S-Curves to Model and Visualise the Energy Performance Gap between Design and Reality

– *first steps to a practical tool*

RODERIC BUNN
BSRIA Ltd and UCL Institute for Environmental Design and Engineering
roderic.bunn@bsria.co.uk and roderic.bunn.13@ucl.ac.uk

ESFANDIAR BURMAN
Centre for Urban Sustainability and Resilience
esfandiar.burman.10@ucl.ac.uk
Making buildings better
Making buildings better

RIBA Plan of Work

0 & 1
Strategy and brief

2 - 4
Concept to technical design

5 & 6
Technical design, Construction & handover

7
In use

Client ambition for low energy (e.g. an A-rated EPC, BREEAM Outstanding, PassivHaus, DEC A)

Simplified dynamic modelling suggests lower energy targets are possible

Funding secured for renewables

Unregulated loads creep in unnoticed – ICT, servers, plug-in loads; not enough risk assessment and sensitivity analysis

Actual loads higher than model; VE and product substitution leads to change in specifications

Fixation on time cost, and programme, subtleties in design compromised

Commissioning poor, controls training non-existent, documentation incomplete, handover rushed, hvac systems dysfunctional

Operating hours emerge higher than design estimations, occupancy densities also higher

Soft Landings interventions might lead to improved performance (but they can’t overcome over-ambitious targets and construction deficiencies)

The realistic energy consumption likely to be sustainable in the long term

Planning requirement

Worse performance

+3
+2
+1

Regulated loads

Better performance

-3
-2
-1

= factor of 2 to 5+ difference in the first year
Whose Performance Gap...?

For which there is no regulatory procedure in place...

The client’s requirements

Making buildings better
Could visualising the consequences of project decisions and actions motivate project teams to focus on a shared set of performance outcomes?

Where the responsibilities lie depends on the context.
“Could visualising the consequences of project decisions and actions motivate project teams to focus on a shared set of performance outcomes?”

How might we do this?

• Could “Notional S-curves” be created for building types, based on inputs from various sources (BRUKL documents, Carbon Buzz, BPE experience etc)?
• What mathematical modelling, dynamic simulating modelling, and lessons from BPE might be needed to create a range of Notional S-curves for different buildings types
• Could a “Project Trajectory S-curve” be created, using project-specific performance inputs (TM54), to track progress against a Notional S-curve?

The point of all this:

To communicate emerging performance before it becomes a surprise after handover.
Calculating a Performance Factor

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For a Performance Factor of 1

We need to be more realistic here

We need to take more care here, and check more

We need to take custody of performance here

We need to do Soft Landings here

Rare, and usually only on small projects
Does evidence from building performance studies support the S-curve concept?
A normalisation formula used to convert from measurement values to a dimensionless Performance Factor.
Normalisation basis
Reference PF level derived by normalising the regulatory calculation or the as-built EPC

<table>
<thead>
<tr>
<th>Stage</th>
<th>Total performance (kgCO₂/m² per annum)</th>
<th>Building A performance relative to Part L TER</th>
<th>Ratio Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage D Projection (regulated loads only)</td>
<td>22.9</td>
<td>-5.8</td>
<td>-1.38</td>
</tr>
<tr>
<td>Stage D Projection (inclusive of equipment load)</td>
<td>35</td>
<td>6.3</td>
<td>1.50</td>
</tr>
<tr>
<td>As-built EPC (regulated loads)</td>
<td>24.5</td>
<td>-4.2</td>
<td>-1.00</td>
</tr>
<tr>
<td>As-built EPC (including allowance for equipment)</td>
<td>36.2</td>
<td>7.3</td>
<td>1.79</td>
</tr>
<tr>
<td>TM54 (actual occupants and equipment load)</td>
<td>40.3</td>
<td>11.6</td>
<td>2.76</td>
</tr>
<tr>
<td>TM54 (procurement issues NOT in as-built calc)</td>
<td>56.4</td>
<td>27.7</td>
<td>6.60</td>
</tr>
<tr>
<td>Post-occupancy Year 1</td>
<td>76</td>
<td>47.3</td>
<td>11.26</td>
</tr>
<tr>
<td>Post-occupancy Year 2</td>
<td>64.9</td>
<td>36.2</td>
<td>8.62</td>
</tr>
</tbody>
</table>

Normalisation basis: reference PF level could be derived by normalising the regulatory calculation (or as-built EPC if the as-built Part L is not available as in this example)

Note: CO₂ conversion factors identical to Part L2A 2006

TER: 28.7
What were the causes of PF6?

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Malfunctioning motorised vents led the maintenance contractor to increase the set point of the low temperature heating to 80 °C to overcome excessive heat loss.
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Stockport Academy  10,496 m²

Making buildings better

Making buildings better
Daily electrical power demand: Stockport Academy

Average weekend

Heating and mechanical ventilation plant fully operational over the weekend!
University arts building 2492 m²

If you can’t visualise what’s going on, how can you manage it?

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Making buildings better

The benchmark

\[ t_2 + t_1 = PF1.5 \]

Better performance

Worse performance

3

2

1

0

-1

-2

-3

The benchmark
The greater the building size, the more the complexity, the greater the risks of over-promise and under-performance.
Would S-curve modelling help project teams share a focus on performance outcomes?

Next steps

- Get more evidence and data from BPE studies to refine the hypothesis
- Normalise data into a dimensionless metric for performance factor level
- Write a formula that can take inputs to generate a notional curve and a project curve
- Trial on a real project
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Questions

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Would S-curve modelling help project teams share a focus on performance outcomes?

Next steps
- Get more evidence and data from BPE studies to refine the curve(s)
- Normalise data into a dimensionless metric for performance factor level
- Write a program that can take inputs to generate a notional curve
- Trial on a real project