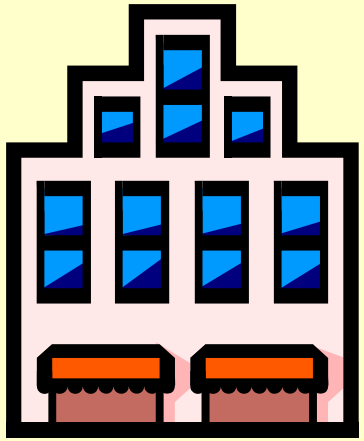
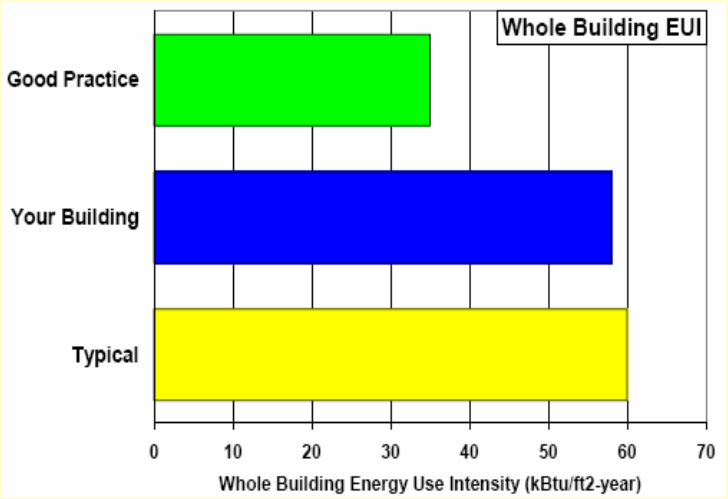
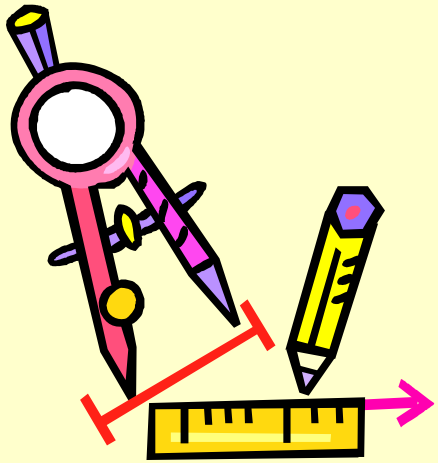
IMechE Hong Kong Branch – Technical Talk

30 July 2008 (Wed), CD307, PolyU







Building Energy Benchmarking

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July 2008

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- What is Benchmarking?
- Why Benchmarking?
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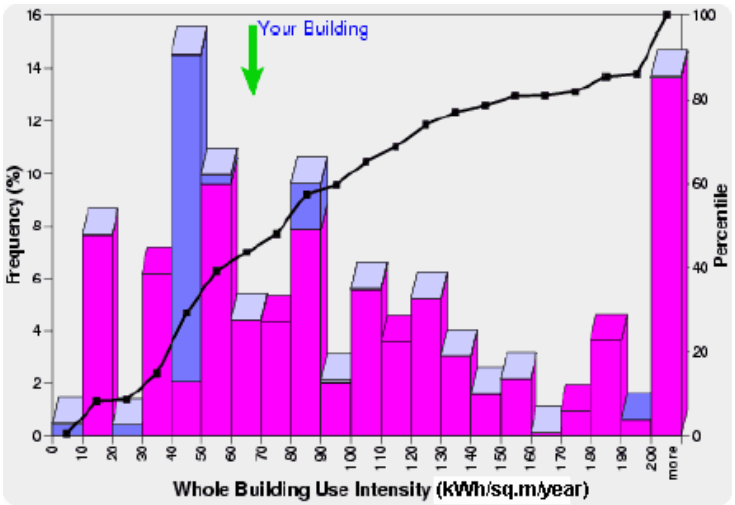
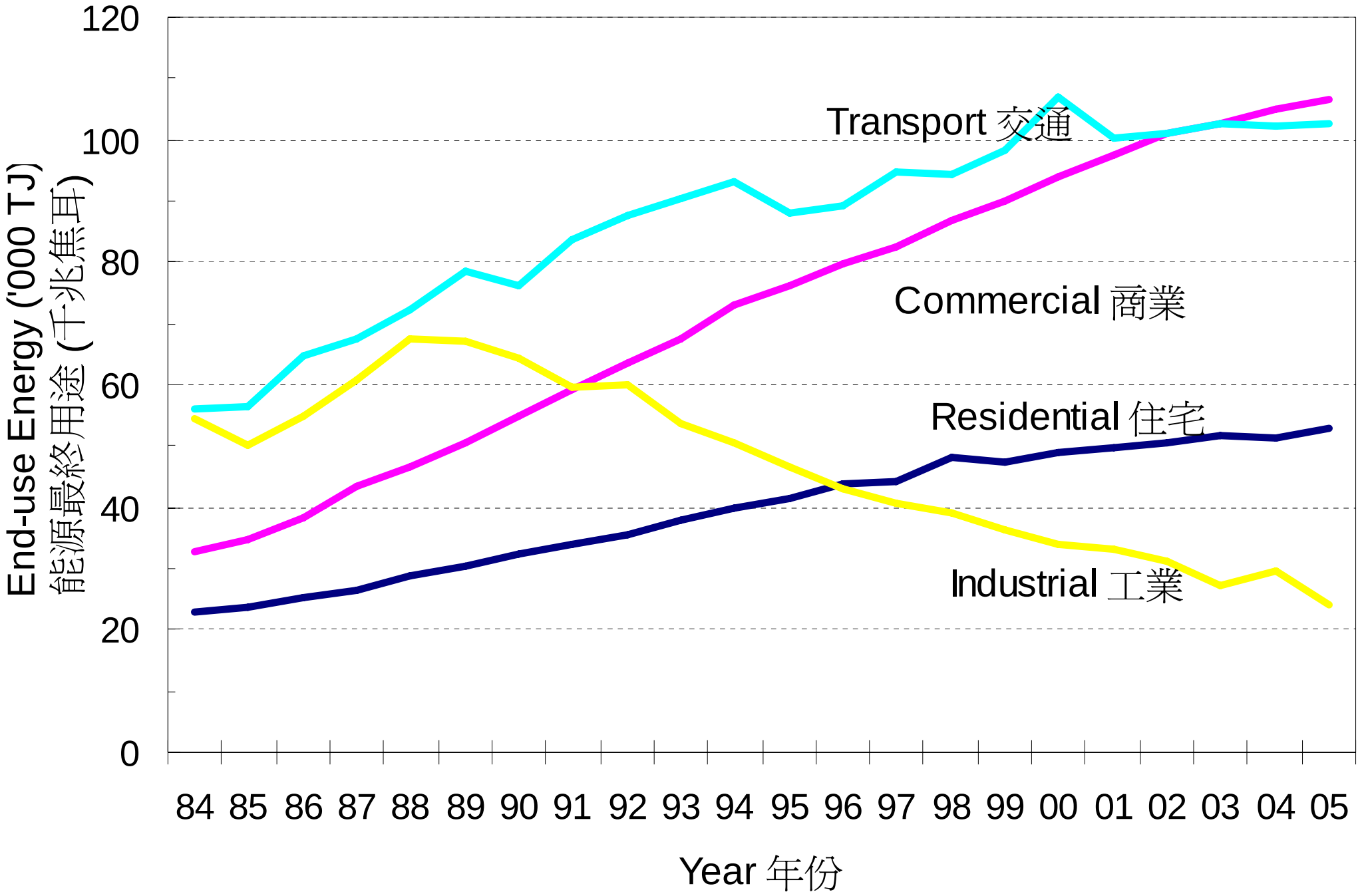


Introduction

- **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

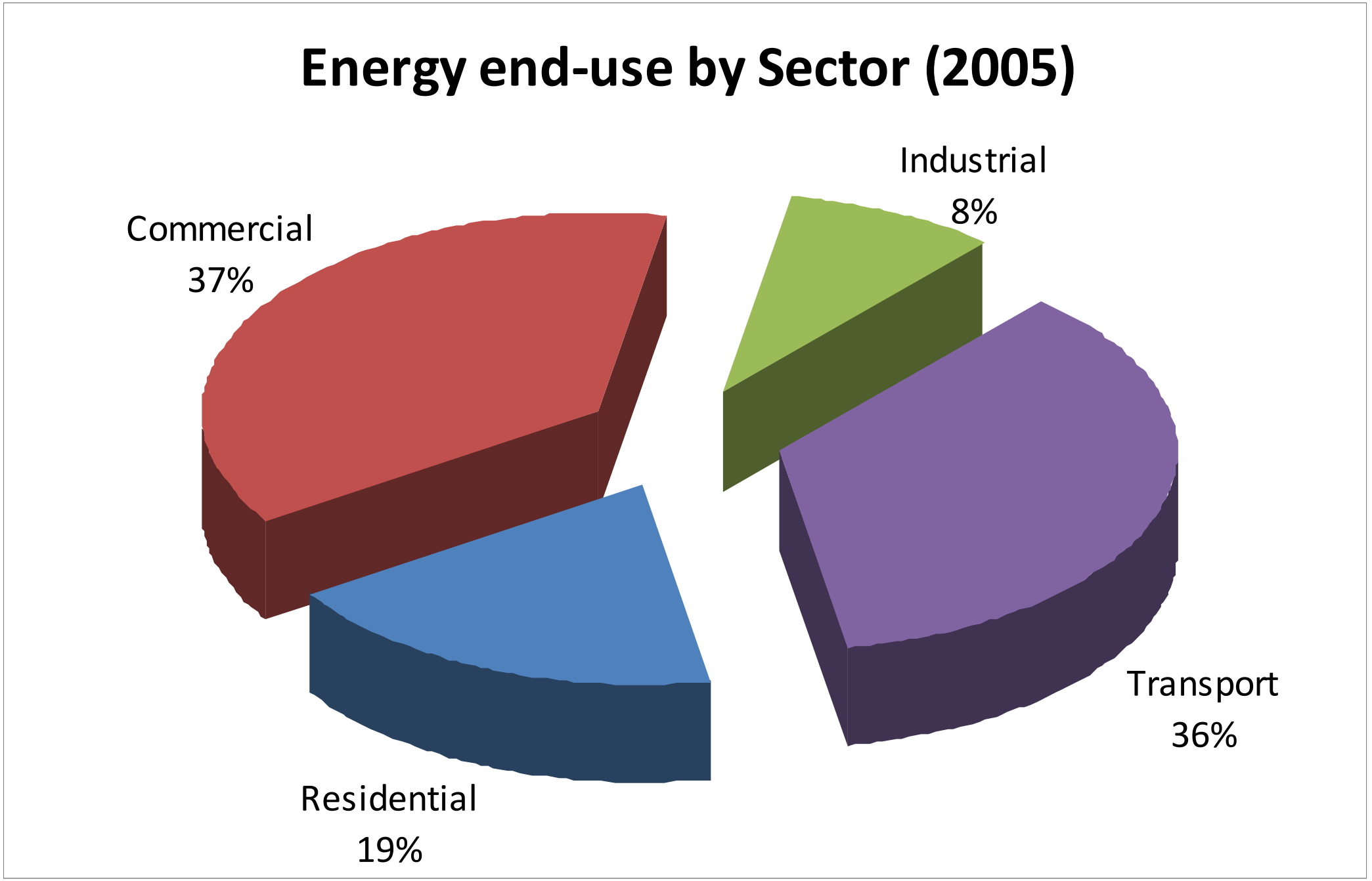
Introduction

- **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 CO_2 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]

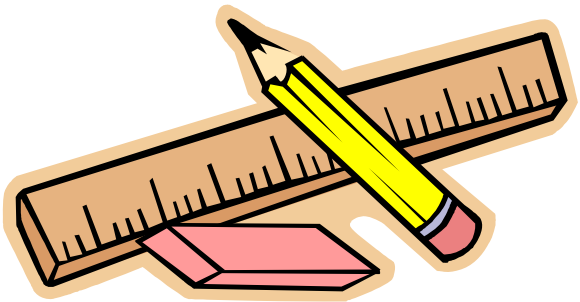


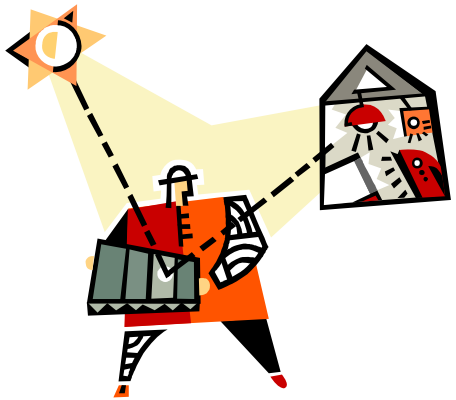
Energy end-use in Hong Kong by sector, 2005

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

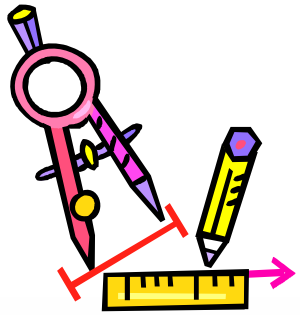
Introduction

- **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

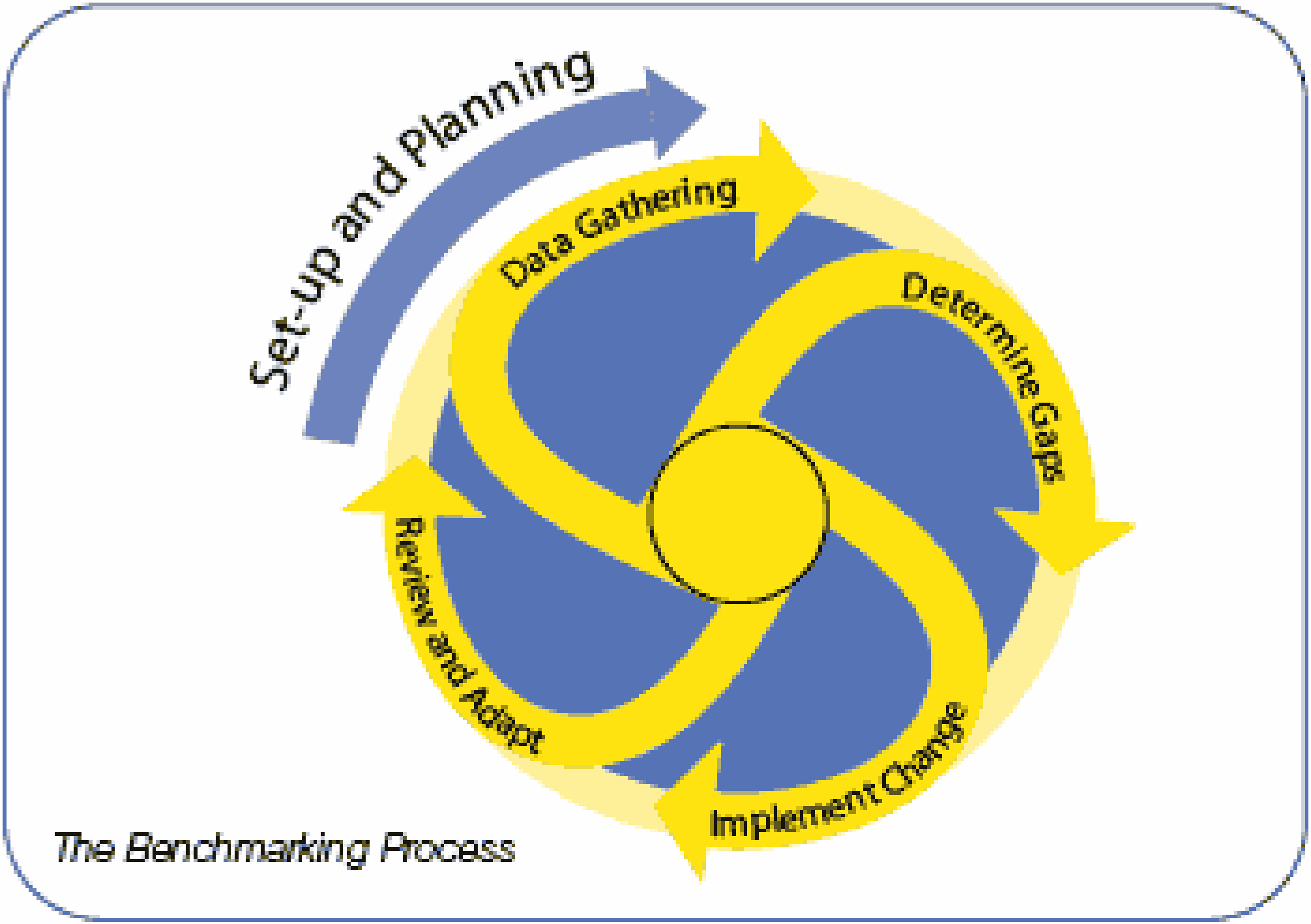




What is Benchmarking?

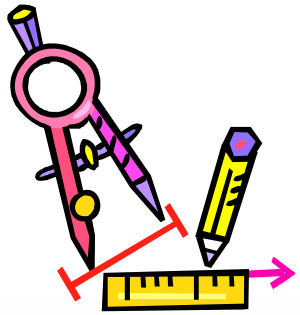


- Business: Total Quality Management
  - "**Benchmarking** - a continuous, systematic process for evaluating the products, services, and work processes of organizations that are recognized as representing *best practices* for the purpose of organizational improvement." -- Michael J. Spendolini, *The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



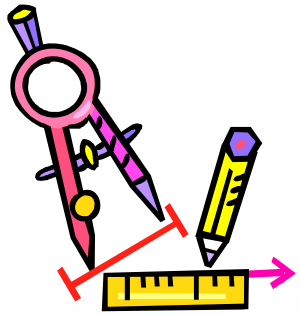
The Benchmarking Process

What is Benchmarking?

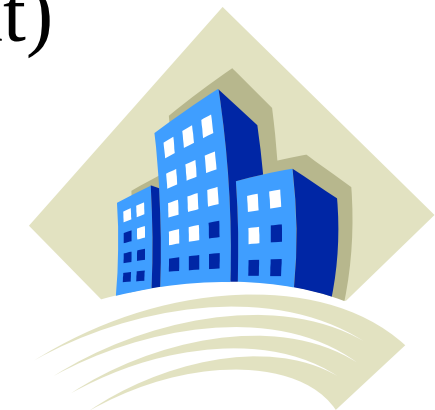


- Major aim of benchmarking: Identify actions to improve performance
  - Identify issues (metrics)
  - Collect internal data (baseline)
  - Collect external data (comparison framework)
  - Analysis
  - Implement change
  - Monitor impact

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?

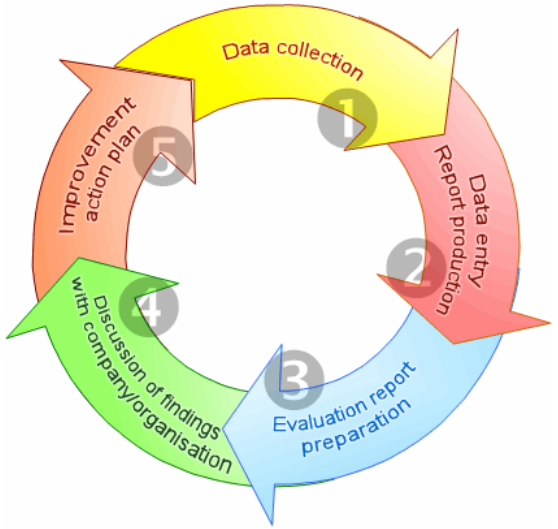
- A tool to help support decisions
  - Is my building using too much energy?
  - How “good” are my buildings?
  - Where are my energy costs going?
  - How am I doing on reaching my goals?
  - Which of my buildings need improved maintenance?
  - Does my building need retrofits?
  - How much should I be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

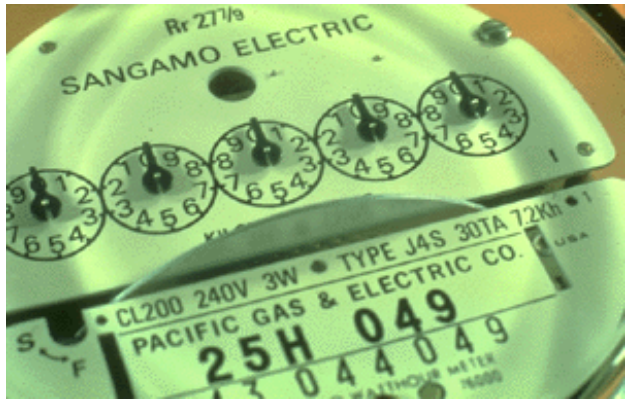


Energy Performance Indicators

- 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

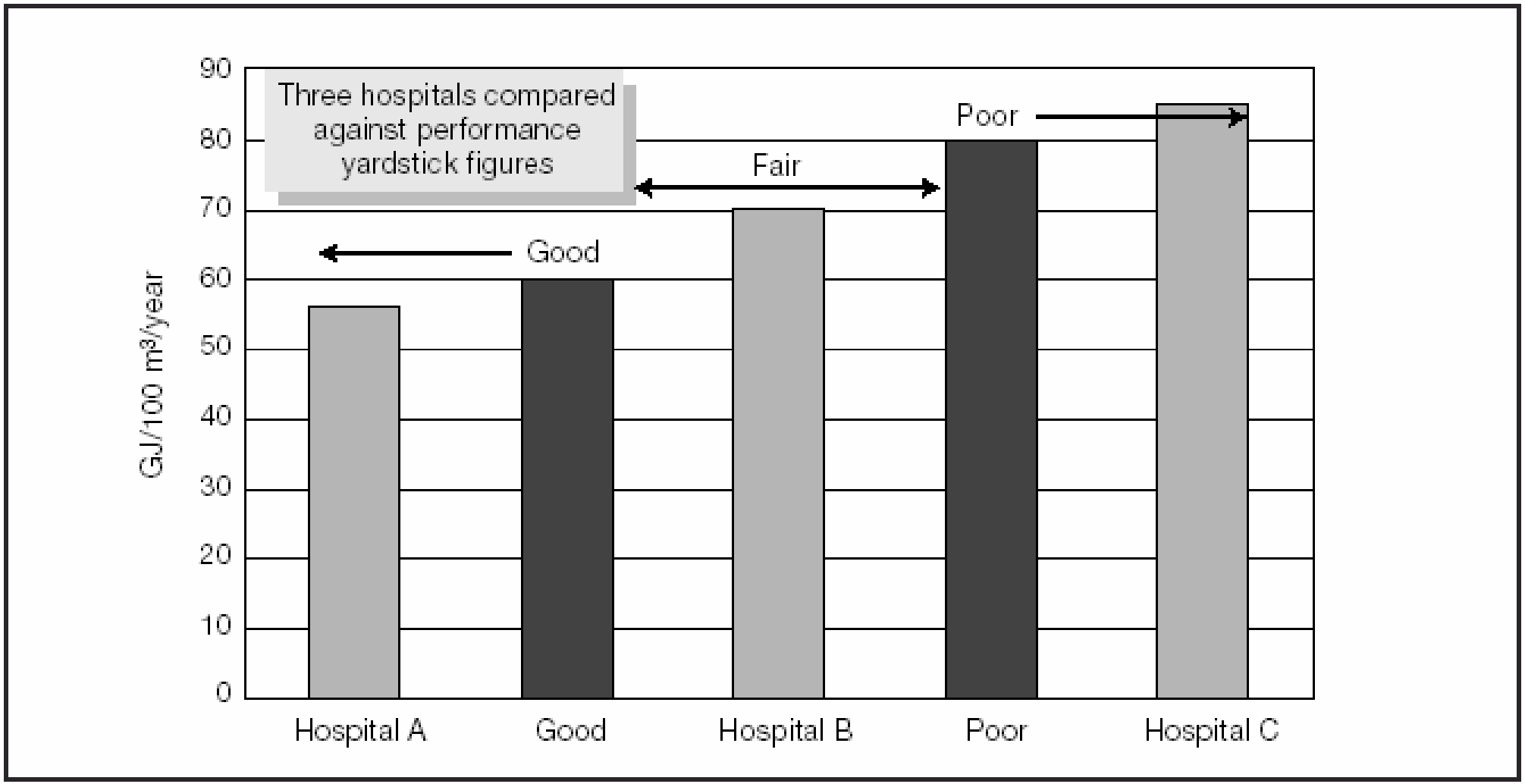
- Building performance metrics
  - Energy cost ($/year, $/month, $/sq.m)
  - Energy use (kWh/year, kWh/month, kWh/sq.m)
  - Normalized for:
    - Number of days in reading
    - Weather
    - Operating hours
  - Segregated for other drivers:
    - Such as data centres, kitchens



Energy Performance Indicators

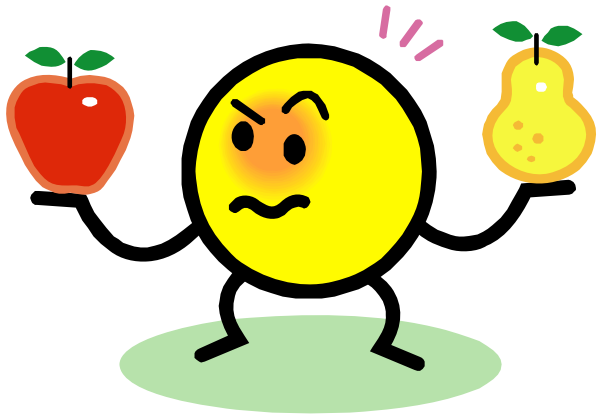
- Energy Utilization Index (EUI)
  - Represent actual energy use; no adjustments or correction factors, site or source energy
- Normalised Performance Indicator (NPI)
  - For buildings, calculated annually – **kWh/m^2/year**
    - Total annual energy consumption / floor area
    - Normalised for operating 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)



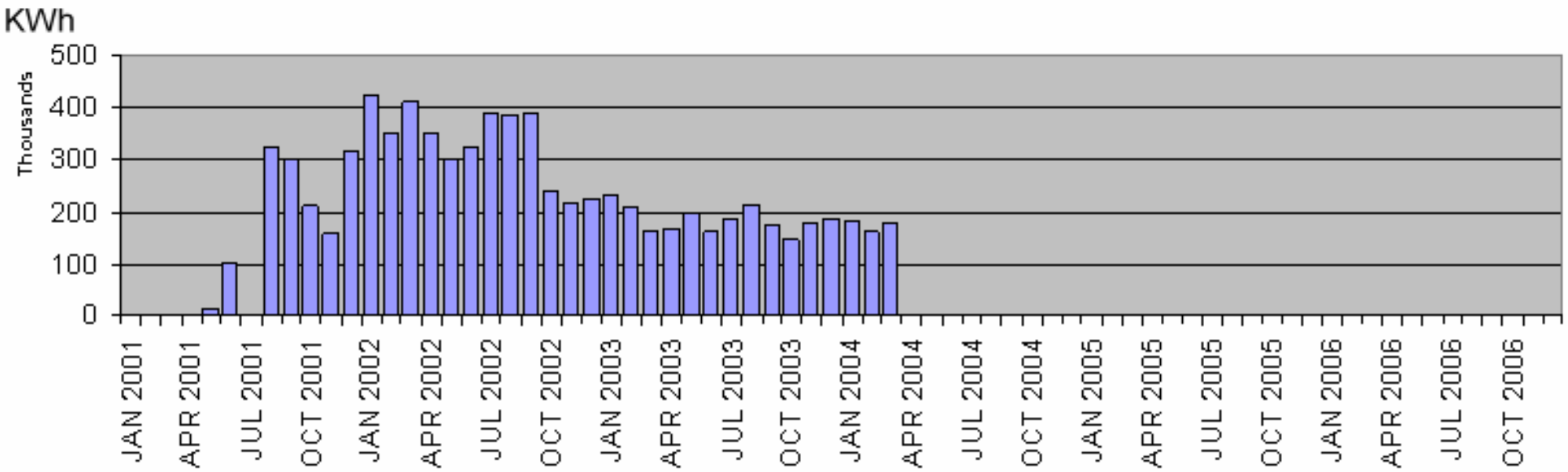
Energy Performance Indicators

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



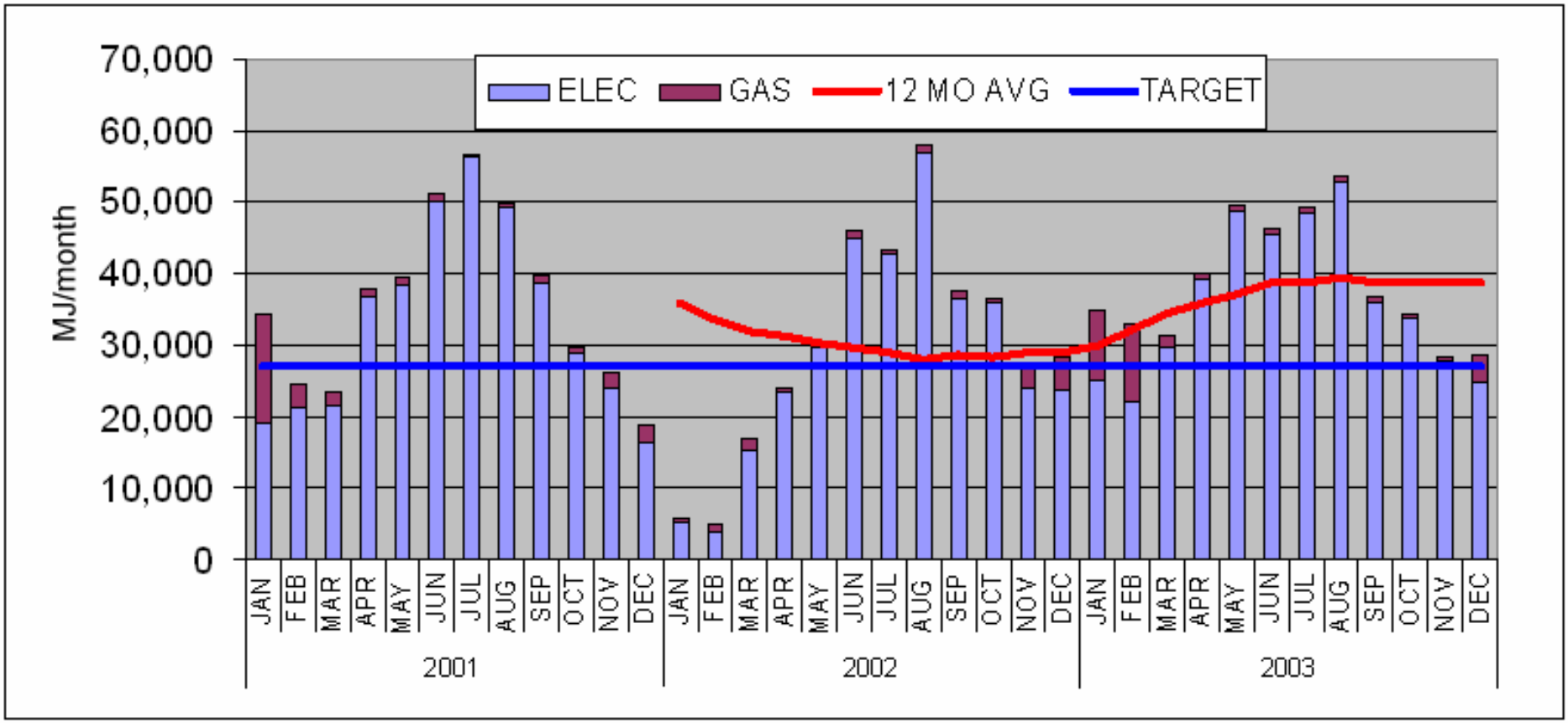
Energy Performance Indicators

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



Energy Performance Indicators

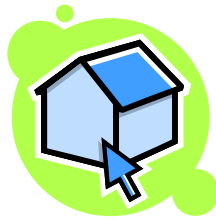
- Benchmarking on expectations
  - Setting targets



Energy Performance Indicators

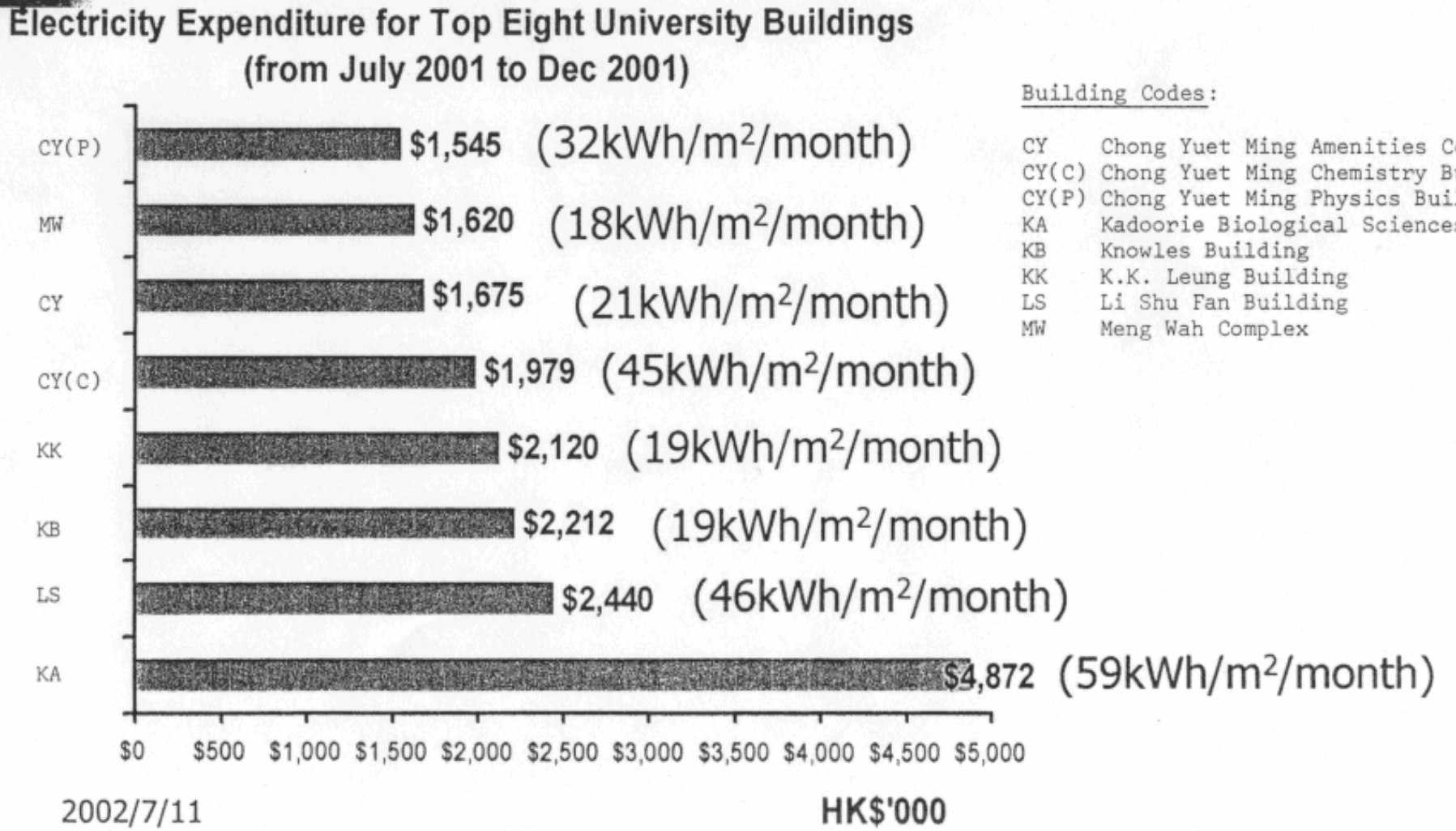
- Compare to other buildings: the ideal benchmark
  - Comparing to comparable buildings:
    - Climate/location, size, building type
    - Activities, end uses, occupancy
    - Operation and maintenance
  - Not easy to find such an ideal benchmark
  - Normalized for anything you don’t have control over

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



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

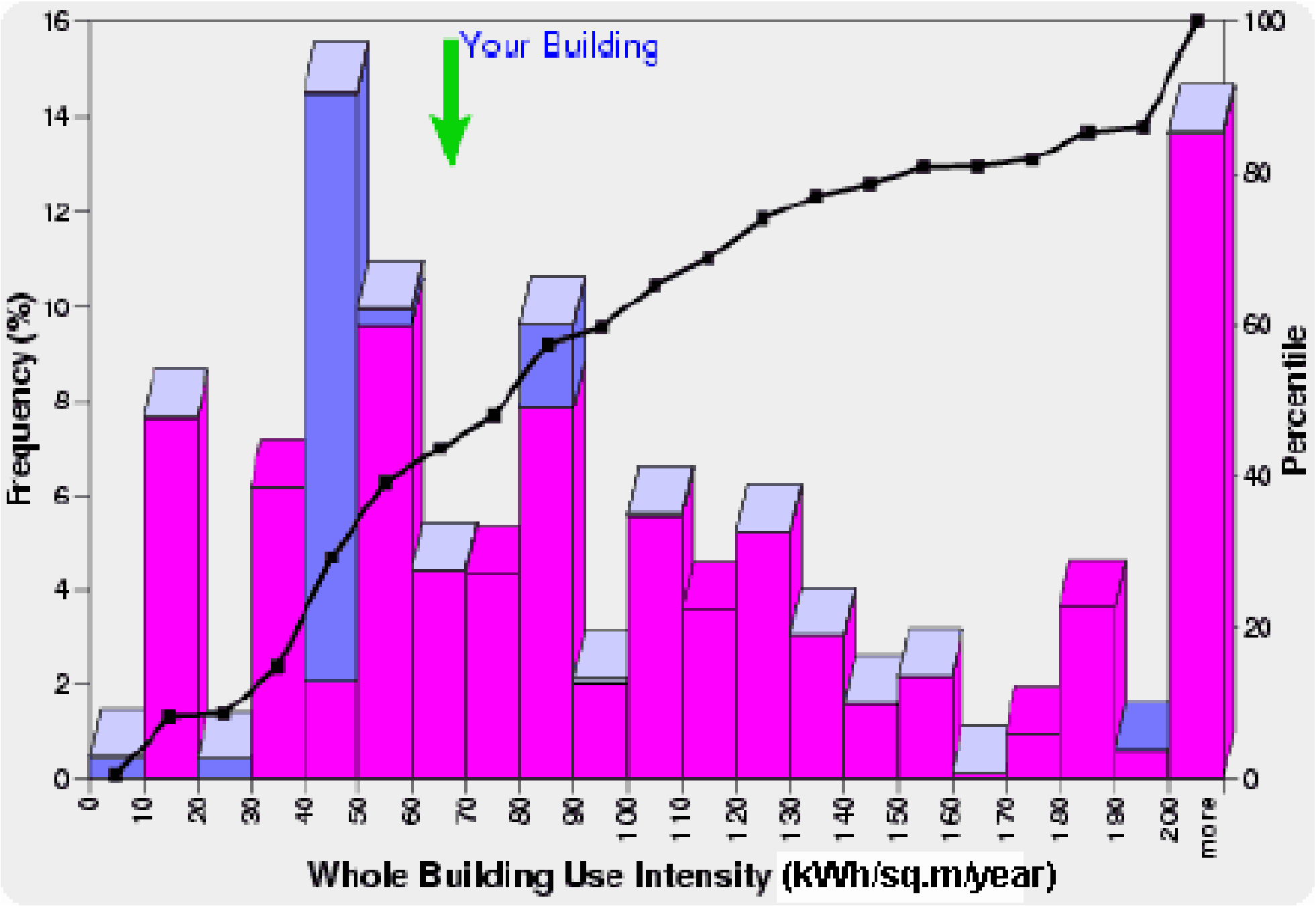
Appendix II

[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

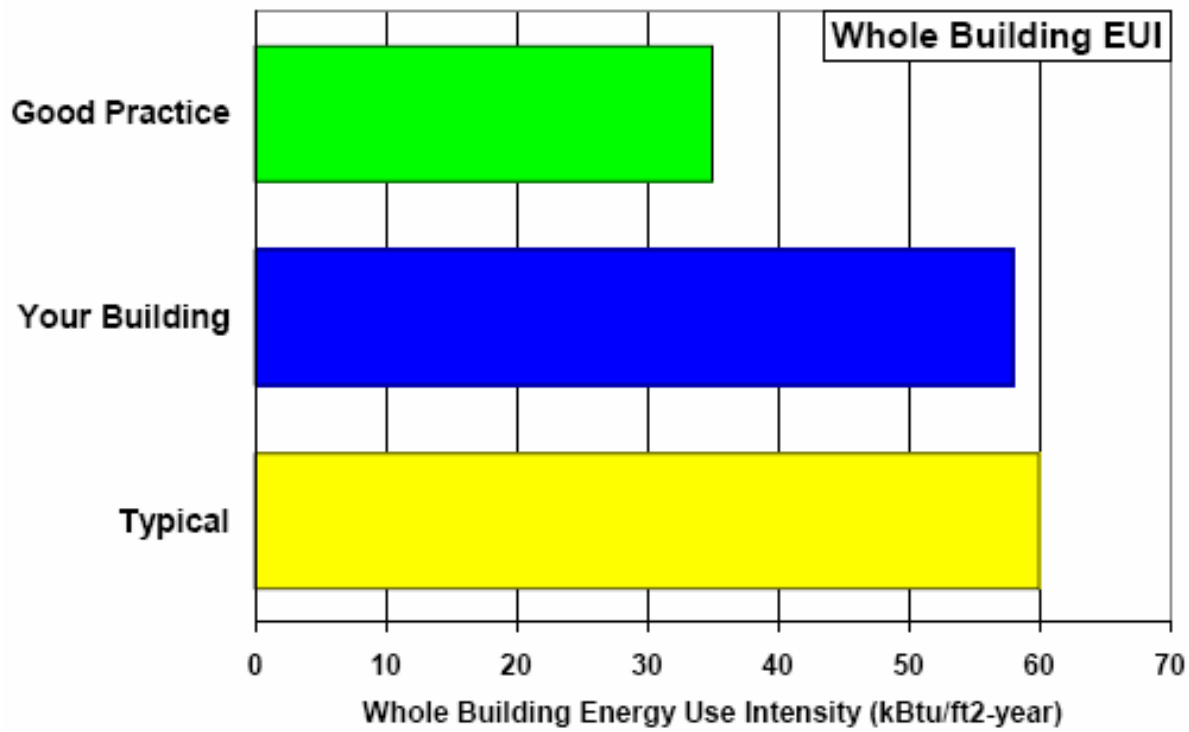
Histogram of building energy use intensity



[Source: www.energy.ca.gov/pier]

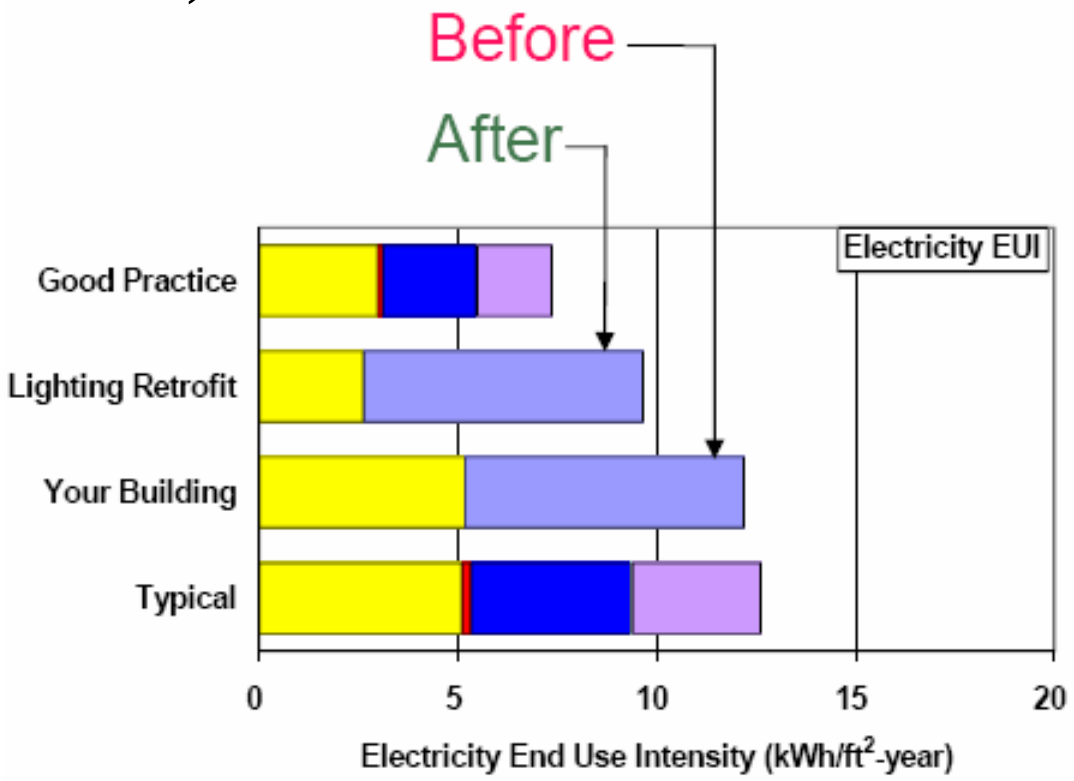
Energy Performance Indicators

- 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

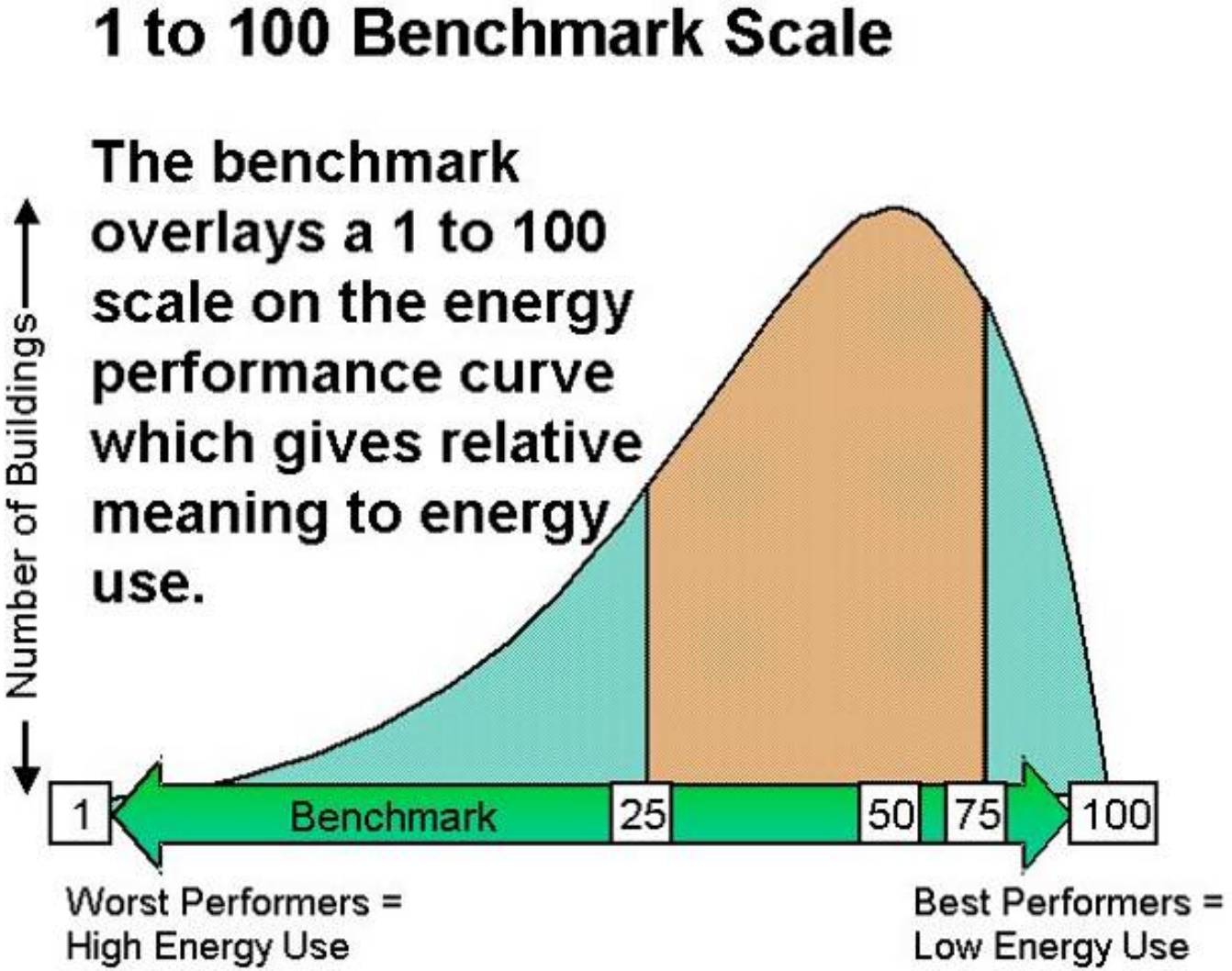
- Energy Star Benchmarking (USA)
  - Developed by US-EPA and US-DOE
  - Based on the USA's Commercial Building Energy Consumption Survey (CBECS) data
    - Using regression models
  - Applied across the nation in USA
  - Energy Star Label for Buildings
  - Normalized for climate, schedules, occupancy, 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

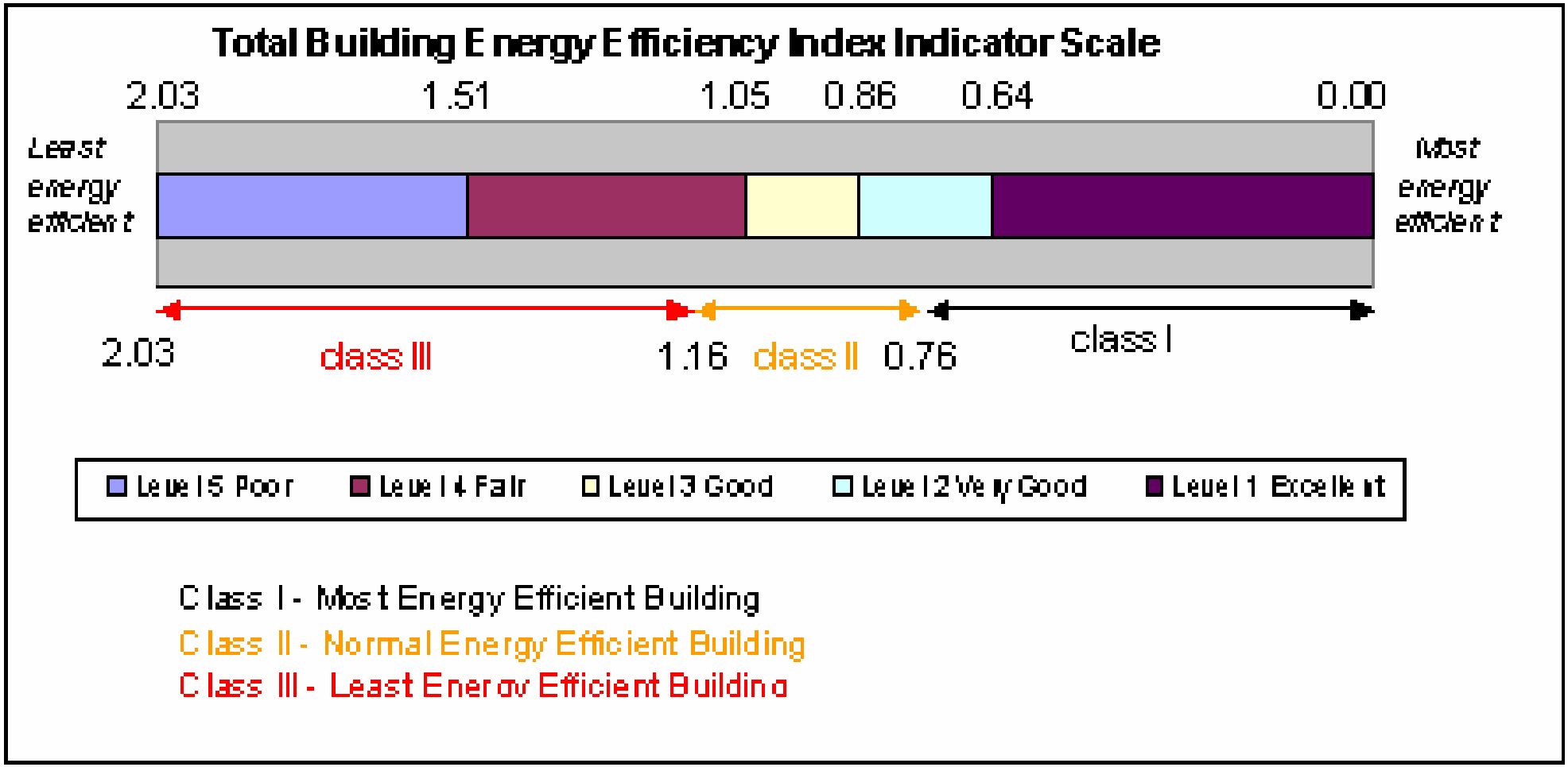
Buildings that rate in the top 25% of energy-efficient buildings in USA

http://www.energystar.gov/



Practical Applications

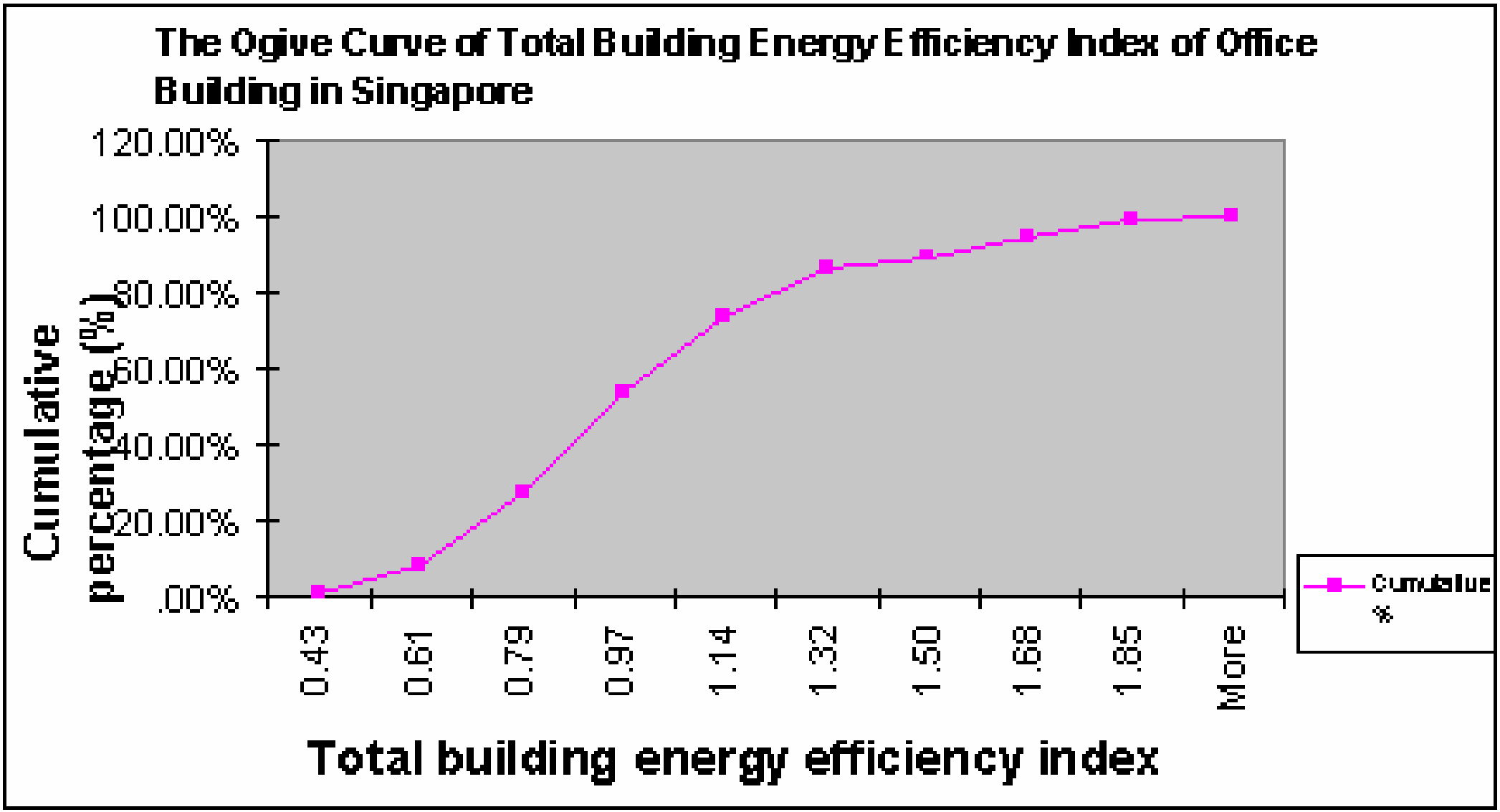
- Building energy benchmarks in Singapore
  - e-Energy (by BCA-NUS Building Energy & Research Information Centre
    - http://www.bdg.nus.edu.sg/buildingEnergy
  - Benchmarking Tools
    - Questionnaires
    - Energy Audit Online
  - For offices, shopping centres and hotels
    - Divided into 3 parts: Total, Landlord and Tenant



Degree Level of Standard	Description Assessment	Total Building Energy Performance Indicator	Total Building Energy Efficiency (kWh/year/m^2)
Level 1	Excellent	0.64>or = Level 1	147.74 >or = Level 1
Level 2	Very Good	0.86> Level 2 >0.64	197.92 >Level 2> 147.74
Level 3	Good	1.05>Level 3>0.84	243.14 > Level 3 > 197.92
Level 4	Fair	1.51>Level 4> 1.05	348.35> Level 4 > 243.14
Level 5	Poor	2.03< or> Level 5 >1.51	469.56 < or > Level 5 >348.350

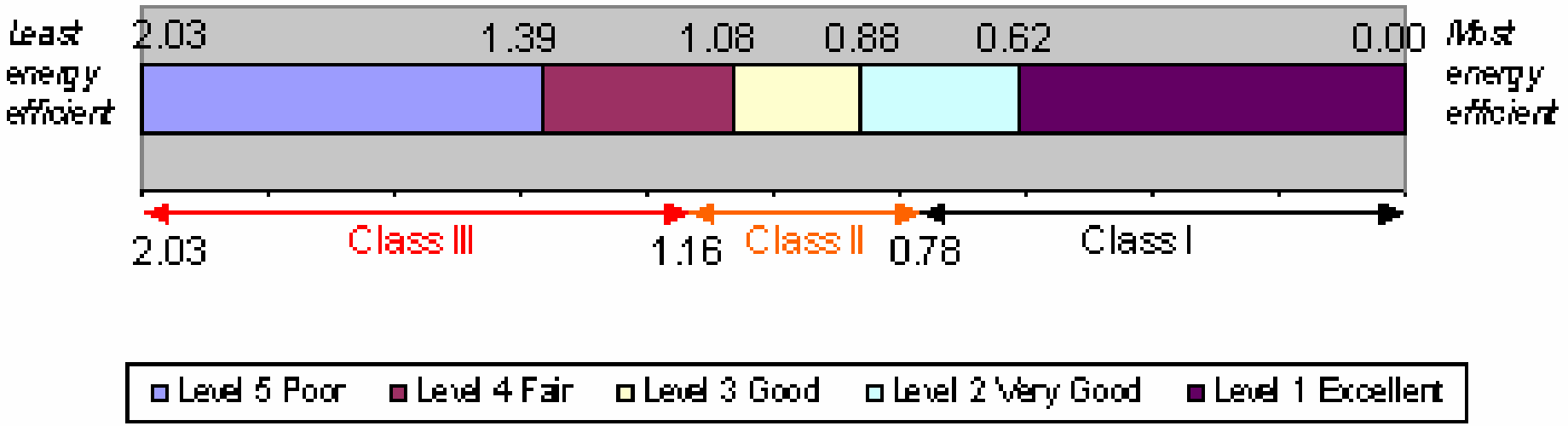
Class Groups	Classification Nomenclature	Total Building Energy Efficiency Indicator	Total Building Energy Efficiency (kWh/year/m^2)
Class I	Most energy efficient building	0.76> Class I	175.83 > Class I
Class II	Normal energy efficient building	1.16> Class II > 0.76	268.23 > Class II > 175.83
Class III	Least energy efficient building	2.03< or > Class III > 1.16	469.56 < or > Class III > 268.23

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



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

Landlord Building Energy Efficiency Index Indicator Scale

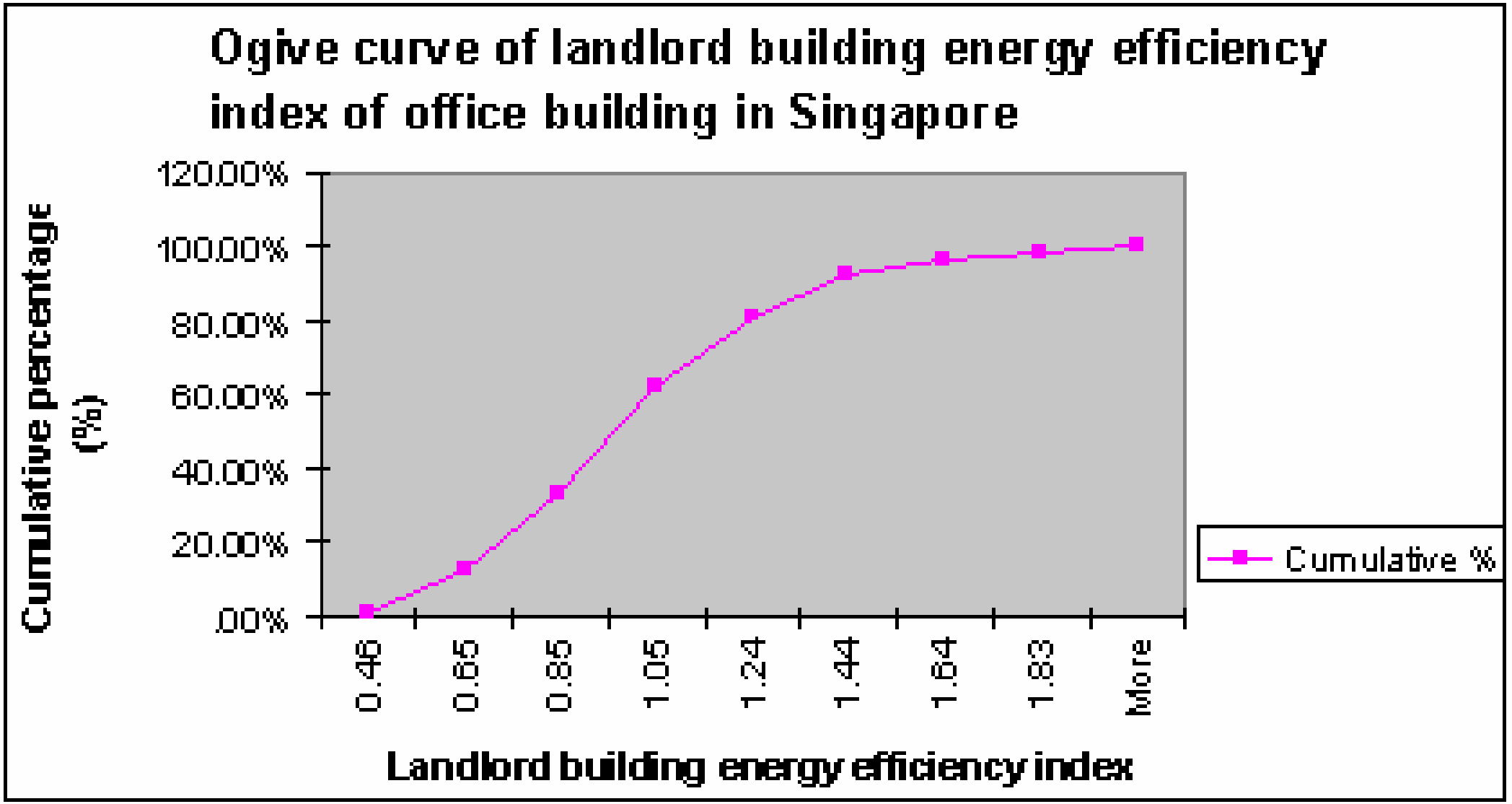


Class I - Most energy efficient building
Class II - Normal energy efficient building
Class III - Least energy efficient building

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

Class Groups	Classification Nomenclature	Landlord Building Energy Efficiency Indicator	Landlord Building Energy Efficiency (kWh/year/m^2)
Class I	Most energy efficient building	0.78 > Class I	113.26 > Class I
Class II	Normal energy efficient building	1.16> Class II > 0.78	167.36 > Class II > 113.26
Class III	Least energy efficient building	2.03< or> Class III > 1.16	293.82< or > Class III> 167.36

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



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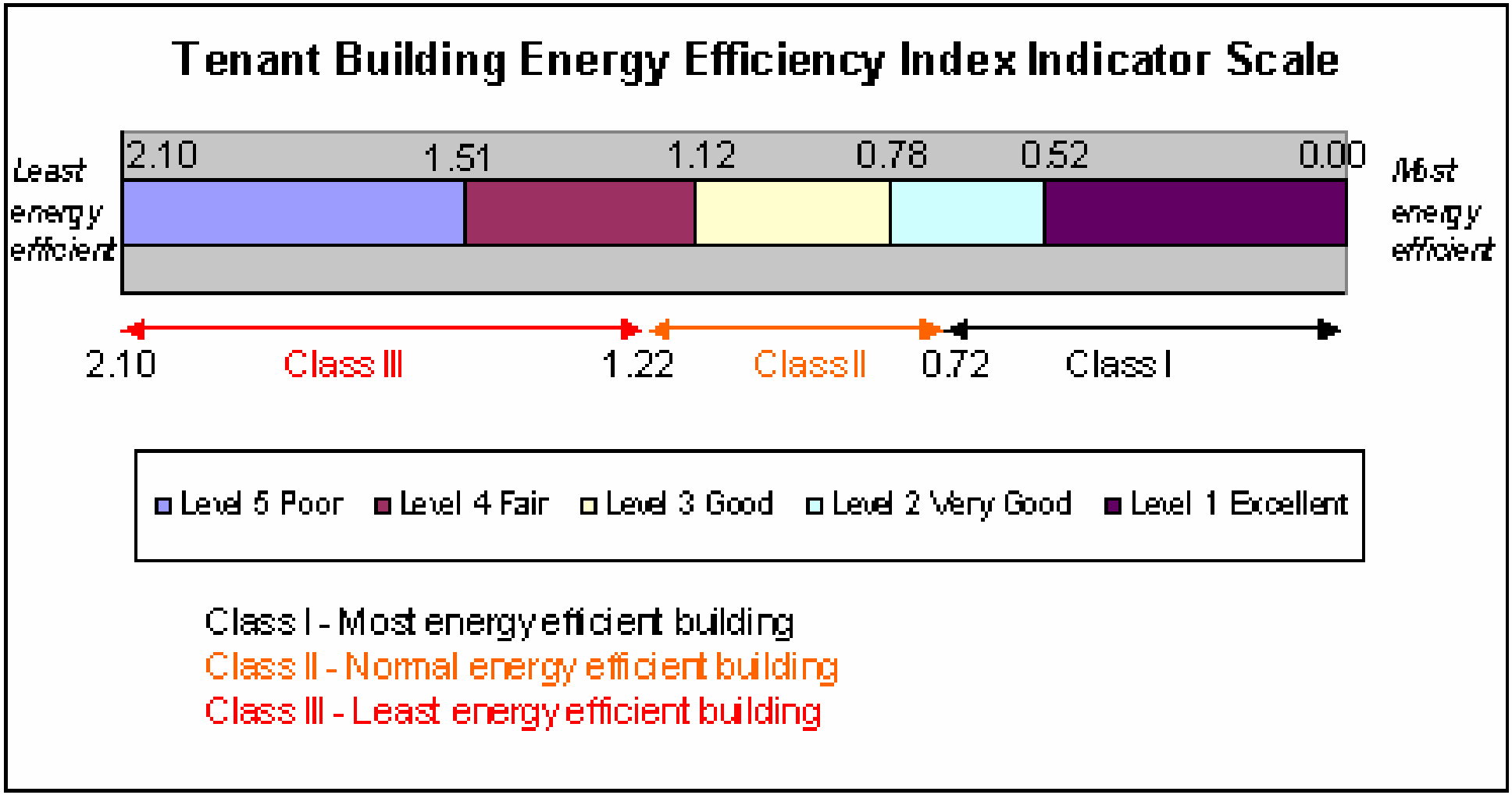
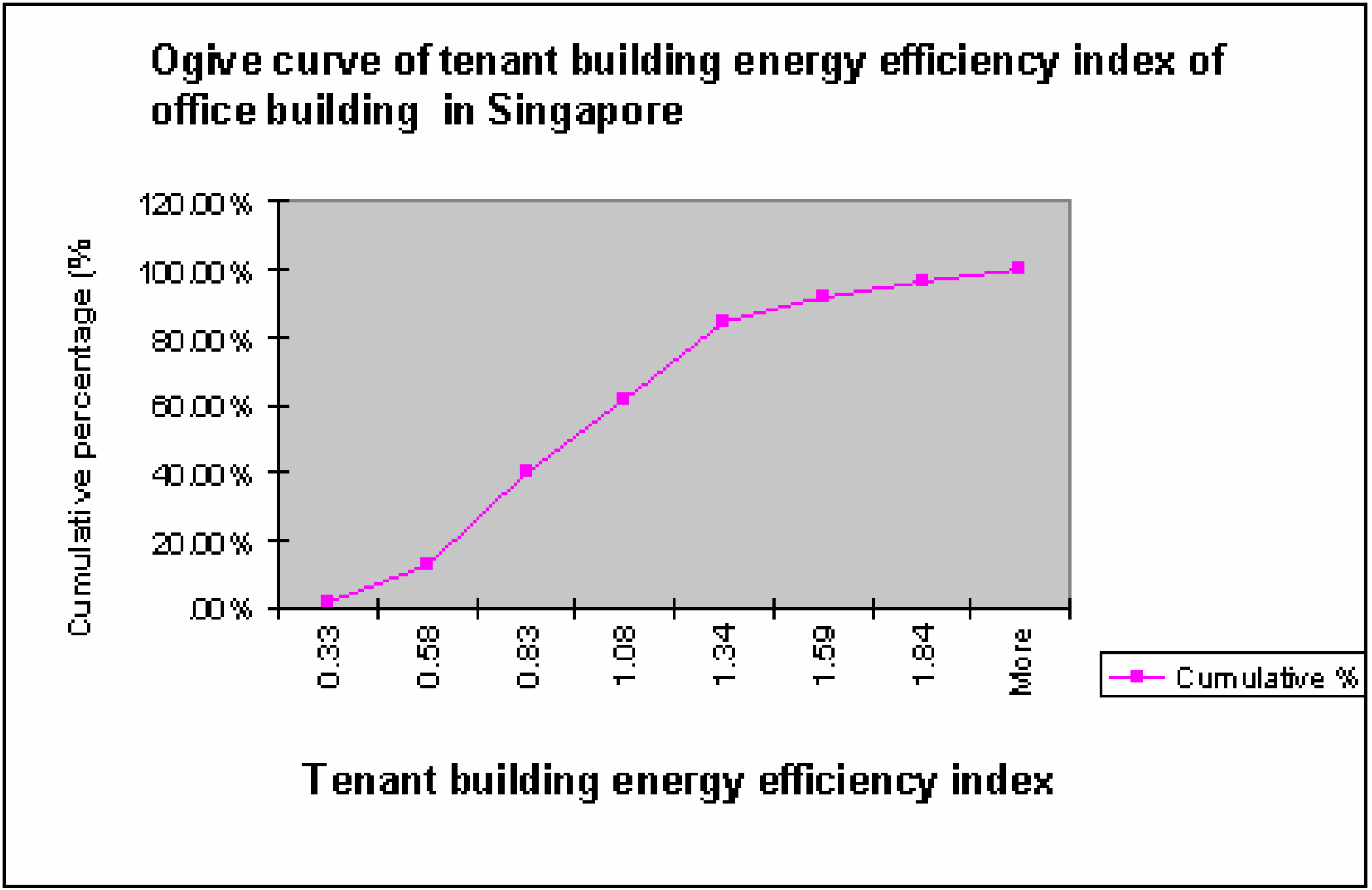


Degree level of standard	Description assessment	Total building energy performance indicator	Total building energy efficiency (kWh/year/m2)
Level 1	Excellent	0.52 > or = Level 1	70.17 > or = Level 1
Level 2	Very Good	0.78 > Level 2 > 0.52	105.87 > Level 2 > 70.17
Level 3	Good	1.12 > Level 3 > 0.78	152.38 > Level 3 > 105.87
Level 4	Fair	1.51 > Level > 1.12	205.98 > Level 4 > 152.38
Level 5	Poor	2.10< or > Level 5 > 1.51	284.90 < or > Level 5 > 205.98

Class groups	Classification Nomenclature	Tenant building Energy Efficiency Indicator	Tenant building Energy Efficiency (kWh/year/m^2)
Class I	Most energy efficient building	0.72 > Class I	97.98 > Class I
Class II	Normal energy efficient building	1.22> Class II > 0.72	165.84 > Class II > 97.98
Class III	Least energy efficient building	2.10< or> Class III > 1.22	284.90 > Class III > 165.84

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

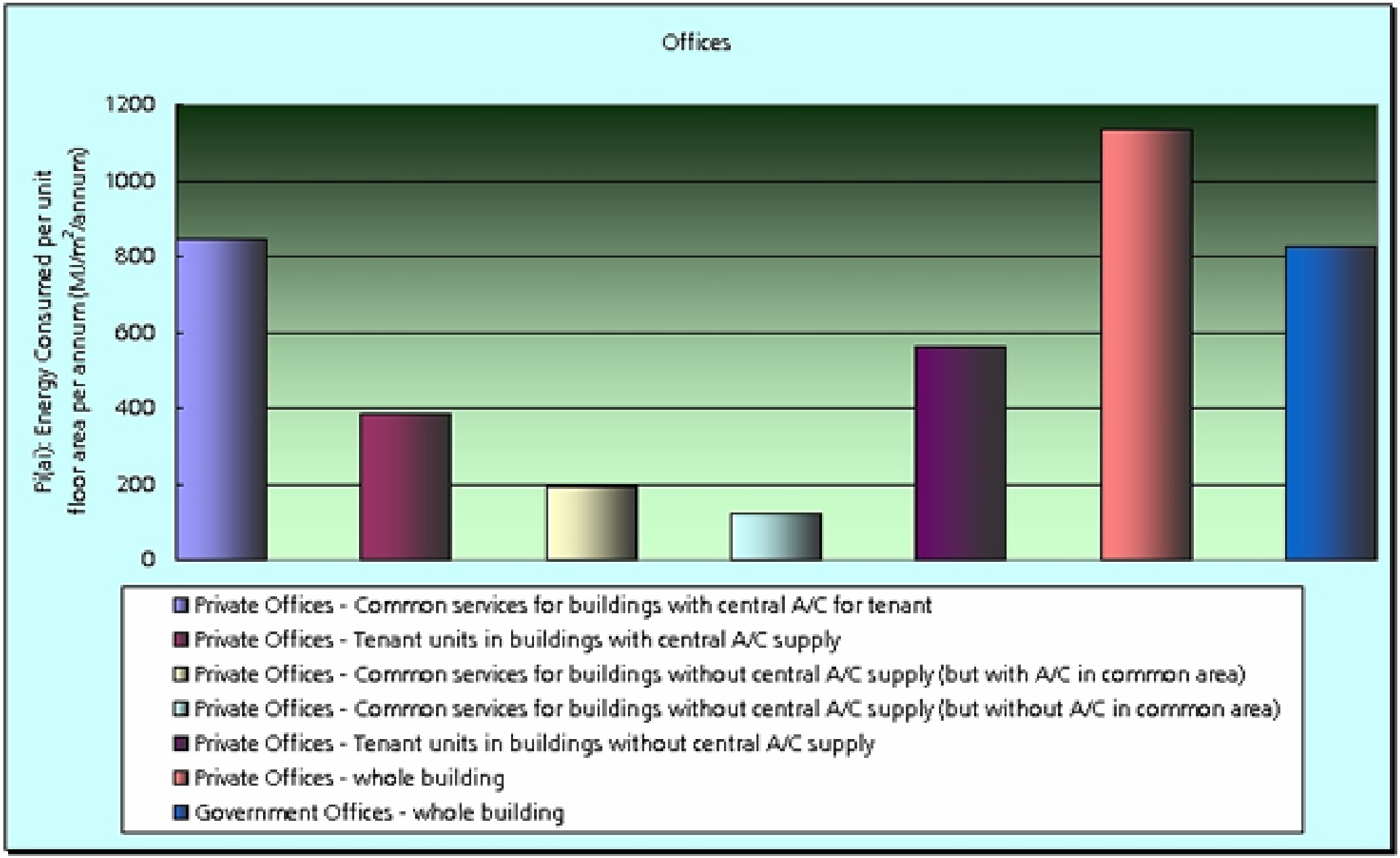


[Source: www.bdg.nus.edu.sg/buildingEnergy]

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

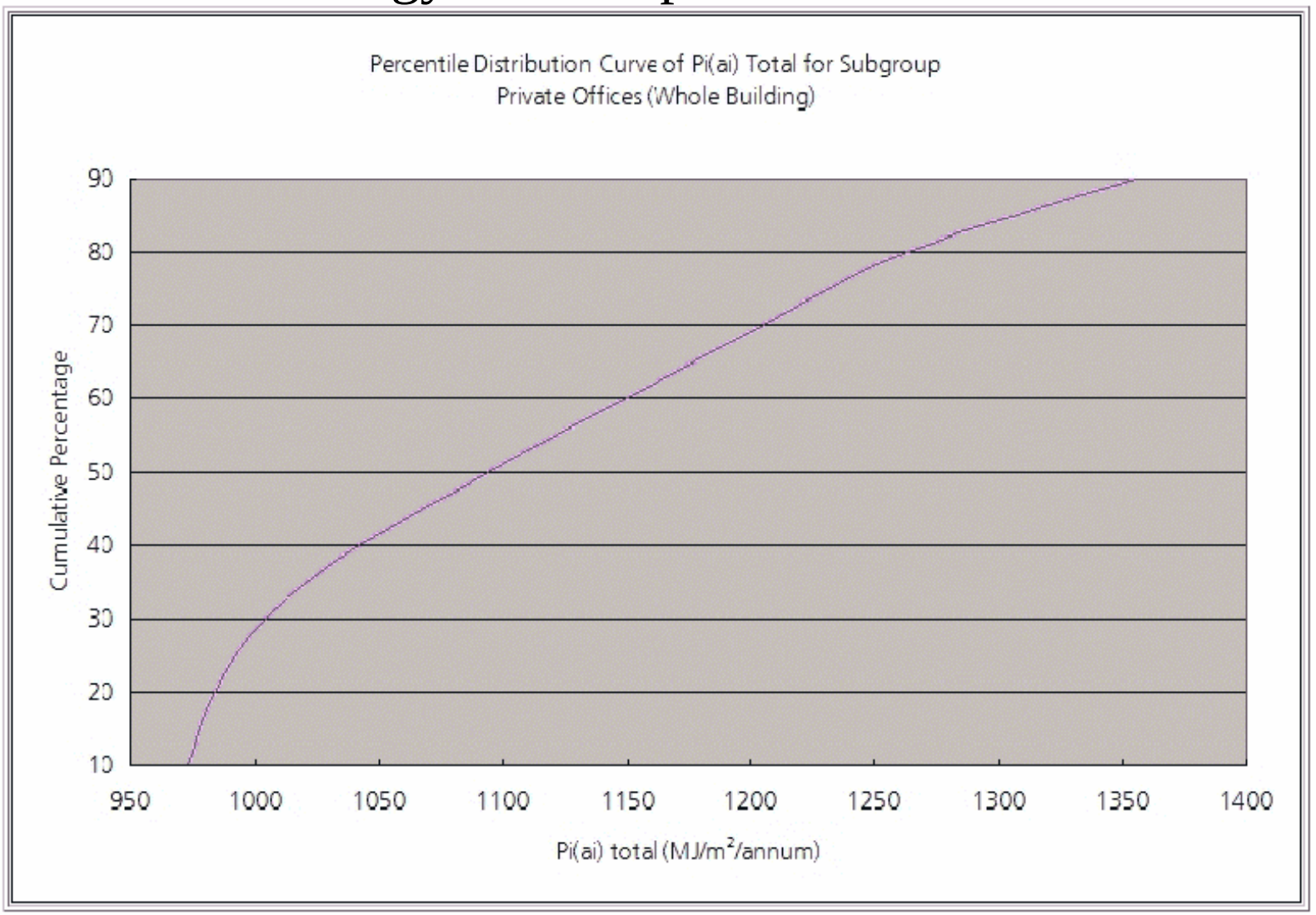


[Source: www.emsd.gov.hk]

Principal Group	Subgroups	Indicator PI(ai): Energy consumed per unit floor area per annum (MJ/m^2/annum)	Detail benchmarks
Private Offices	Common services for buildings with central A/C for tenant	848	Benchmarks
	Tenant units in buildings with central A/C supply	385	Benchmarks
	Common services for buildings without central A/C supply (but with A/C in common area)	192.3	Benchmarks
	Common services for buildings without central A/C supply (but without A/C in common area)	122.3	Benchmarks
	Tenant units in buildings without central A/C supply	561	Benchmarks
	Private Offices (whole building)	1132	Benchmarks
Government Offices	Government Offices (whole building)	826.5	Benchmarks

[Source: www.emsd.gov.hk]

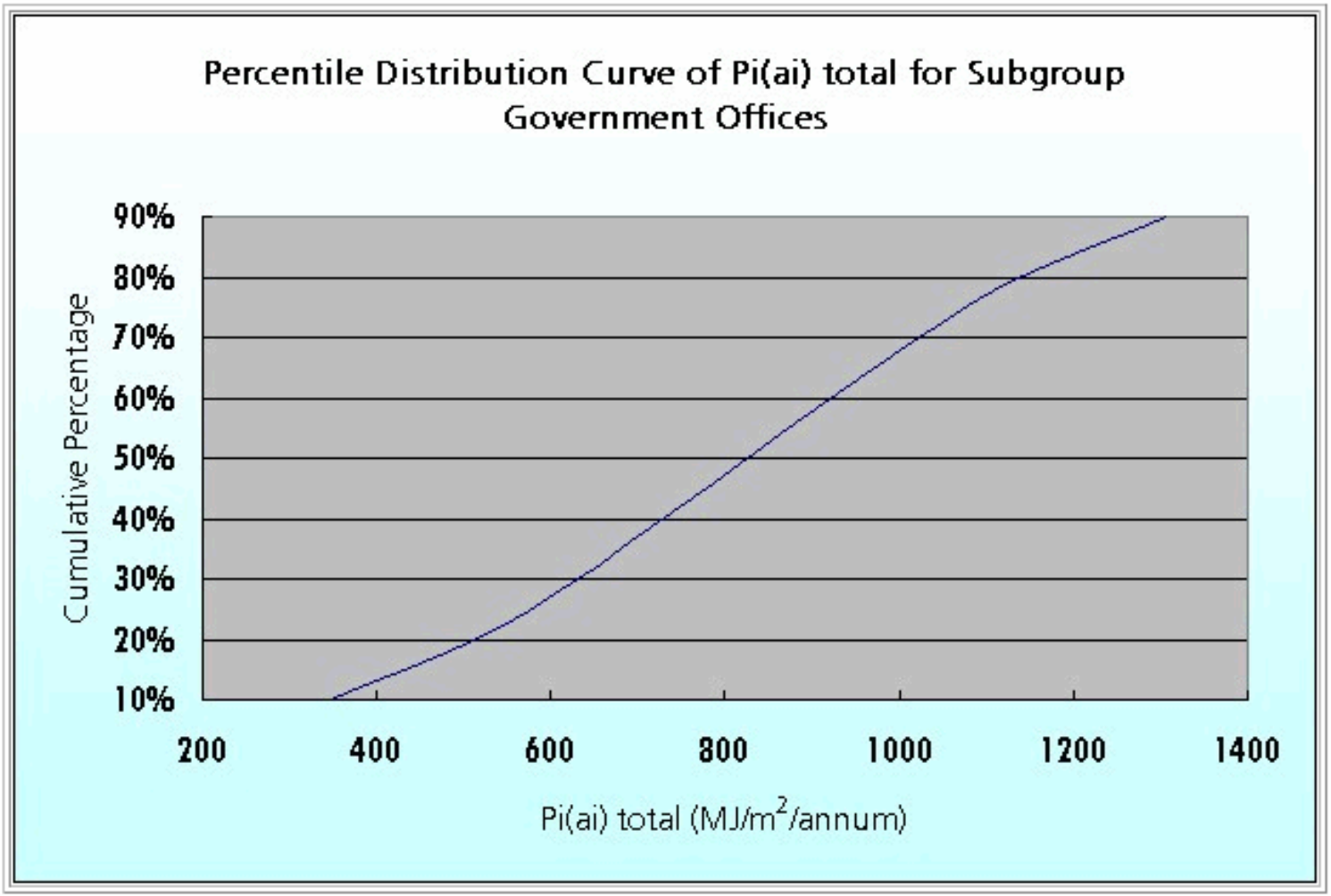
Energy Consumption Benchmark



The 10th , 30th , 50th , 70th and 90th percentile benchmarks are :				
10^{th}	30^{th}	50^{th}	70^{th}	90^{th}
973 MJ/m^2/annum	1004 MJ/m^2/annum	1094 MJ/m^2/annum	1205 MJ/m^2/annum	1355 MJ/m^2/annum

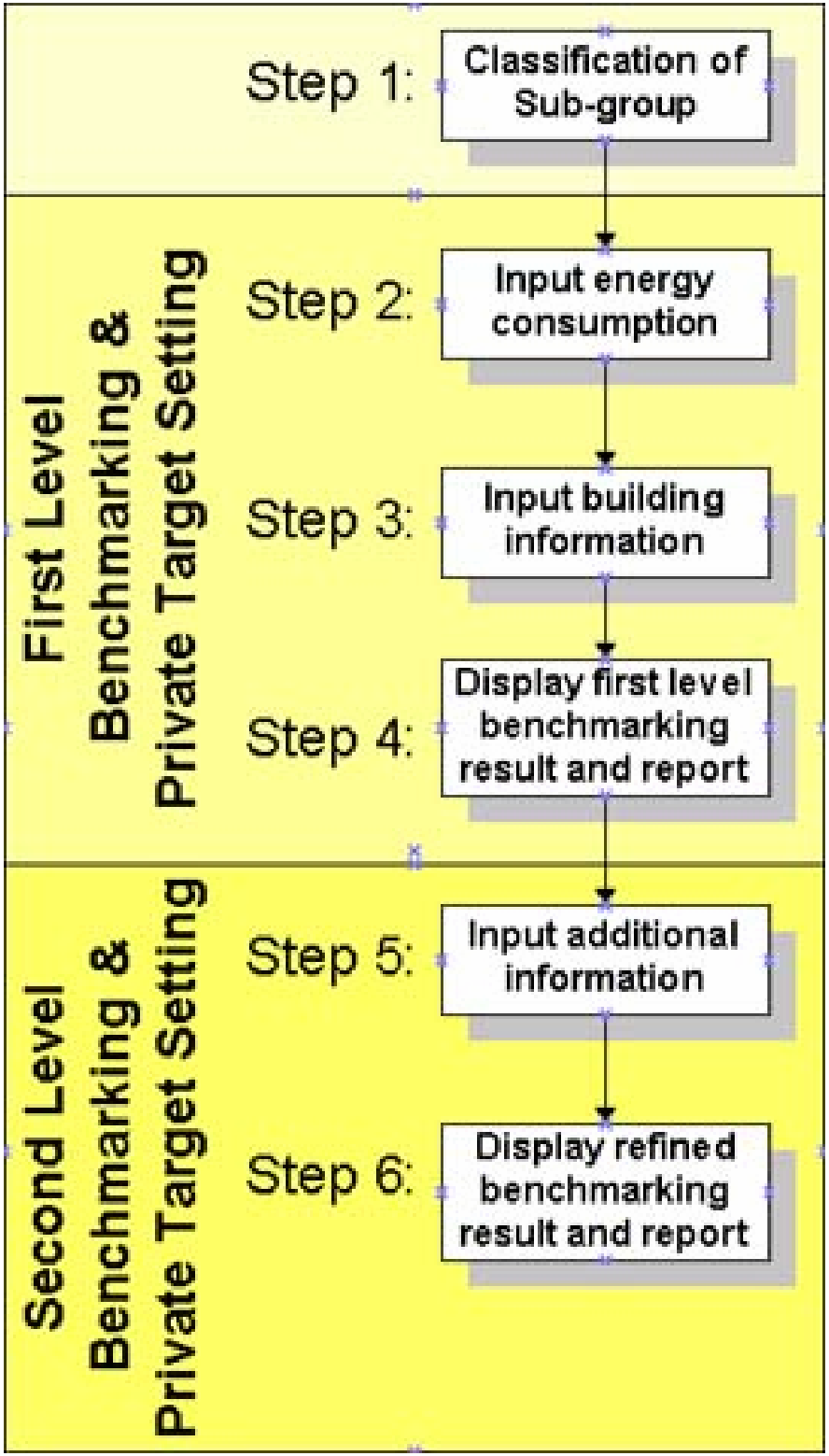
[Source: www.emsd.gov.hk]

Energy Consumption Benchmark



The 10 th, 30 th, 50 th, 70 th, 90 th percentile benchmarks are				
10 th	30 th	50 th	70 th	90 th
346.56 MJ/m^2/annum	630.11 MJ/m^2/annum	826.50 MJ/m^2/annum	1022.89 MJ/m^2/annum	1306.44 MJ/m^2/annum

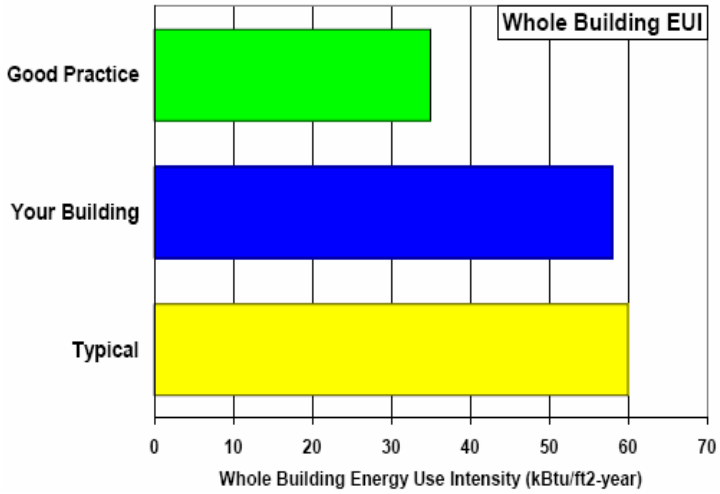
[Source: www.emsd.gov.hk]



[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

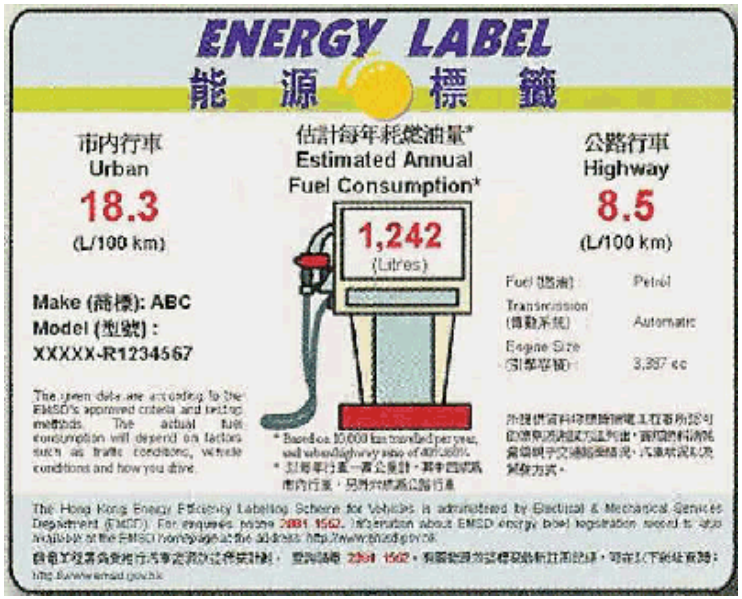
- Future prospects
  - Energy label & certification of buildings
    - For new buildings: specify energy performance baseline (allow people to know & compare)
    - For existing buildings: upgrade to meet the building energy codes (during retrofits)
  - Offer suggestions for improvement (simple actions,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

Examples of energy efficiency labels in Hong Kong

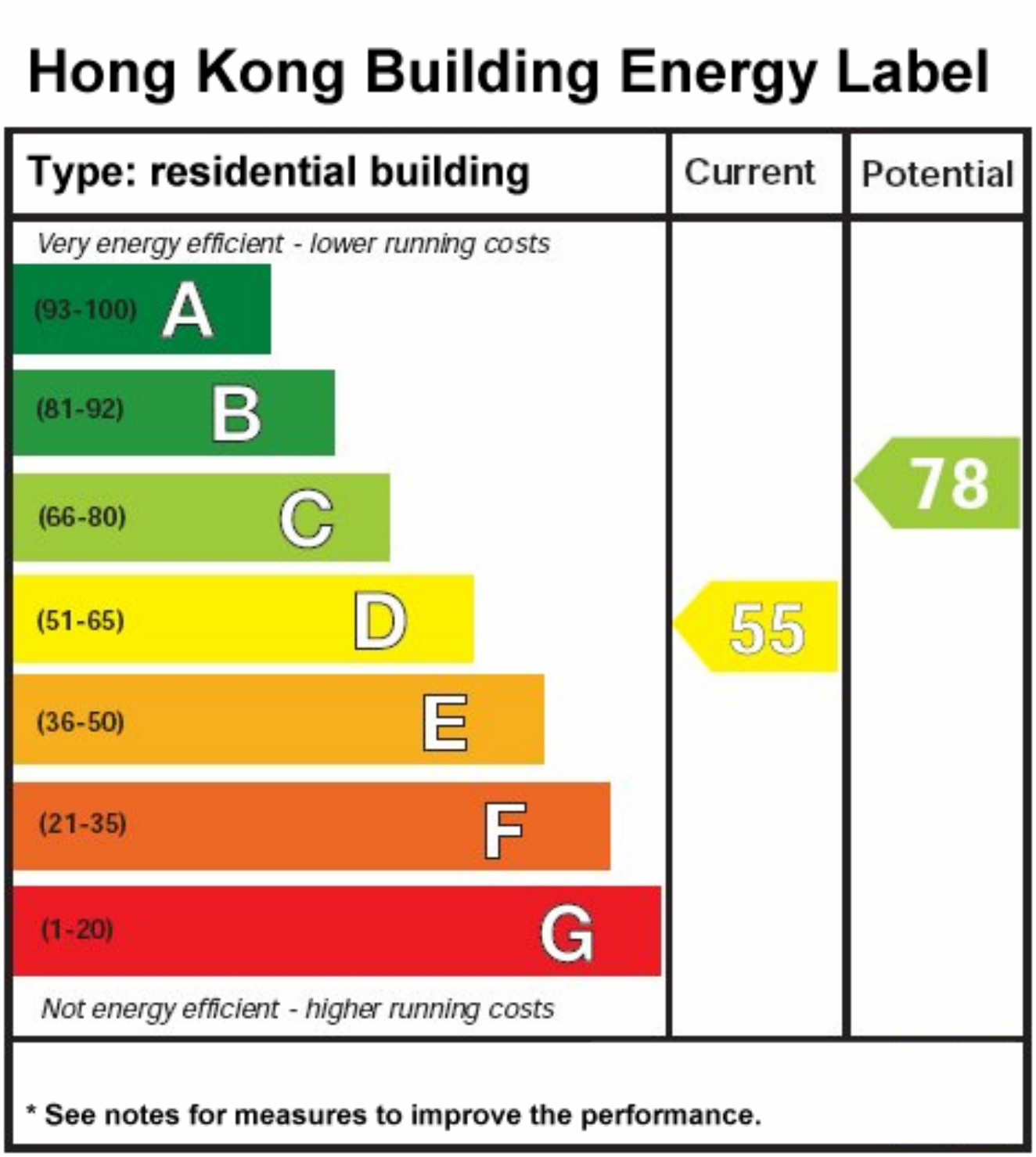
Energy label for appliance (grading-type)

Energy label for appliance (recognition-type)

Energy label for passenger car

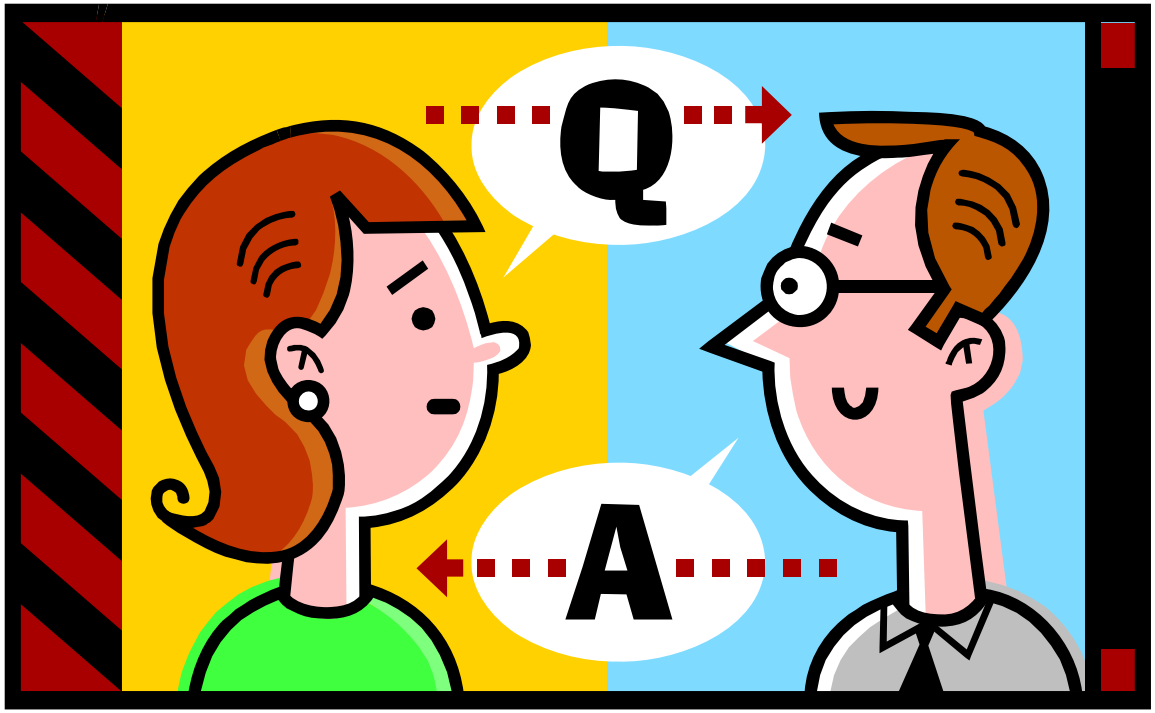


(Source: www.emsd.gov.hk)



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