TM54 2022

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Evaluating operational energy performance of buildings at the design stage

Annual consumption (kW-h/m²)

- Lifts
- Servers
- Catering electricity
- Office equipment
- Lighting
- Fans, pumps, controls
- Cooling
- Hot water (gas)
- Heating (gas)

Original Part L model vs. Actual
Why a revision?

Net Zero

Contractual performance targets

Advances in modelling

Approved Document (during the revision)
9.4 For new buildings with a total useful floor area over 1000m$^2$, the information to be handed over to the building owner should include a **forecast of the actual energy use of the building in kWh/year broken down by fuel type**. The energy forecast should include all metered energy uses, including unregulated loads.

This may be determined using any of the following methods, and should be recorded in the building log book:

- design calculations
- energy benchmarks
- an energy forecasting methodology such as CIBSE’s TM54
- other building modelling or spreadsheet tools
- any combination of (a) to (d).

**NOTE:** The compliance outputs of SBEM or other Building Regulations compliance tools are not suitable for direct use as energy forecasting estimates for any size of building.
TM54 modelling within a project lifecycle

Industry targets e.g. UK RIBA Challenge, LEED, NABERS UK rating.

Brief
Setting targets. Targets should relate to performance, not compliance.

Benchmarks
E.g. past projects (e.g. CIBSE online platform for benchmarks and distribution curve).

Design stage guidance
Design guidance, e.g. CIBSE Guides B and F
Metering strategy — CIBSE TM39
CIBSE Commissioning Codes.
Modelling: CIBSE AMT1; software-specific guidance; scheme-specific guidance, e.g. PHPP, chapter 6 of the Guide to Design for Performance (V1.1)

Design
Design, controls, metering strategy, commissioning plan.
Performance modelling to inform the design and evaluate performance against targets, at regular points (not as one-off exercise)

Construction, commissioning and handover
Checking implementation of design intent and managing change. Updating information.

As-built TMS4 energy performance model
- Updating the model for as-built record and check against targets.

At-use TMS4 energy performance model
- Updating the model to reflect actual operation.
- Comparing in-use performance with modelling results, with targets and with benchmarks (with caution, including context factors).
- Using the model as a live tool to identify possible reasons for under-performance, and options for improvements.

In-use stage guidance
CIBSE TM3 methodology framework to undertake measurement and verification of building energy performance in use;
CIBSE TM32: Energy assessment and reporting method.

In use

Design stage TMS4 energy performance model
- Sensing detailed as design progresses.
- Sensing checking modelling results against benchmarks.
- Assessing modelling results against what the design team sets as targets are on track and whether targets are achievable.
- Informing the design to meet targets (building shape, systems, control strategies, ensuring compatibility between metering strategy and model, and future in-use evaluation.
- Scenario and sensitivity analysis.
- Testing the impact of proposed changes.
Key updates

Same spirit as original TM54: performance, not compliance

More emphasis on targets, informing the design and testing the results

Guidance on different types of modelling, from steady state to dynamic with “detailed HVAC modelling”

Regulatory model not necessarily the starting point: more on building and set-up the model

More on HVAC and controls

No “blanket” approach to management factors

QA & Implementation matrix

+ General updates e.g. gains in/out of the model; lift & hot water calcs
## TM54 Methodology

### Step 0: Choosing the modelling approach

### Step 1: Constructing and building the model
- Constructing and zoning the model
- Establishing floor areas
- Weather file

### Step 2: Estimating operating hours and occupancy factors
- Operating hours
- Occupancy factors

### Step 3: Lighting

### Step 4: Lifts and escalators

### Step 5: Small power

### Step 6: Catering

### Step 7: Server rooms

### Step 8: Additional plant and equipment

### Step 9: Domestic hot water

### Step 10: Adding internal heat gains to the model, for energy uses calculated outside the model

### Step 11: Modelling HVAC systems and their controls
- These may be calculated inside or outside the model, depending on the modelling approach and context

### Step 12: Taking management considerations into account

### Producing, analysing, reporting and checking the results

### Step 13: Sensitivity analysis

### Step 14: Scenario testing

### Step 15: Review against targets and benchmarks

### Step 16: Reporting and implementation matrix

### Step 17: Quality assurance (QA)
## Step 16 – Reporting and Implementation matrix

### Table 13 Example TM54 implementation matrix

<table>
<thead>
<tr>
<th>TM54 steps</th>
<th>Recommendation</th>
<th>Modelling approach (summary)</th>
<th>Probable range</th>
<th>Confidence level (L/M/H)</th>
<th>QA check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplifications and assumptions (see section 5.2)</td>
<td>They should be used appropriately and judiciously, and detailed in the report</td>
<td>See report entitled 'xxx_TM54 modelling report' dated 12/2/22, sections x and y.</td>
<td>n/a</td>
<td>n/a</td>
<td>Yes</td>
</tr>
<tr>
<td>Use of benchmarks and targets (see section 6.2)</td>
<td>Benchmark should not replace a dedicated calculation of energy use.</td>
<td>Project has targeted LET1 Energy Use Intensity target of 65 kW h/m² (GIA/year) and space heating targets for schools. The report references these and reports results against these targets.</td>
<td>n/a</td>
<td>n/a</td>
<td>Yes</td>
</tr>
<tr>
<td>Step 0: Choosing the right level of modelling</td>
<td>The project team should establish early on in the project, in discussion with the client, the right level of modelling for the project. This should consider multiple factors including</td>
<td>The building is a large secondary school which is largely naturally ventilated but with significant mechanical ventilation using centralized AHUs. The building is controlled by a BMS system.</td>
<td>n/a</td>
<td>n/a</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Call for case studies!

UCL to produce an illustrative case study

Get in touch to showcase your project:

- TM54 modelling
- Comparison with in-use data
Thank you

Net Zero guidance page

CIBSE TM54:2022

Using modelling to meet operational energy targets

Step 0: Choosing the right approach

Jennifer Elias
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Delivering a better world
As we move towards net zero carbon:

- Designs need to be more innovative
- Modelling needs to be more accurate
- Modelling needs to better inform post occupancy evaluation

Figure 1.1 Energy performance modelling can help with dual aims: reducing the performance gap, and producing better, lower energy use buildings (image courtesy of Buro Happold)
Targets and Benchmarks

Targets:
Set by the project owner, e.g.
- Net zero carbon Energy Use Intensity target
- NABERS UK, DEC
- Improvement on a precedent project

Benchmarks:
- Can inform targets
- Can act as a ‘sanity check’ for TM54 results
- Inform specific components of the TM54 model
- Support in use performance monitoring
Step 0: Choosing the Right Approach

**TM54 Steady State**
- Simple systems, limited interaction with each other & hourly weather conditions
- HVAC energy doesn’t drive results or design decisions

**TM54 Dynamic modelling with template HVAC**
- More complex buildings
- Significant detail and certainty are not paramount
- HVAC system is typical
- HVAC component level detail is not required

**TM54 Dynamic modelling with detailed HVAC**
- Contractual performance targets (Net Zero Carbon, DEC etc)
- Complex or innovative HVAC system
- Selection / Optimisation of HVAC system
- Centralised (de)humidification systems
- Component-level HVAC results comparison
- Expertise is available
Step 0: Choosing the Right Approach
Choosing HVAC modelling

Template HVAC Modelling
Select Simple HVAC in model options and all HVAC settings are described in the HVAC model data lab.

Detailed Component Level HVAC Modelling
Select Detailed HVAC in model options and HVAC model is created graphically and settings are defined for individual components separately.

Template HVAC Modelling
Use Apache Systems to set up the key HVAC system input parameters.

Detailed Component Level HVAC Modelling
Create a schematic model in Apache HVAC and describe the system configuration in detail, component by component.

Template HVAC Modelling
Use Tas System Project Wizard to set up the HVAC system from template.

Detailed Component Level HVAC Modelling
Use the HVAC system model created in TAS Systems and describe the system configuration and controls in detail, component by component.

Figure 4.5 Illustration of 'template' and 'detailed' HVAC system modelling in DesignBuilder software (courtesy of DesignBuilder Software)

Figure 4.6 Illustration of 'template' and 'detailed' HVAC system modelling in IES software (courtesy of IES)

Figure 4.7 Illustration of 'template' and 'detailed' HVAC system modelling in TAS software (courtesy of EdSL)
Choosing HVAC modelling

Template Systems:

- A better match for constant volume systems than for variable volume systems
- Less accurate where systems provide heating and cooling at the central AHU and at the terminal unit
- Less accurate than detailed models for systems with (de)humidification

Figure 4.6 Illustration of ‘template’ and ‘detailed’ HVAC system modelling in IES software (courtesy of IES)
Component Level Comparison to actual

AHU Load

AHU Supply Temperature - Weekly
### Using the Implementation Matrix at Step 0

<table>
<thead>
<tr>
<th>TMS4 steps</th>
<th>Recommendation</th>
<th>Modelling approach (summary)</th>
<th>Probable range</th>
<th>Confidence level (L/M/H)</th>
<th>QA check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 0: Choosing the right level of modelling</td>
<td>The project team should establish early on in the project, in discussion with the client, the right level of modelling for the project. This should consider multiple factors including the complexity of the building and its systems, the resources available for the modelling, and the level of accuracy and certainty needed from the results. The discussions should also determine whether some steps in this methodology should be carried out within or outside the model, e.g. Step 3 (Lighting), Step 9 (Domestic hot water).</td>
<td>The building is a large secondary school which is largely naturally ventilated but with significant mechanical ventilation using centralised AHUs. The building is controlled by a BMS system. A dynamic thermal modelling approach has been chosen as this enables the model to be used for additional tasks such as thermal comfort analysis and building regulations compliance. HVAC will be modelled starting from templates and tuned to more accurately reflect the design proposals. Energy use associated with hot water and lighting will be calculated within the DSM. DHW volumes based on anticipated usage data provided by the client.</td>
<td>n/a</td>
<td>n/a</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Key takeaways and Next Steps

1. CIBSE Advanced simulation model training

2. Review modelling scopes and ensure they’re clear on:
   - Applicable energy performance targets (NZC EUI, NABERS UK, DEC etc)
   - Significant and complexity of HVAC System and controls, whether the model will guide HVAC system selection
   - Whether the model is required for component level end use comparisons in the future
Thank you
& onto Nishesh to talk through sensitivity analysis and scenario testing
TM54: 2022
Sensitivity Analysis & Scenario Testing
(Steps 13 and 14)

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8th March 2022
Sensitivity Analysis & Scenario Testing

What is Sensitivity Analysis & Scenario Testing?

Why do we need these analysis and tests?

How can these be done for a design as per TM54?
Sensitivity Analysis

- Process where impact of various design variables on calculation results are analysed

- Helps to identify most important and influential variables that can affect the design’s performance.
Scenario Testing

- Quantification of total variability in the calculation results due to uncertainties in the model inputs

- Can be called as Uncertainty analysis.
Sensitivity Analysis and Scenario Testing

These are necessary because

- assumptions used in models during design stage are uncertain.
- there is difference between buildings ideal performance and how it is likely to operate.
- designs often go through changes (specification change, value engineering, late determination of the control strategy etc.)
- it is important to know how design changes can impact performance so that safeguards can be put in place.
Sensitivity Analysis and Scenario Testing

These will help to address model uncertainties and:

• find the factors that have the greatest impact on the end energy consumption

• understand the drivers for building’s energy performance and potential risk factors

• highlight the importance of modelling assumptions (design, operational and occupancy)
Step 13: Sensitivity Analysis - Recommended TM54 Approach

Basic sensitivity tests

- A simple approach

- Iterative one at a time changes
  - Weather and climate
  - Occupancy and other loads
  - Operation hours
  - Impacts of management and occupancy behavior

- Identify important parameters to inform scenario testing
Parametric sensitivity and uncertainty analysis

- A holistic analysis
- Determine effects of multiple inputs changing at a time
- Accurately calculated ranking and uncertainty
- Useful in risk quantification (e.g., in performance contracts)

For typical projects **basic sensitivity tests** may be sufficient.
Step 14: Scenario testing - Recommended TM54 Approach

The modelling results demonstrate the level of uncertainty in results

4 Scenarios to be explored

- A mid-range scenario (baseline case)
- High-end and low-end scenarios
- ‘Worst case’ scenario
Step 14: Scenario testing - Recommended TM54 Approach

What variables to change and scenarios to consider?

- **Inputs identified as**
  - important in Step 13: Sensitivity test/analysis
  - low or medium confidence in implementation matrix
- **Controls**
- **Occupancy and hours of operation**
- **Internal gains (equip/lighting loads etc.)**
- **System efficiencies**
- **Weather (incl. future climate)**
- **Management considerations (Step 12)**

Scenarios to test will differ per project.

Avoid blanket approach of ±10% variation to all results or to all inputs.

Use the probable range from implementation matrix.
Step 14: Scenario testing - Recommended TM54 Approach

<table>
<thead>
<tr>
<th>Category</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupancy number</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Occupancy hrs / schedules</td>
<td>8-10</td>
<td>12-14</td>
<td>16-18</td>
</tr>
<tr>
<td>Heating EER</td>
<td>3.5</td>
<td>3.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Heating set-point (° C)</td>
<td>20</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Lighting load (W)</td>
<td>800</td>
<td>1200</td>
<td>2500</td>
</tr>
<tr>
<td>Lighting operating hrs</td>
<td>6-8</td>
<td>6-10</td>
<td>10-12</td>
</tr>
<tr>
<td>Equipment Load (W)</td>
<td>2500</td>
<td>3200</td>
<td>6000</td>
</tr>
<tr>
<td>Equipment operating hrs</td>
<td>6-8</td>
<td>6-10</td>
<td>10-12</td>
</tr>
<tr>
<td>Parasitic Load (W)</td>
<td>1500</td>
<td>2000</td>
<td>4000</td>
</tr>
<tr>
<td>Weather (2050 CIBSE future emission scenarios)</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>

![Graph showing energy consumption across different scenarios]

- **Low-End**
- **Mid-Range**
- **High-End**
- **Worst Case**

Projected (CIBSE TM54)
TM54: 2022
Sensitivity Analysis & Scenario Testing
(Steps 13 and 14)

Thank You

Nishesh Jain (n.jain@ucl.ac.uk)
Coming soon…
Leti Modelling Guide

Who is it for?

Clients
- Caution about compliance
- The modelling timeline
- Expectations of your modellers
- The risks of an EUI target

Design Teams
- What modellers will need from you
- Additional benefits of modelling

Modellers
- Modelling for an EUI
- What to be aware of
- Reporting the analysis and the risks
How does it relate to TM54?

1. Choose the right tool for the job
2. Get the basics right
3. Consider the impact of occupants
4. Include all the energy uses
5. Assume realistic internal heat gains
6. Model complicated systems in detail
7. Stress test for robustness, and manage risk
8. Report clearly and QA your work

All buildings

35 kWh/m².yr

EUI
Wider topics?

- How to meet the other LETI KPIs
- Overheating risk assessment against TM59/52 or GHA tool/PHPP
- Unmet hours check (ensuring comfort)
- EUI targets hit using ‘baseline’ (mid) estimate WITH risk management exercise
- By detailed design ‘high’ confidence level achieved for all the key modelling inputs, or included in risk management plan
- Modeller integrity and transparency – models should be replicable from reports
Thank you

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