EC-ASEAN Energy Facility (EAEF)

Projects 64 and 68
2nd Meeting

Development of a Comprehensive Database for Building Energy Performance Benchmarking in the ASEAN Region

– First results

Sun Hansong (M. Sc)

Energy Sustainability Unit

National University of Singapore

Agenda

1. Sample frame
2. Manageable and unmanageable factors
3. Primary filters
4. Data validity test
5. Parameter analysis and normalization strategy
6. First benchmark result
7. Refinement of data collection forms and terminology
8. Further work

Sample frame

Before applying any filtering criteria, the initial sample involved 107 buildings (3 new buildings in addition to previous 104 buildings) in Singapore. However, 7 buildings were rejected due to the lack of tenants' energy consumption data.

The sample is found to be representative of the entire building stock in Singapore, as it covers a wide spectrum of each building parameter.

Sample frame

- Building age: 1 to 79 years (with respect to 1999)
- Proportion of public and private office buildings: 56% vs. 44%
- Building use pure office and office cum retail: 56% vs. 44%
  Gross floor area: 1021 to 135631 m^2 (excluding car park)
- Number of storey: 1 to 66 storey above ground
- Energy usage intensity (EUI): 103 to 428 (kWh/ m2/year)

Manageable parameters

Manageable factors refer to those can be optimized by building designer, contractor, operator and occupants during various stages of the entire building life cycle, which comprises of design, construction, commission, occupation, operation and maintenance, as well as retrofitting.

Such factors can be:

- **Type of façade, WWR, OTTV, shading device**
- **Indoor environment setting points, i.e. temperature and RH**
- **Type of HVAC system, ratio of over-sizing**
- **Percent of use of systems during off-hours**

Manageable parameters

- Energy management strategy and control system
- People behavior factor
- Presence of energy and cost saving measures
- Use of energy efficient PC and office equipment
- Percent lit by fluorescent

@ Where energy and cost saving potential and measures should be sought from.

Unmanageable parameters

Unmanageable factors refer to those cannot or hard to be optimized by building designer, contractor, operator, and occupants during various stages of the entire building life cycle, which comprises of design, construction, commission, occupation, and operation and maintenance, as well as retrofitting.

Such factors can be:

- **Geographical location of building**
- **Climatic conditions**
- **Type of building, e.g. office, hotel, hospital, shopping mall, etc.**
- **Type of main HVAC, e.g. central system, stand-alone, MV, natural vent.**

Unmanageable parameters

- Building usage (for individual building type), e.g. pure office and office (primary function) with secondary functional area such as retail, restaurant, supermarket, labs or large data centre.
- Building ownership, i.e. sole owner occupied, tenanted or mixed with owner and tenants. (This group of factors have influence on landlords' benchmarking results)
- Standards to which building and its services are designed or offered

Unmanageable parameters

- Gross floor area
- Building age
- Floor vacancy rate (%)
- Building operating schedule. However this may also be manageable
- # of occupants, # of office equipment
- # of storey
- % of retail area, % of ACA, % of GLA, % of car park, % of data centre

@ These are potential areas/ parameters for which normalization factors maybe considered during the benchmarking process.

Primary filters

Parameters	Abbreviation	Filtering criteria
Building location	LOC	Singapore
Type of building	TB	Commercial office buildings
Type of main HVAC	HVAC	Central air conditioning
Building age	BA	<= 25 years
Gross floor area	GFA	>=1000 m^2, air conditioned and excluding car park area
Vacancy rate of gross office area	FLOCR	<= 30% during last 12 months
Occupant density	OCDEN	0.3 to 10 persons/ 100 m^2
Weekly operating hours	WKHRS	>=44 and <= 75 hours/ week
No. of computers	COMNUM	>=0
% of gross lettable area	GLA/ GFA	>50% and <100%
% of air conditioned area	ACA/ GFA	>50% and <= 100%
% of common area	CA/GFA	> 0 %
% of retail area	RETA/ GFA	<= 10 %. If >10 %, correction factor will be applied.
% of data centre area	DCA/GFA	<= 0.24%. If >0.24%, correction factor will be applied.
% of car park area	CPA/GFA	<= 8% above ground, <=5% below ground, otherwise correction factor will be applied.

Primary filters

After applying those filtering criteria, 5 buildings were eliminated.

Among those one was because the majority of the building is not commercial office space and not really central air conditioned especially the second floor, and 4 buildings were eliminated because of high floor vacancy rate (above 30%).

As a result, information of 95 building was used for the parameter analysis and development of benchmark

However, the analysis highlighted that there are possible errors relating to the accuracy of some parameters.

Data validity test

Integrity and normality test

Parameter analysis and normalization

Normalization strategy

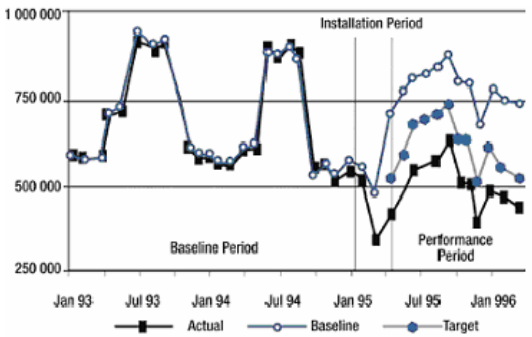
1. Weather normalization of energy consumption
2. Primary determinant factors
3. Correction factors
4. Secondary determinant factors

Normalization factors

1. Weather normalization of energy consumption

To answer the questions:

1. Whether one year energy data can really represent building's energy consumption and performance, if there was extreme weather condition occurred during the year of data collection?



Baselining

2. How to compare the energy performance of buildings locating at different cities or countries under different climatic conditions, assuming building designs are similar?

Normalization factors

2. Primary determinant factors (i.e. GFA & Occupied GFA)

Simple linear regression (95 buildings)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.949[a]	.900	.899	2236306.342	.900	837.450	1	93	.000

a. Predictors: (Constant), Gross floor area

b. Dependent Variable: TBEC

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.950[a]	.902	.901	216930.626	.902	853.785	1	93	.000

a. Predictors: (Constant), Occypied GFA=GFA-(GLA-NLA)

b. Dependent Variable: TBEC

Normalization factors

After removing outliers: building ID 38 and 96

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.961[a]	.924	.923	1854233.594	.924	1098.894	1	91	.000

a. Predictors: (Constant), Gross floor area

b. Dependent Variable: TBEC

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.961[a]	.923	.922	863526.948	.923	1087.056	1	91	.000

a. Predictors: (Constant), Occypied GFA=GFA-(GLA-NLA)

b. Dependent Variable: TBEC

Normalization factors

3. Correction factors

EUI-1= TBEC/ GFA

Car park area

EUI-2= TBEC/ (GFA- CPA)

EUI-3= (TBEC- ECCPA) / (GFA- CPA)

Data centre area

EUI-4= (TBEC- ECCPA- ECDC) / (GFA- CPA- DCA)

Where, CPA-- car park area, ECCPA-- car park energy consumption,

DCA-- data centre area, ECDC-- data centre energy consumption

Normalization factors

It suggested that for any cases where above ground car park is higher than 8.5 % of GFA or under ground car park higher than 6% of GFA, car park area should be removed from gross floor area but not necessary for its energy consumption when conduct benchmarking. The error is equal to or below 5%.

Where data centre area occupied more than 0.2% of GFA (excluding car park), data centre's energy consumption need to be removed from the total building energy consumption, but not necessary for its area. The error is equal to or below 5%.

Normalization factors

4. **Secondary determinant factors**

- **Building use**
- **Building age**
- **Floor vacancy rate**
- **Operating hours**
- **# of office equipment**
- **# of occupants**
- **# of storey**
- **% of retail area, % of ACA, % of GLA, % of car park, % of data centre**

Normalization factors

Summary of multiple regression (95 buildings)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.949[a]	.900	.899	236306.342	.900	837.450	1	93	.000
2	.959[b]	.919	.917	021925.825	.019	21.767	1	92	.000
3	.963[c]	.927	.924	936429.468	.007	9.303	1	91	.003
4	.964[d]	.930	.927	899896.208	.004	4.533	1	90	.036

a. Predictors: (Constant), Gross floor area

b. Predictors: (Constant), Gross floor area, BU (office or office cum retail)

c. Predictors: (Constant), Gross floor area, BU (office or office cum retail), No. of occupants

d. Predictors: (Constant), Gross floor area, BU (office or office cum retail), No. of occupants, Category of yea retrofitting

e. Dependent Variable: TBEC

Normalization factors

Summary of multiple regression (93 buildings, after removing outliers)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.961[a]	.924	.923	854233.594	.924	1098.894	1	91	.000
2	.966[b]	.933	.932	740188.175	.010	13.318	1	90	.000

a. Predictors: (Constant), Gross floor area

b. Predictors: (Constant), Gross floor area, BU (office or office cum retail)

c. Dependent Variable: TBEC

First benchmark

Phase 1: benchmarking look-up table and cumulative curve

First benchmark

Phase 2: Separate pure office & office cum retail

Pure office:

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.967[a]	.936	.935	675112.183	.936	1060.660	1	73	.000

a. Predictors: (Constant), Gross floor area

b. Dependent Variable: TBEC

Benchmark look up table and cumulative curve

First benchmark

Phase 2: Separate pure office & office cum retail

Office cum retail:

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.977[a]	.954	.951	524967.593	.954	333.995	1	16	.000

a. Predictors: (Constant), Air conditioned area

b. Dependent Variable: TBEC

Benchmark look up table and cumulative curve

Data collection

Simplified data collection forms

Next step

Commercial office buildings:

- **Weather normalization**
- **Refine data & extend sample size**
- **Multiple regression (linear and non linear)**

$Y\ (TBEC_{predicted}) = f\ (GFA, BU, operating\ hour, floor\ vacancy\ rate\ (\%), \%\ of\ retail\ area, \%\ of\ ACA, \%\ of\ GLA, \%\ of\ car\ park, \%\ of\ data\ centre, \#\ of\ computer)$

- **Residual distribution based benchmark**

$TBEC_{benchmark} = TBEC_{observed} - TBEC_{predicted}$

(Residual)

Next step

- System level benchmark
- Evaluation of energy saving potential

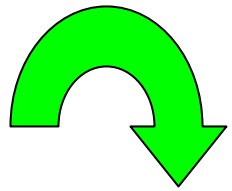
Hotel buildings:

- Review
- Sample frame
- Data collection

Benchmark mechanism

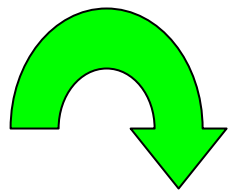
Design sample frame

Ensure the sample is representative of the entire building stock targeted and covers a wide spectrum of each building parameter.



Parameter investigation

Understand manageable and unmanageable factors



Design data collection form & define terminology

Benchmark mechanism

Data collection & processing

Applying primary filters and exclude unqualified data set

Data validity test

Apply statistical tests integrity and normality to ensure accuracy and validity of data set

Benchmark mechanism

Parameter analysis & normalization

- Weather normalization of energy consumption
- Primary determinant factors
- Correction factors
- Secondary determinant factors

Establish benchmark

Benchmark look-up table and cumulative percentile curve

Develop web-based benchmarking and application concepts

Thank You