Energy Benchmarking for Commercial Buildings

by Michael F. Keohane BE MEngSc
What are Benchmarks for?

1. To identify if a building’s energy performance is poor, average or good with respect to other buildings of its type. (Empirical benchmarks derived from energy statistics)

2. To identify if a building’s energy performance matches its potential and if not by how much. (Realistic Theoretical Energy Model of the building and integrated systems is required)
Prescriptive Based Assessment

Codes & Standards

Design Stage

Predict future performance

- Response by EU – EPBD
  - Building energy usage to be compared to benchmarks
  - Asset Rating
  - Operational Rating

Building Life Cycle
Energy Benchmark Codes and Standards

- Carbon Trust (Action Energy)
- CIBSE (Guides and technical journals)
- ASHRAE (Guides and technical journals)
- German Solarbau Standards
- BRE (sustainable techniques)
- Irish Building Regulations (Part L)
- EU Directives (Buildings)
- Organisations with Inhouse Benchmarks
- Alternative methods of Benchmarking
ECON 19 Energy Consumption Guide for Offices (DEFRA)

- Energy Benchmark for Offices based on Typical or Good Practice
- Indices used are kWh/m²/year, kgsCo2/m²/year, /m²/year
- Four types of offices
- Based on Surveys in mid 1990s
- Natural Gas Heating
- Air Con – VAV - Water Cooled Chiller
- New Designs should improve on Good Practice
  (lower Quartile of data collected)
ECON 19 Energy Benchmarks
Energy Benchmark Codes and Standards cont.

CIBSE Guides (Chartered Institute of Building Service Engineers)

- Guide F - Energy Efficiency in Buildings
- TM22:2006 - Energy Assessment and Reporting Methodology: Office Assessment Method
- TM46:2008 - Energy Benchmarks
Table 20.5 Fossil and electric building benchmarks for some retail buildings\(^{12,25}\)

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Electricity / kW·h·m(^{-2}) p.a.</th>
<th>Fossil fuel / kW·h·m(^{-2}) p.a.</th>
<th>Sample size</th>
<th>All-electric buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Good</td>
<td>Typical</td>
<td>Good</td>
<td>Typical</td>
</tr>
<tr>
<td>Banks</td>
<td>71</td>
<td>101</td>
<td>63</td>
<td>98</td>
</tr>
<tr>
<td>Bookstores</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Butchers’ shops</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Catalogue stores</td>
<td>83</td>
<td>101</td>
<td>37</td>
<td>69</td>
</tr>
<tr>
<td>Clothes shops</td>
<td>234</td>
<td>287</td>
<td>65</td>
<td>108</td>
</tr>
<tr>
<td>Department stores</td>
<td>237</td>
<td>294</td>
<td>194</td>
<td>248</td>
</tr>
<tr>
<td>Distribution warehouses</td>
<td>53</td>
<td>67</td>
<td>103</td>
<td>169</td>
</tr>
<tr>
<td>DIY stores</td>
<td>127</td>
<td>160</td>
<td>149</td>
<td>192</td>
</tr>
<tr>
<td>Electrical goods:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>— rental</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>— retail</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Frozen food centres</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Off-licenses</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Shoe shops</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Supermarkets</td>
<td>1034</td>
<td>1155</td>
<td>200</td>
<td>261</td>
</tr>
</tbody>
</table>

Note: the results from small samples, e.g. less than 50 buildings, may be unrepresentative of the whole sector
Table 20.4 Fossil and electric building benchmarks for some public sector buildings in Northern Ireland\(^{(24)}\)

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Mixed fuel buildings</th>
<th>All-electric buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electricity / kW-h-m(^{-2}) p.a.</td>
<td>Fossil fuel / kW-h-m(^{-2}) p.a.</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>Typical</td>
</tr>
<tr>
<td>Community centres</td>
<td>29</td>
<td>39</td>
</tr>
<tr>
<td>Fire stations</td>
<td>64</td>
<td>74</td>
</tr>
<tr>
<td>Libraries</td>
<td>24</td>
<td>45</td>
</tr>
<tr>
<td>Nurseries</td>
<td>17</td>
<td>23</td>
</tr>
<tr>
<td>Offices:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>naturally ventilated, cellular-</td>
<td>47</td>
<td>83</td>
</tr>
<tr>
<td>naturally ventilated, open plan</td>
<td>65</td>
<td>81</td>
</tr>
<tr>
<td>Police:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>— headquarters</td>
<td>108</td>
<td>135</td>
</tr>
<tr>
<td>— stations</td>
<td>91</td>
<td>121</td>
</tr>
<tr>
<td>Public toilets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schools:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>— dining centres</td>
<td>19</td>
<td>42</td>
</tr>
<tr>
<td>— kitchens</td>
<td>47</td>
<td>63</td>
</tr>
<tr>
<td>— primary</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>— secondary</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>University:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>— non-residential</td>
<td>29</td>
<td>39</td>
</tr>
<tr>
<td>— residential, mixed fuel:</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>electricity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Youth centres</td>
<td>17</td>
<td>28</td>
</tr>
</tbody>
</table>

Note: the results from small samples, e.g. less than 50 buildings, may be unrepresentative of the whole sector.
Energy Benchmark Codes and Standards cont.

**ASHRAE** (American Society of Heating, Refrigerating & Air Conditioning Engineers)

- Applies to New Buildings and Extensions
- Applies to Existing Buildings plus alterations
- Requires Dynamic Building Simulation Modelling
- Compares ASHRAE Baseline Reference Building versus Proposed Design (existing)
Intended for use in rating Energy Efficiency of building designs that exceed the requirement of the standard.


Gives Credit for advanced design strategies, and HVAC System Selection.

Allows for variations in Climate, Building Sizes, Building Types, HVAC systems.

Performance Rating Method includes the total energy consumption of all end uses.

Comparison in $ saved as opposed to kWh saved (Can lead to anomalies).

Why is ASHRAE 90.1-2007 important in terms of Ireland?
Energy Benchmark Codes and Standards cont.

LEED NC 2.2 (Leadership in Energy & Environmental Design)

- Green Building Rating System developed by US Green Building Council
- American version of BREEAM
- Preferred US Corporate Multinational Green Building Benchmark
- 12 Energy Credits available out of a total of 69 Credits
- LEED Certified, LEED Silver, LEED Gold, and LEED Platinum
- EA Credit 1 Optimise Energy by % improvement above ASHRAE 90.1-2007

<table>
<thead>
<tr>
<th>New Buildings</th>
<th>Renovations</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.5%</td>
<td>3.5%</td>
<td>1</td>
</tr>
<tr>
<td>14.0%</td>
<td>7.0%</td>
<td>2</td>
</tr>
<tr>
<td>17.5%</td>
<td>10.5%</td>
<td>3</td>
</tr>
<tr>
<td>21.0%</td>
<td>14.0%</td>
<td>4</td>
</tr>
<tr>
<td>24.5%</td>
<td>17.5%</td>
<td>5</td>
</tr>
<tr>
<td>28.0%</td>
<td>21.0%</td>
<td>6</td>
</tr>
<tr>
<td>31.5%</td>
<td>24.5%</td>
<td>7</td>
</tr>
<tr>
<td>35.0%</td>
<td>28.0%</td>
<td>8</td>
</tr>
<tr>
<td>38.5%</td>
<td>31.5%</td>
<td>9</td>
</tr>
<tr>
<td>42.0%</td>
<td>35.0%</td>
<td>10</td>
</tr>
</tbody>
</table>
Energy Benchmark Codes and Standards cont.

**BREEAM (BRE Environmental Assessment Method)**

- Green Building Rating System developed by BRE
- More Sustainable than LEED?
- Preferred UK based Green Building Benchmark
- 15 Energy Credits available out of a total of 100 Credits
- Pass, Good, Very Good, Excellent and Outstanding
- Reduce CO2 by % improvement above UK building regulations (SBEM)
Energy Benchmarks Codes & Standards cont.

**Solarbau**

- German Good Practice
- 40 kWh/m²/y for thermal demand
- 100 kWh/m²/y for HVAC and Lighting
Energy Benchmarks Codes & Standards cont.

**In House Benchmarks**

- Organisations can develop their own in house energy benchmarks
- Can apply to specialist type buildings, which might not have readily available published benchmarks
- Allows control of existing building stock energy consumption and sets targets for new buildings
- Allows development of Energy Culture within organisations
- Can be used to promote corporate ethos outside the organisation
- Examples would include Third level institutions, Pharmaceutical Companies, Food Retailers etc.
EU Energy Performance of Buildings Directive:

- Building energy usage to be compared to benchmarks
- Asset Rating
- Operational Rating
- Inspection of Equipment

**Response by EU – EPBD**

**Building Life Cycle**

**Integrated Life Cycle Model**

**Energy Certificate**

**GB 2004**

**Building Energy Performance >**

<table>
<thead>
<tr>
<th>Certificates sunset</th>
<th>FULL</th>
<th>In use:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Type</td>
<td>Office</td>
<td></td>
</tr>
<tr>
<td>Whole or part of building</td>
<td>Whole building</td>
<td></td>
</tr>
</tbody>
</table>

**Very energy efficient**

- Asset Rating: A
- Operational Rating: A

**Not energy efficient**

- Asset Rating: GB
- Operational Rating: GB

**Further information can be found in the Energy Log Book**

**Certificate Ref No:** XXXXXXX

**Date of Issue:** XX-XX-XXXXX
Asset Ratings and Building Energy Rating Certificates (BER)

- What does a building’s BER and advisory report tell us?
- It tells us what the potential energy performance of the building is under standard operating conditions.
- It is a tool for building regulation compliance rather than prediction of energy consumption.
- Just like the potential engine performance (0-60 in 6 seconds) quoted by Manufacturers for new cars.
Operational Ratings and Display Energy Certificates (DECs)

- What is a DEC?
  - An indication of the actual building energy use compared to typical energy use by similar buildings of that type (CIBSE Guide F, ECON 19 etc)

- How does it differ from from BER?
  - More like the MPG then “0-60 in 6 seconds” tells you how effectively the asset is managed, a measure of real operational use

- Only for Public Buildings over 1,000 m², but can be applied for voluntarily

- EBPD 2 Where are we going?
Analysis of Current Building Energy Benchmarks

Comparisons can be notoriously difficult;

- Design & Planning - kWh/m2 ?
- Conventional kWh/m2 Benchmark is a blunt instrument
- Variations in hours of operation?
- Variations in Climate, London to Dublin to Cork?
- Variations in local building regulations, Cork to New York
- Available Range of HVAC Systems is diverse with increasing complexity
- Occupant Density 3m2/person – 15 m2/person?? (Sweating the Asset!)
- As Measured in Design, Commissioning? - No Optimisation After
- Operational Maintenance – BEMS, Log Books,
- Building process is devoid of quantitative feedback
Alternative Benchmark? (UCC Sustainable Energy Research Group\textsuperscript{1})

Building Effectiveness Communication Ratios:

**Benchmark Metric**
- Min Idealised Energy Required to maintain thermal comfort
- Produced by Dynamic Energy Building Simulation Model
- Independent of HVAC systems etc

**Simulated Metric**
- HVAC system dependant energy quantification
- Commissioning results used to calibrate Dynamic Energy Building Simulation model

**Measured Metric**
- Energy Meter data archived by BEMS

\textsuperscript{1} “Building Effectiveness Communication Ratios for Improving Building Lifecycle Management” E Morrissey, M Keane, J o’Donnell & J McCarthy
Alternative Benchmark? (UCC Sustainable Energy Research Group)

Building Effectiveness Communication Ratios:

Idealised Effectiveness Ratio

<table>
<thead>
<tr>
<th>Building Phase</th>
<th>Design</th>
<th>Commissioning</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculation Method</td>
<td>Benchmark Metric/Simulated Metric (Ideal)</td>
<td>Benchmark Metric/Simulated Metric (Calibrated)</td>
<td>Benchmark Metric/Measured Metric</td>
</tr>
</tbody>
</table>

Performance Effectiveness Ratio
Advantages over traditional benchmarks

- Benchmark is a ratio between 0 – 1 rather the kWh/m2
- Allows Building from different climates and building codes to be compared directly against each other
- Allows buildings with completely different HVAC systems to be compared against each other
- Allows inefficiencies in the Building HVAC systems to be identified through on-going monitoring