Building Energy Benchmarking

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Introduction

- **Energy** is important to every society
  - Economic, environmental & social impacts
  - It is also a key issue for *sustainable development*
- Use energy …
  - Consume finite fossil fuels (oil, coal, natural gas)
  - Cause air pollution & environmental damage
  - Contribute to global warming
  - Cost money
Introduction

- **Buildings** constitute 30-50% of energy needs
  - Residential + commercial + industrial
  - The potential for energy saving is large
- Possible benefits from energy efficiency:
  - Life-cycle cost savings
  - Reduced CO₂ emissions and consumption of fossil fuels
  - Improved building design and operation
  - Better working environments
  - Added market value of buildings
  - Reduced capital cost by better integration of building fabric and systems
Energy end-use in Hong Kong by sectors, 1984-2005

[Data source: www.emsd.gov.hk]
Energy end-use in Hong Kong by sector, 2005

- Commercial: 37%
- Residential: 19%
- Industrial: 8%
- Transport: 36%

[Data source: www.emsd.gov.hk]
Introduction

• **Building energy benchmarking (BEB)**
  - A valuable tool to manage energy usage
  - Allow comparison of whole-building energy use relative to a set of similar buildings
  - Useful for individual energy audits and for targeting buildings for energy saving measures
What is Benchmarking?

- Business: Total Quality Management
  - “Benchmarking - a continuous, systematic process for evaluating the products, services, and work processes of organizations that are recognized as representing best practices for the purpose of organizational improvement.” -- Michael J. Spendolini, *The Benchmarking Book*, 1992
The Benchmarking Process

Set-up and Planning

Data Gathering

Determine Gaps

Implement Change

Review and Adapt
What is Benchmarking?

• Major aim of benchmarking: Identify actions to improve performance
  • Identify issues (metrics)
  • Collect internal data (baseline)
  • Collect external data (comparison framework)
  • Analysis
  • Implement change
  • Monitor impact
What is Benchmarking?

- Building energy benchmarking: Rate building energy performance
  - Score (percentile)
  - Energy index (per sq.m)
- Based on annual energy use
  - Physical efficiency (building, equipment)
  - Operational efficiency
Why Benchmarking?

- A tool to help support decisions
  - Is my building using too much energy?
  - How “good” are my buildings?
  - Where are my energy costs going?
  - How am I doing on reaching my goals?
  - Which of my buildings need improved maintenance?
  - Does my building need retrofits?
  - How much should I be willing to spend to do a retrofit?
Why Benchmarking?

• Benefits:
  • Determine how well a building is performing
  • Compare energy consumption to similar buildings
  • Set targets for improved performance
  • Facilitate assessment of property value
  • Gain recognition for exemplary achievement
  • Identify actions for energy savings
  • Facilitate energy audit and energy efficiency campaign
Why Benchmarking?

Key elements of benchmarking

1. Continuous systematic search for and identifying best practices
2. Careful study to find the reasons of success
3. Develop recommendations and implementation for improvement
Energy Performance Indicators

- Define performance by a meaningful metric
- Rich dataset for comparison
  - Compare to what? Data source?
  - Comparison method?
- Normalize for unmanaged characteristics
  - Building area
  - Building use
  - Level of service
  - Comfort
  - Hours of use
Energy Performance Indicators

- Building performance metrics
  - Energy cost ($/year, $/month, $/sq.m)
  - Energy use (kWh/year, kWh/month, kWh/sq.m)
- Normalized for:
  - Number of days in reading
  - Weather
  - Operating hours
- Segregated for other drivers:
  - Such as data centres, kitchens
Energy Performance Indicators

- **Energy Utilization Index (EUI)**
  - Represent actual energy use; no adjustments or correction factors, site or source energy

- **Normalised Performance Indicator (NPI)**
  - For buildings, calculated annually – **kWh/m²/year**
    - Total annual energy consumption / floor area
    - Normalised for operating hours, weather, etc.
  - NPI can be for total energy, energy types (electricity, gas, oil) & by use (A/C, light, heat)
  - Allows comparison of buildings of a similar type
Normalised Performance Indicator (NPI)

Three hospitals compared against performance yardstick figures

- **Hospital A**: Good
- **Hospital B**: Fair
- **Hospital C**: Poor

**GJ/100 m³/year**

- Hospital A: 50
- Good: 60
- Hospital B: 70
- Poor: 80
- Hospital C: 90
Energy Performance Indicators

- Defining building performance
- Comparing it to...
  - Past performance
    - Trending (self reference)
  - Expectations
    - Target setting and trending
    - Diagnostics
  - Other buildings
    - Internal benchmarks
    - External benchmarks
Energy Performance Indicators

- Benchmarking on past performance
  - Collect and calculate metrics
  - Trend them over time (no comparison to others)
Energy Performance Indicators

- Benchmarking on expectations
- Setting targets
Energy Performance Indicators

• Compare to other buildings: the ideal benchmark
  • Comparing to comparable buildings:
    • Climate/location, size, building type
    • Activities, end uses, occupancy
    • Operation and maintenance
  • Not easy to find such an ideal benchmark
  • Normalized for anything you don’t have control over
Energy Performance Indicators

- Compare to other buildings: internal benchmarks
  - Internal data source (small organization)
    - Tabular ranking for small number of buildings
  - Internal data source (large portfolio)
    - Rank similar properties
    - Implied similar characteristics
    - Can quantify benefit of reducing large users to norm
    - See only internal best practices
The Top Eight High Energy Consumption Buildings

Electricity Expenditure for Top Eight University Buildings
(from July 2001 to Dec 2001)

<table>
<thead>
<tr>
<th>Building Code</th>
<th>Expenditure</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>CY(P)</td>
<td>$1,545</td>
<td>(32kWh/m²/month)</td>
</tr>
<tr>
<td>MW</td>
<td>$1,620</td>
<td>(18kWh/m²/month)</td>
</tr>
<tr>
<td>CY</td>
<td>$1,675</td>
<td>(21kWh/m²/month)</td>
</tr>
<tr>
<td>CY(C)</td>
<td>$1,979</td>
<td>(45kWh/m²/month)</td>
</tr>
<tr>
<td>KK</td>
<td>$2,120</td>
<td>(19kWh/m²/month)</td>
</tr>
<tr>
<td>KB</td>
<td>$2,212</td>
<td>(19kWh/m²/month)</td>
</tr>
<tr>
<td>LS</td>
<td>$2,440</td>
<td>(46kWh/m²/month)</td>
</tr>
<tr>
<td>KA</td>
<td>$4,872</td>
<td>(59kWh/m²/month)</td>
</tr>
</tbody>
</table>

Building Codes:
- CY: Chong Yuet Ming Amenities Centre
- CY(C): Chong Yuet Ming Chemistry Building
- CY(P): Chong Yuet Ming Physics Building
- KA: Kadoorie Biological Sciences Building
- KB: Knowles Building
- KK: K.K. Leung Building
- LS: Li Shu Fan Building
- MW: Meng Wah Complex

Source: HKU Staff Newsletter
Energy Performance Indicators

- Compare to other buildings: external benchmarks
  - Comparison to large scale data
    - From energy survey & statistical data
    - From building energy labelling schemes (e.g. EnergyStar Building Label, www.energystar.gov)
  - Type of comparison
    - Ranks / Distributions
    - Regressions
    - Standard / Best Practices
  - Limited by existing data sets
Histogram of building energy use intensity

[Source: www.energy.ca.gov/pier]
Energy Performance Indicators

• Compare your building’s EUI to typical and good practice
  • Your building
  • Typical
  • Good practice
Energy Performance Indicators

• Select and evaluate retrofits
  • Such as lighting retrofit
    • Lamp replacement (T8 to T5)
    • Electronic ballast
    • Lighting controls
    • Re-zoning
    • Occupancy sensors
Practical Applications

• How to do Benchmarking
  • Collect energy data
  • Calculate and chart metrics for individual buildings
  • Chart trends in individual buildings and groups of buildings
  • Define baselines and targets for individual buildings or groups of buildings
  • Periodically evaluate your performance and goals
Practical Applications

• Examples of benchmarking programmes
  • USA: Energy Star Benchmarking ✓
  • Singapore: e-Energy benchmarking tools ✓
  • Hong Kong: Energy Consumption Indicators and Benchmarks (EMSD) ✓
  • APEC Building Energy Benchmarking
  • CalArch (California Bldg Energy Reference Tool)
  • Carbon Trust (UK)
  • EPLabel programme in Europe
Practical Applications

- **Energy Star Benchmarking (USA)**
  - Developed by US-EPA and US-DOE
  - Based on the USA’s Commercial Building Energy Consumption Survey (CBECS) data
    - Using regression models
  - Applied across the nation in USA
  - Energy Star Label for Buildings
  - Normalized for climate, schedules, occupancy, etc.
    - Score between 1-100 (a score of at least 75 is required for an Energy Star Label for Buildings)
Energy Star Label for Buildings (USA)

Energy Star Label for Buildings

Buildings that rate in the top 25% of energy-efficient buildings in USA

http://www.energystar.gov/
Practical Applications

• Building energy benchmarks in Singapore
  • e-Energy (by BCA-NUS Building Energy & Research Information Centre)
  • Benchmarking Tools
    • Questionnaires
    • Energy Audit Online
  • For offices, shopping centres and hotels
    • Divided into 3 parts: Total, Landlord and Tenant
Class I - Most Energy Efficient Building
Class II - Normal Energy Efficient Building
Class III - Least Energy Efficient Building

<table>
<thead>
<tr>
<th>Degree Level of Standard</th>
<th>Description Assessment</th>
<th>Total Building Energy Performance Indicator</th>
<th>Total Building Energy Efficiency (kWh/year/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Excellent</td>
<td>0.64 &gt; or = Level 1</td>
<td>147.74 &gt; or = Level 1</td>
</tr>
<tr>
<td>Level 2</td>
<td>Very Good</td>
<td>0.86 &gt; Level 2 &gt; 0.64</td>
<td>197.92 &gt; Level 2 &gt; 147.74</td>
</tr>
<tr>
<td>Level 3</td>
<td>Good</td>
<td>1.05 &gt; Level 3 &gt; 0.84</td>
<td>243.14 &gt; Level 3 &gt; 197.92</td>
</tr>
<tr>
<td>Level 4</td>
<td>Fair</td>
<td>1.51 &gt; Level 4 &gt; 1.05</td>
<td>348.35 &gt; Level 4 &gt; 243.14</td>
</tr>
<tr>
<td>Level 5</td>
<td>Poor</td>
<td>2.03 &lt; or &gt; Level 5 &gt; 1.51</td>
<td>469.56 &lt; or &gt; Level 5 &gt; 348.350</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class Groups</th>
<th>Classification Nomenclature</th>
<th>Total Building Energy Efficiency Indicator</th>
<th>Total Building Energy Efficiency (kWh/year/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>Most energy efficient building</td>
<td>0.76 &gt; Class I</td>
<td>175.83 &gt; Class I</td>
</tr>
<tr>
<td>Class II</td>
<td>Normal energy efficient building</td>
<td>1.16 &gt; Class II &gt; 0.76</td>
<td>268.23 &gt; Class II &gt; 175.83</td>
</tr>
<tr>
<td>Class III</td>
<td>Least energy efficient building</td>
<td>2.03 &lt; or &gt; Class III &gt; 1.16</td>
<td>469.56 &lt; or &gt; Class III &gt; 268.23</td>
</tr>
</tbody>
</table>

[Source: www.bdg.nus.edu.sg/buildingEnergy]
The Ogive Curve of Total Building Energy Efficiency Index of Office Building in Singapore

Cumulative percentage (%) of different total building energy efficiency index ranges.

[Source: www.bdg.nus.edu.sg/buildingEnergy]
### Landlord Building Energy Efficiency Index Indicator Scale

- **Least energy efficient**
  - 2.03

- **Class III**
  - 1.16

- **Class II**
  - 0.78

- **Class I**
  - 0.00

#### Scale:
- Level 5 Poor
- Level 4 Fair
- Level 3 Good
- Level 2 Very Good
- Level 1 Excellent

#### Class Descriptions:
- **Class I** - Most energy efficient building
- **Class II** - Normal energy efficient building
- **Class III** - Least energy efficient building

### Energy Efficiency Table

<table>
<thead>
<tr>
<th>Degree Level of Standard</th>
<th>Description Assessment</th>
<th>Total Building Energy Performance Indicator</th>
<th>Total Building Energy Efficiency (kWh/year/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Excellent</td>
<td>0.62 &gt; or = Level 1</td>
<td>89.59 &gt; or = Level 1</td>
</tr>
<tr>
<td>Level 2</td>
<td>Very Good</td>
<td>0.88 &gt; Level 2 &gt; 0.62</td>
<td>126.93 &gt; Level 2 &gt; 89.59</td>
</tr>
<tr>
<td>Level 3</td>
<td>Good</td>
<td>1.08 &gt; Level 3 &gt; 0.88</td>
<td>155.94 &gt; Level 3 &gt; 126.93</td>
</tr>
<tr>
<td>Level 4</td>
<td>Fair</td>
<td>1.39 &gt; Level 4 &gt; 1.08</td>
<td>201.53 &gt; Level 4 &gt; 155.94</td>
</tr>
<tr>
<td>Level 5</td>
<td>Poor</td>
<td>2.03 &lt; or &gt; Level 5 &gt; 1.39</td>
<td>293.82 &lt; or &gt; Level 5 &gt; 201.53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class Groups</th>
<th>Classification Nomenclature</th>
<th>Landlord Building Energy Efficiency Indicator</th>
<th>Landlord Building Energy Efficiency (kWh/year/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>Most energy efficient building</td>
<td>0.78 &gt; Class I</td>
<td>113.26 &gt; Class I</td>
</tr>
<tr>
<td>Class II</td>
<td>Normal energy efficient building</td>
<td>1.16 &gt; Class II &gt; 0.78</td>
<td>167.36 &gt; Class II &gt; 113.26</td>
</tr>
<tr>
<td>Class III</td>
<td>Least energy efficient building</td>
<td>2.03 &lt; or &gt; Class III &gt; 1.16</td>
<td>293.82 &lt; or &gt; Class III &gt; 167.36</td>
</tr>
</tbody>
</table>

[Source: www.bdg.nus.edu.sg/buildingEnergy]
Ogive curve of landlord building energy efficiency index of office building in Singapore

Cumulative percentage (%)

Landlord building energy efficiency index

[Source: www.bdg.nus.edu.sg/buildingEnergy]
Tenant Building Energy Efficiency Index Indicator Scale

Class I - Most energy efficient building
Class II - Normal energy efficient building
Class III - Least energy efficient building

<table>
<thead>
<tr>
<th>Degree level of standard</th>
<th>Description assessment</th>
<th>Total building energy performance indicator</th>
<th>Total building energy efficiency (kWh/year/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Excellent</td>
<td>0.52 &gt; or = Level 1</td>
<td>70.17 &gt; or = Level 1</td>
</tr>
<tr>
<td>Level 2</td>
<td>Very Good</td>
<td>0.78 &gt; Level 2 &gt; 0.52</td>
<td>105.87 &gt; Level 2 &gt; 70.17</td>
</tr>
<tr>
<td>Level 3</td>
<td>Good</td>
<td>1.12 &gt; Level 3 &gt; 0.78</td>
<td>152.36 &gt; Level 3 &gt; 105.87</td>
</tr>
<tr>
<td>Level 4</td>
<td>Fair</td>
<td>1.51 &gt; Level 4 &gt; 1.12</td>
<td>205.98 &gt; Level 4 &gt; 152.36</td>
</tr>
<tr>
<td>Level 5</td>
<td>Poor</td>
<td>2.10 &lt; or &gt; Level 5 &gt; 1.51</td>
<td>284.90 &lt; or &gt; Level 5 &gt; 205.98</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class groups</th>
<th>Classification Nomenclature</th>
<th>Tenant building Energy Efficiency Indicator</th>
<th>Tenant building Energy Efficiency (kWh/year/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I</td>
<td>Most energy efficient building</td>
<td>0.72 &gt; Class I</td>
<td>97.98 &gt; Class I</td>
</tr>
<tr>
<td>Class II</td>
<td>Normal energy efficient building</td>
<td>1.22 &gt; Class II &gt; 0.72</td>
<td>165.84 &gt; Class II &gt; 97.98</td>
</tr>
<tr>
<td>Class III</td>
<td>Least energy efficient building</td>
<td>2.10 &lt; or &gt; Class III &gt; 1.22</td>
<td>284.90 &gt; Class III &gt; 165.84</td>
</tr>
</tbody>
</table>

[Source: www.bdg.nus.edu.sg/buildingEnergy]
Ogive curve of tenant building energy efficiency index of office building in Singapore

Cumulative percentage (%)

Tenant building energy efficiency index

[Source: www.bdg.nus.edu.sg/buildingEnergy]
Practical Applications

• Building energy benchmarks in Hong Kong
  • Energy Consumption Indicators and Benchmarks
    • Developed by EMSD
    • http://www.emsd.gov.hk/emsd/eng/pee/ecib.shtml
  • Building types include:
    • Private offices
    • Commercial outlets
    • Hotels and boarding houses
    • Universities, post-secondary colleges and schools
    • Hospitals and clinics
Energy Consumption Indicators for Offices

[Source: www.emsd.gov.hk]
<table>
<thead>
<tr>
<th>Principal Group</th>
<th>Subgroups</th>
<th>Indicator PI(ai): Energy consumed per unit floor area per annum (MJ/m²/ annum)</th>
<th>Detail benchmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Offices</td>
<td>Common services for buildings with central A/C for tenant</td>
<td>848</td>
<td>Benchmarks</td>
</tr>
<tr>
<td></td>
<td>Tenant units in buildings with central A/C supply</td>
<td>385</td>
<td>Benchmarks</td>
</tr>
<tr>
<td></td>
<td>Common services for buildings without central A/C supply (but with A/C in common area)</td>
<td>192.3</td>
<td>Benchmarks</td>
</tr>
<tr>
<td></td>
<td>Common services for buildings without central A/C supply (but without A/C in common area)</td>
<td>122.3</td>
<td>Benchmarks</td>
</tr>
<tr>
<td></td>
<td>Tenant units in buildings without central A/C supply</td>
<td>561</td>
<td>Benchmarks</td>
</tr>
<tr>
<td></td>
<td>Private Offices (whole building)</td>
<td>1132</td>
<td>Benchmarks</td>
</tr>
<tr>
<td>Government Offices</td>
<td>Government Offices (whole building)</td>
<td>826.5</td>
<td>Benchmarks</td>
</tr>
</tbody>
</table>

[Source: www.emsd.gov.hk]
Energy Consumption Benchmark

Percentile Distribution Curve of P(ai) Total for Subgroup
Private Offices (Whole Building)

The 10th, 30th, 50th, 70th and 90th percentile benchmarks are:

<table>
<thead>
<tr>
<th>Percentile</th>
<th>10th</th>
<th>30th</th>
<th>50th</th>
<th>70th</th>
<th>90th</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MJ/m²/annum</td>
<td>MJ/m²/annum</td>
<td>MJ/m²/annum</td>
<td>MJ/m²/annum</td>
<td>MJ/m²/annum</td>
</tr>
<tr>
<td>10th</td>
<td>973</td>
<td>1004</td>
<td>1064</td>
<td>1205</td>
<td>1355</td>
</tr>
</tbody>
</table>

[Source: www.emsd.gov.hk]
Energy Consumption Benchmark

Percentile Distribution Curve of Pi(ai) total for Subgroup
Government Offices

<table>
<thead>
<tr>
<th>Cumulative Percentage</th>
<th>10 th</th>
<th>30 th</th>
<th>50 th</th>
<th>70 th</th>
<th>90 th</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>346.56 MJ/m²/annum</td>
<td>630.11 MJ/m²/annum</td>
<td>826.50 MJ/m²/annum</td>
<td>1022.89 MJ/m²/annum</td>
<td>1306.44 MJ/m²/annum</td>
</tr>
</tbody>
</table>

[Source: www.emsd.gov.hk]
Conclusions

• Benchmarking is a useful tool, but it is not the destination, just the mile marker
  • Benchmark only hints at potential for improvement
• We still need to figure out where to go
  • Apply expertise
  • Investigate systems
  • Devise changes
  • Assess performance
Conclusions

• Future prospects
  • Energy label & certification of buildings
    • For new buildings: specify energy performance baseline (allow people to know & compare)
    • For existing buildings: upgrade to meet the building energy codes (during retrofits)
  • Offer suggestions for improvement (simple actions, technical solutions)
Examples of energy efficiency labels in Hong Kong

Energy label for appliance (grading-type)

Energy label for appliance (recognition-type)

Energy label for passenger car

(Source: www.emsd.gov.hk)
Building energy benchmarks will form the basis for building energy label.
THANK YOU 謝謝

This presentation file can be downloaded at:
http://web.hku.hk/~cmhui/present.htm