Compliance vs Performance modelling

Repurposing a certification model for better design stage performance estimates
(as per CIBSE TM54)

Nishesh Jain
Research Fellow, IEDE, University College London
KTP Associate, DesignBuilder Software Ltd.

n.jain@ucl.ac.uk

23rd June 2020

Icons from: thenounproject.com/
Content

1. Background on compliance vs performance modelling

2. TM54 approach and requirements

3. Repurpose a certification model to a performance model, in accordance with TM54

4. TM54 recommended calculations and results
Compliance Modelling

- Created for comparative assessments and benchmarking

- Major driver for energy modelling of buildings in the UK

- Compliance calculation results often mistakenly interpreted as predictions of energy use
Compliance Modelling

Why Part L calculations are not suitable for energy projections:

- Totals only report on fixed building services, heating, hot water, cooling, ventilation, lighting only.
- Calculations use standardised assumptions and schedules (NCM based)

Using Part L calculations as the design baseline can lead to a perception of an inflated performance gap

Source: CIBSE TM54
Reasons why Part L calculations differ from operation energy use (CIBSE TM54 / CarbonBuzz)

- Building management and related training, commissioning, controls and metering have a major impact on how long and at what intensity services or equipment operate each day.
- Occupant density beyond compliance assumptions can affect energy usage but can be difficult to estimate or verify.
- Operating hours beyond those assumed in compliance calculations, including intermittent occupancy, are not required to be considered for compliance.
- Special functions are specialist activities that can cause a major increase in energy consumption such as lifts, swimming pools, medical equipment, etc.
- Small power equipment including plug loads and other electrical equipment are excluded from the compliance stage totals.
- ICT including servers, telecoms, security, etc. can have a major impact on energy use.
- Assumptions and simplifications in the energy model (e.g. weather, infiltration etc.) can increase or reduce energy use.
- Part L calculations include heating, hot water, cooling, ventilation and fixed lighting at set occupancy and opening hours.

Source: CIBSE TM54
Guidance on performing predictive energy modelling during the design stage

• Uses building specific model data and operational parameters such as occupancy, schedules, lighting power, and plug loads

• Results include unregulated energy end uses such as plug loads, servers, security, external lighting, lifts
Perceived Performance Gap

Case study school

CIBSE TM54

Primary recommendations of CIBSE TM54 are:

• Better calculations
  – Use Dynamic Simulation Models (like DesignBuilder)
  – Source complete and accurate data for operational parameters.

• Better presentation and explanations
  – Explore multiple scenarios by determining high and low estimates for inputs
  – Undertake sensitivity analysis
  – Compare results against existing benchmarks
Modelling

Overview of the compliance model
Repurposing in accordance with TM54
Calculation results
TM54 modelling prerequisites

- Full dynamic thermal simulation software, e.g. DesignBuilder Software
- Information from stakeholders about likely operations and management regimes
- List of probable high and low energy use changes for scenarios and sensitivity analysis
- Identified benchmarks for relevant building type
Acquire information about the building and prospective use

Step 1: Establish floor areas
Step 2: Establish operating hours and occupancy factors

Calculations outside a DSM
Step 3: Lighting
Step 5: Small power
Step 7: Server rooms
Step 9: Domestic hot water

Step 4: Lifts and escalators
Step 6: Catering
Step 8: Other equipment

Calculations within the DSM
Step 10: Internal heat gains
Step 11: Space heating, cooling, fans and pumps
Step 12: Humidification and dehumidification

Step 13: Estimating management factors

Using the results
Step 14: Running scenarios
Step 15: Sensitivity analysis
Step 16: Review against benchmarks
Step 17: Presenting the results

TM54 Methodology
# My TM54 Checklist

<table>
<thead>
<tr>
<th>TM54 baseline</th>
<th>Scenario/Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Location (weather) data</td>
<td>- Overall management quality</td>
</tr>
<tr>
<td>- Operating hours and occupancy</td>
<td>- HVAC system efficiency</td>
</tr>
<tr>
<td>- Lighting (load and operation)</td>
<td>- Control inefficiency in HVAC system (e.g. heating when windows open)</td>
</tr>
<tr>
<td>- Small power (load and operation)</td>
<td>- Hours of operation</td>
</tr>
<tr>
<td>- Lifts, escalators &amp; other equipment (load and operation)</td>
<td>- Loads (occupancy and equipment)</td>
</tr>
<tr>
<td>- Server (load and operation)</td>
<td>- Future weather data</td>
</tr>
<tr>
<td>- Heating and cooling system operation</td>
<td></td>
</tr>
<tr>
<td>- Fan power and operations</td>
<td></td>
</tr>
<tr>
<td>- Hot water consumption</td>
<td></td>
</tr>
<tr>
<td>- Detail HVAC system design (optional)</td>
<td></td>
</tr>
</tbody>
</table>

- CIBSE TM46: Energy Benchmarks
- Other building specific guides
My TM54 Checklist

- Location (weather) data
- Operating hours and occupancy
- Lighting (load and operation)
- Small power (load and operation)
- Lifts, escalators & other equipment (load and operation)
- Server (load and operation)
- Heating and cooling system operation
- Fan power and operations
- Hot water consumption
- Detail HVAC system design (optional)

- Overall management quality
- HVAC system efficiency
- Control inefficiency in HVAC system (e.g. heating when windows open)
- Hours of operation
- Loads (occupancy and equipment)
- Future weather data

- CIBSE TM46: Energy Benchmarks
- Other building specific guides
My TM54 Checklist

- Location (weather) data
- Operating hours and occupancy
- Lighting (load and operation)
- Small power (load and operation)
- Lifts, escalators & other equipment (load and operation)
- Server (load and operation)
- Heating and cooling system operation
- Fan power and operations
- Hot water consumption
- Detail HVAC system design (optional)

Benchmark:
- Overall management quality
- HVAC system efficiency
- Control inefficiency in HVAC system (e.g. heating when windows open)
- Hours of operation
- Loads (occupancy and equipment)
- Future weather data

Scenario/Sensitivity:
- CIBSE TM46: Energy Benchmarks
- Other building specific guides
NCM vs Actual

NCM Schedules for University Bedroom
(majority area)

Occupancy Schedule
Lighting Schedule
Heating Schedule
Equipment Schedule

Actual load profiles from student accommodation

UCL Student Residence 1 (2017)
UCL Student Residence 2 (2017)

Source: https://platform.carbonculture.net
My TM54 Checklist

- Location (weather) data
- Operating hours and occupancy
- Lighting (load and operation)
- Small power (load and operation)
- Lifts, escalators & other equipment (load and operation)
- Server (load and operation)
- Heating and cooling system operation
- Fan power and operations
- Hot water consumption
- Detail HVAC system design (optional)

- Overall management quality
- HVAC system efficiency
- Control inefficiency in HVAC system (e.g. heating when windows open)
- Hours of operation
- Loads (occupancy and equipment)
- Future weather data

Benchmark
- CIBSE TM46: Energy Benchmarks
- Other building specific guides
My TM54 Checklist

- Location (weather) data
- Operating hours and occupancy
- Lighting (load and operation)
- Small power (load and operation)
- Lifts, escalators & other equipment (load and operation)
- Server (load and operation)
- Heating and cooling system operation
- Fan power and operations
- Hot water consumption
- Detail HVAC system design (optional)

Scenario/Sensitivity

- Overall management quality
- HVAC system efficiency
- Control inefficiency in HVAC system (e.g. heating when windows open)
- Hours of operation
- Loads (occupancy and equipment)
- Future weather data

Benchmark

- CIBSE TM46: Energy Benchmarks
- Other building specific guides
Detailed HVAC system design

Source: DesignBuilder Software
My TM54 Checklist

- Location (weather) data
- Operating hours and occupancy
- Lighting (load and operation)
- Small power (load and operation)
- Lifts, escalators & other equipment (load and operation)
- Server (load and operation)
- Heating and cooling system operation
- Fan power and operations
- Hot water consumption
- Detail HVAC system design (optional)

- Overall management quality
- HVAC system efficiency
- Control inefficiency in HVAC system (e.g. heating when windows open)
- Hours of operation
- Loads (occupancy and equipment)
- Future weather data
- CIBSE TM46: Energy Benchmarks
- Other building specific guides
Projected energy use, Part L vs TM54

Demonstration Model

Energy (kWh/m²)
- Heating
- Auxiliary
- Lighting
- Hot Water
- Equipment

Projected (Part L)
Projected (CIBSE TM54)
My TM54 Checklist

- Location (weather) data
- Operating hours and occupancy
- Lighting (load and operation)
- Small power (load and operation)
- Lifts, escalators & other equipment (load and operation)
- Server (load and operation)
- Heating and cooling system operation
- Fan power and operations
- Hot water consumption
- Detail HVAC system design (optional)

Benchmark

- Overall management quality
- HVAC system efficiency
- Control inefficiency in HVAC system (e.g. heating when windows open)
- Hours of operation
- Loads (occupancy and equipment)
- Future weather data

Scenario/Sensitivity

- CIBSE TM46: Energy Benchmarks
- Other building specific guides
### Table for scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Assumptions</th>
<th>Scenario</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-end</td>
<td>Fully functional controls, excellent management and no weekend operation</td>
<td>Low-end</td>
<td>Excellent management, no weekend operation and low internal gains</td>
</tr>
<tr>
<td>Mid-range</td>
<td>Partially functional controls, average management and weekend operation</td>
<td>Mid-range</td>
<td>Average management, weekend operation and average internal gains</td>
</tr>
<tr>
<td>High-end</td>
<td>Non-functional controls, poor management and extended hours of operation</td>
<td>High-end</td>
<td>Poor management, extended hours of operation and high internal gains</td>
</tr>
<tr>
<td>Total installed power (kW)</td>
<td>366</td>
<td>Chiller cooling capacity (kW)</td>
<td>1450</td>
</tr>
<tr>
<td>Constant illuminance factor</td>
<td>1.0</td>
<td>SEER</td>
<td>3.5</td>
</tr>
<tr>
<td>Occupancy dependency factor</td>
<td>0.90</td>
<td>Lighting gains (W/m²)</td>
<td>0.0</td>
</tr>
<tr>
<td>Daylight dependency factor</td>
<td>0.90</td>
<td>Small power gains (W/m²)</td>
<td>13.5</td>
</tr>
<tr>
<td>Daylight time usage (h)</td>
<td>2620</td>
<td>Small power gains (out-of-hours) (W/m²)</td>
<td>1.5</td>
</tr>
<tr>
<td>Non-daylight time usage (h)</td>
<td>500</td>
<td>Fan coil unit gains (W/m²)</td>
<td>6.8</td>
</tr>
<tr>
<td>Parasitic control energy (kW/h/m²)</td>
<td>5.00</td>
<td>Servers gains (W/room)</td>
<td>1500</td>
</tr>
<tr>
<td>Parasitic emergency energy (kW/h/m²)</td>
<td>1.00</td>
<td>Occupant gains (m³ per person)</td>
<td>6.0</td>
</tr>
<tr>
<td>Management factor</td>
<td>1.00</td>
<td>Occupancy hours</td>
<td>3120</td>
</tr>
<tr>
<td></td>
<td>1.05</td>
<td>Management factor</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Source: CIBSE TM54
Scenario analysis of the demonstration model

<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 hours</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 (2020/2050 CIBSE future emission scenarios)</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>
Scenario analysis of the demonstration model

<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 hours</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 (2020/2050 CIBSE future emission scenarios)</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>

![Bar chart showing energy consumption for different categories]
Sensitivity Analysis

Source: CIBSE TM54
Uncertainty Analysis

Sensitivity Analysis

Source: https://designbuilder.co.uk/
Sensitivity Results

- Fabric Infiltration
- Small power equipment load density
- Load requirement of pumps and vents
- Lighting equipment load density
- Setpoint temperatures
- Efficiency of Heating System
- Windows and vents thermal performance
- Occupancy density
- Thermal performance of roof
- Thermal performance of wall

Source: https://designbuilder.co.uk/
My TM54 Checklist

- Location (weather) data
- Operating hours and occupancy
- Lighting (load and operation)
- Small power (load and operation)
- Lifts, escalators & other equipment (load and operation)
- Server (load and operation)
- Heating and cooling system operation
- Fan power and operations
- Hot water consumption
- Detail HVAC system design (optional)

Scenario/Sensitivity
- Overall management quality
- HVAC system efficiency
- Control inefficiency in HVAC system (e.g. heating when windows open)
- Hours of operation
- Loads (occupancy and equipment)
- Future weather data

Benchmark
- CIBSE TM46: Energy Benchmarks
- Energy Eff. Best Practice Programme (ECON Series)
Benchmarking of the demonstration model
Conclusion

- Compliance models and performance models serve different purposes

- Repurposing compliance model as per TM54 requires changes to NCM defaults

- Scenario and sensitivity analysis can provide information for more informed decisions

- Comparing against the benchmark data contextualises the building performance
Nishesh Jain
Research Fellow, IEDE, University College London
KTP Associate, DesignBuilder Software Ltd.
n.jain@ucl.ac.uk

23rd June 2020