment loads, etc.)
3. Select minimum and maximum values for each
4. Vary 1 input for each simulation
5. Run all simulations and analyse results
Results 2: Differential Sensitivity Analysis

Percentage change in CO2 emissions due to variations in input factors

Change in kgCO2/m²/yr from base case value (%)
Further Simulation: Monte Carlo Analysis (MCA)

‘Generic’ school model
Further Simulation: MCA

Step 1: set variable distributions
Step 2: generate list of input values
Step 3: simulate – all inputs varied simultaneously

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Ventilation Rate</th>
<th>Heating Set Point</th>
<th>Variable 3</th>
<th>Variable 4</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation 1</td>
<td>18</td>
<td>21</td>
<td></td>
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<tr>
<td>Simulation 2</td>
<td>18.5</td>
<td>21.5</td>
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<tr>
<td>Simulation 3</td>
<td>17.5</td>
<td>22</td>
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<td>18</td>
<td>19</td>
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</tbody>
</table>
Further Simulation: MCA

Frequency distribution of possible CO2 emissions

Annual CO2 emissions per m2 per yr

Frequency

kgCO2/m2/yr

30 32.5 35 37.5 40 42.5 45 47.5 50 52.5 55 57.5 60 62.5 65 67.5 70 72.5 75 77.5 80 82.5 85 87.5 More
Main Conclusions

• Occupant behaviour is highly variable and unpredictable
• Factors controlled by occupants are most variable and most sensitive
• Better hand-over and post-occupancy analysis and education necessary

→ estimate range of likely energy consumption
→ highlight key factors affecting energy use
→ focus on most influential factors throughout procurement and operation

Enhanced understanding of impact of design decisions and building operations on energy performance of schools
Thank you

Questions?