Energy Efficient Building

Tan Chin Hong

Green Building Consultant, IEN Consultants

Energy Efficiency and Green Building Consultancy

www.ien.com.my

Malaysia | China

We are a Green Building Consultancy

- ❖ 15 year track record in Malaysia with European roots

- ❖ Portfolio of 3.2 million square meters of green building space

❖ Building consultancy services:

a) Energy efficiency consultancy
b) Daylighting design consultancy
c) Green building certification (GBI, LEED, BREEAM, Green Mark)
d) Masterplanning

www.ien.com.my
Twitter: @ienconsultants

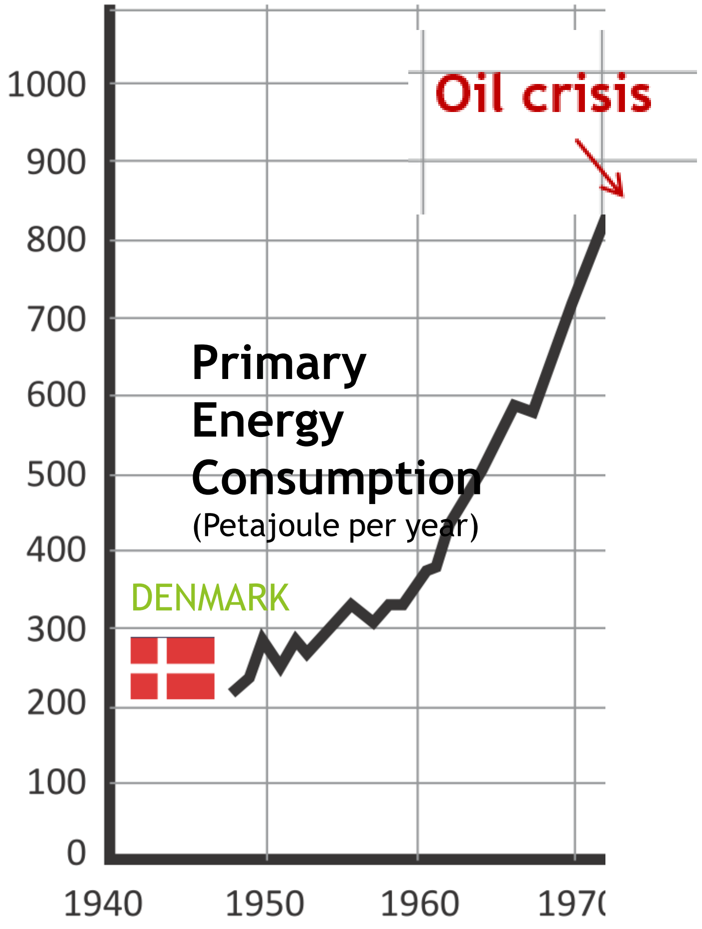
A real conversation that I had here in Malaysia.....

Courtesy of Gregers Reimann/IEN Consultants Sdn Bhd / Illustration by Rachel Chen Ruiqi

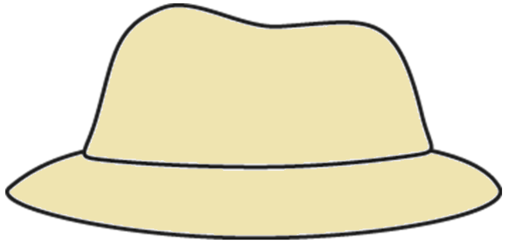
The Star newspaper, 16 August 2013

I optimised the design of buildings through computer simulation – and then they are built without any big surprises ☺

ENERGY EFFICIENCY
Denmark's experience

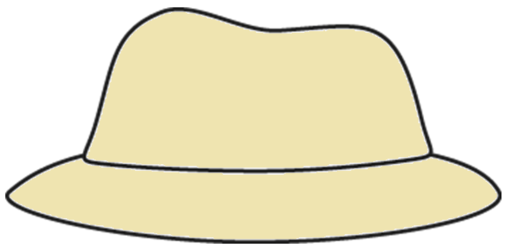


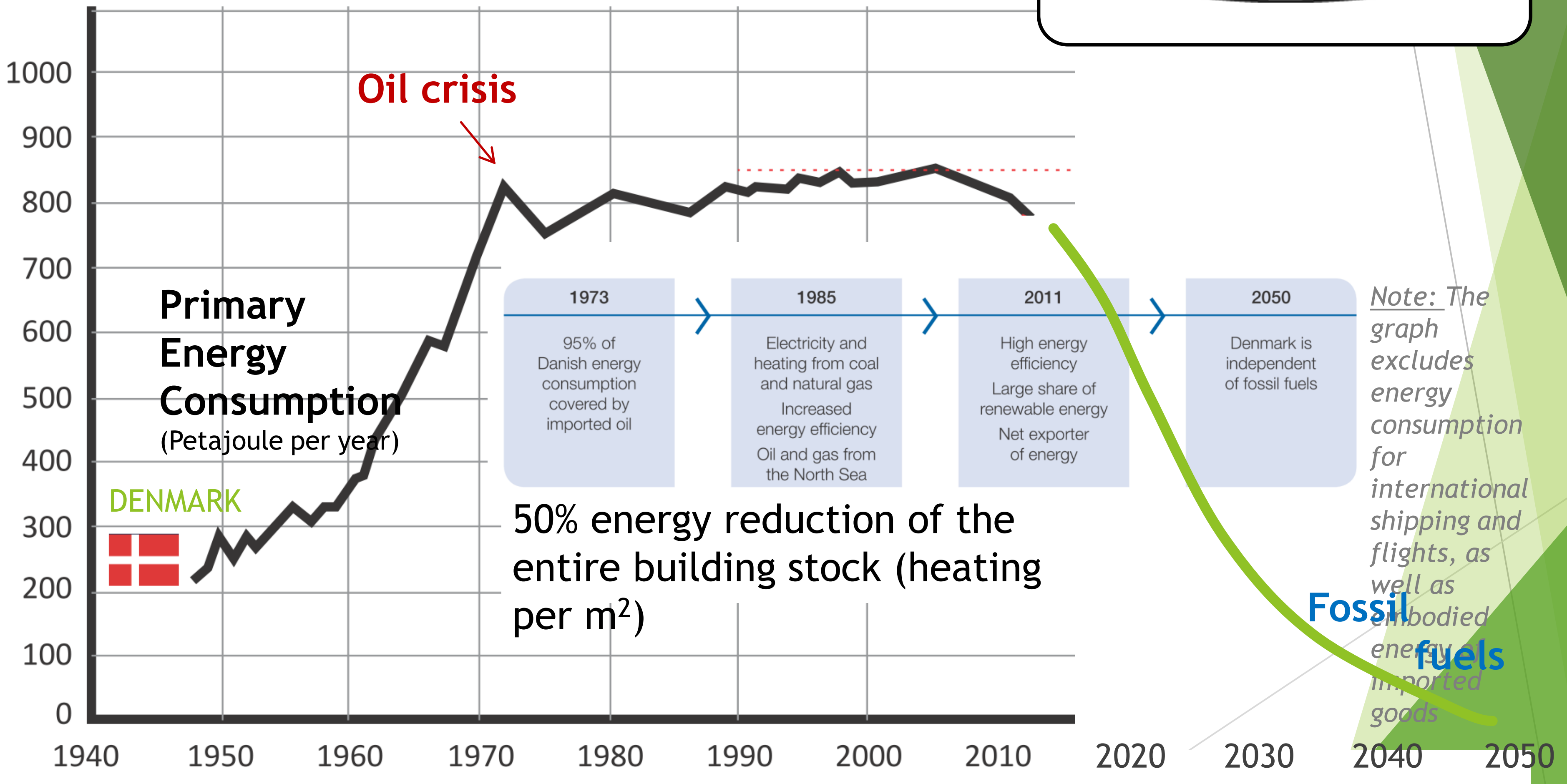
GET A HAT



ENERGY EFFICIENCY
Denmark’s experience

GET A HAT



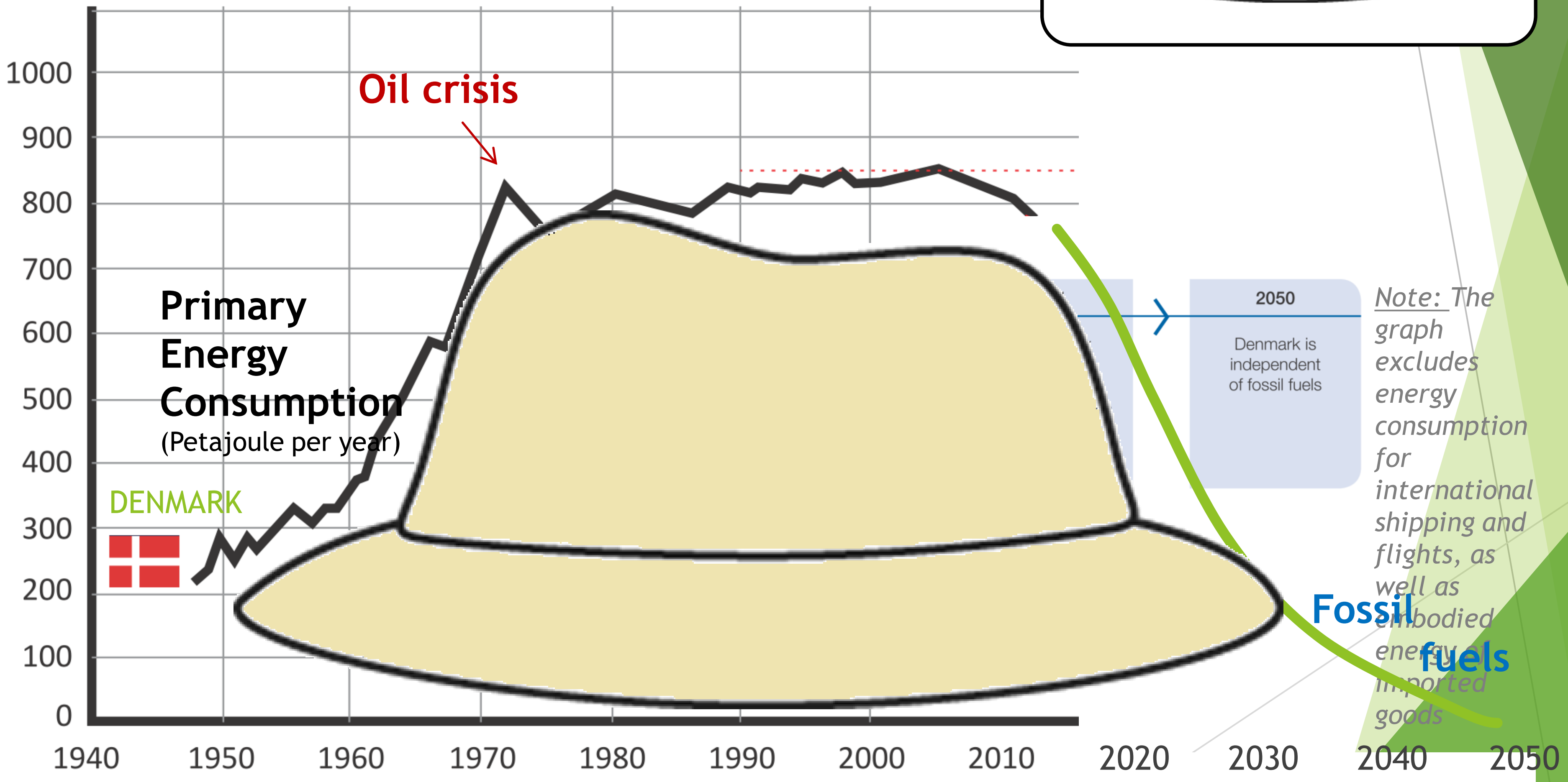


50% energy reduction of the entire building stock (heating per m^2)

Note: The graph excludes energy consumption for international shipping and flights, as well as embodied energy of imported goods

Fossil fuel fraction: 97% 80% 0%

ENERGY EFFICIENCY
Denmark's experience

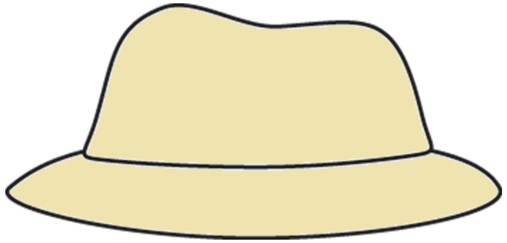


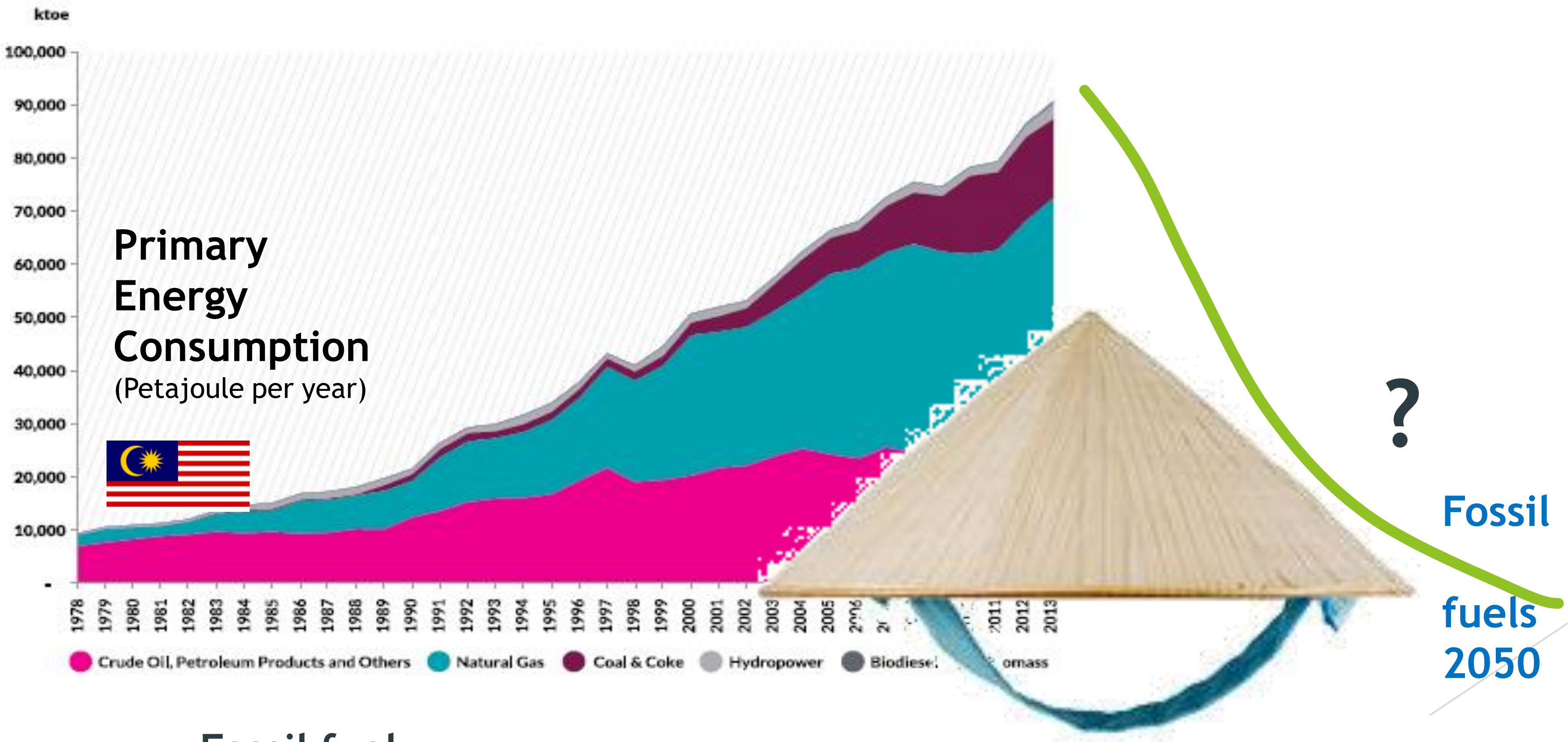
Fossil fuel	97%	80%	0%

ENERGY EFFICIENCY

Three Fundamental Observations

GET A HAT



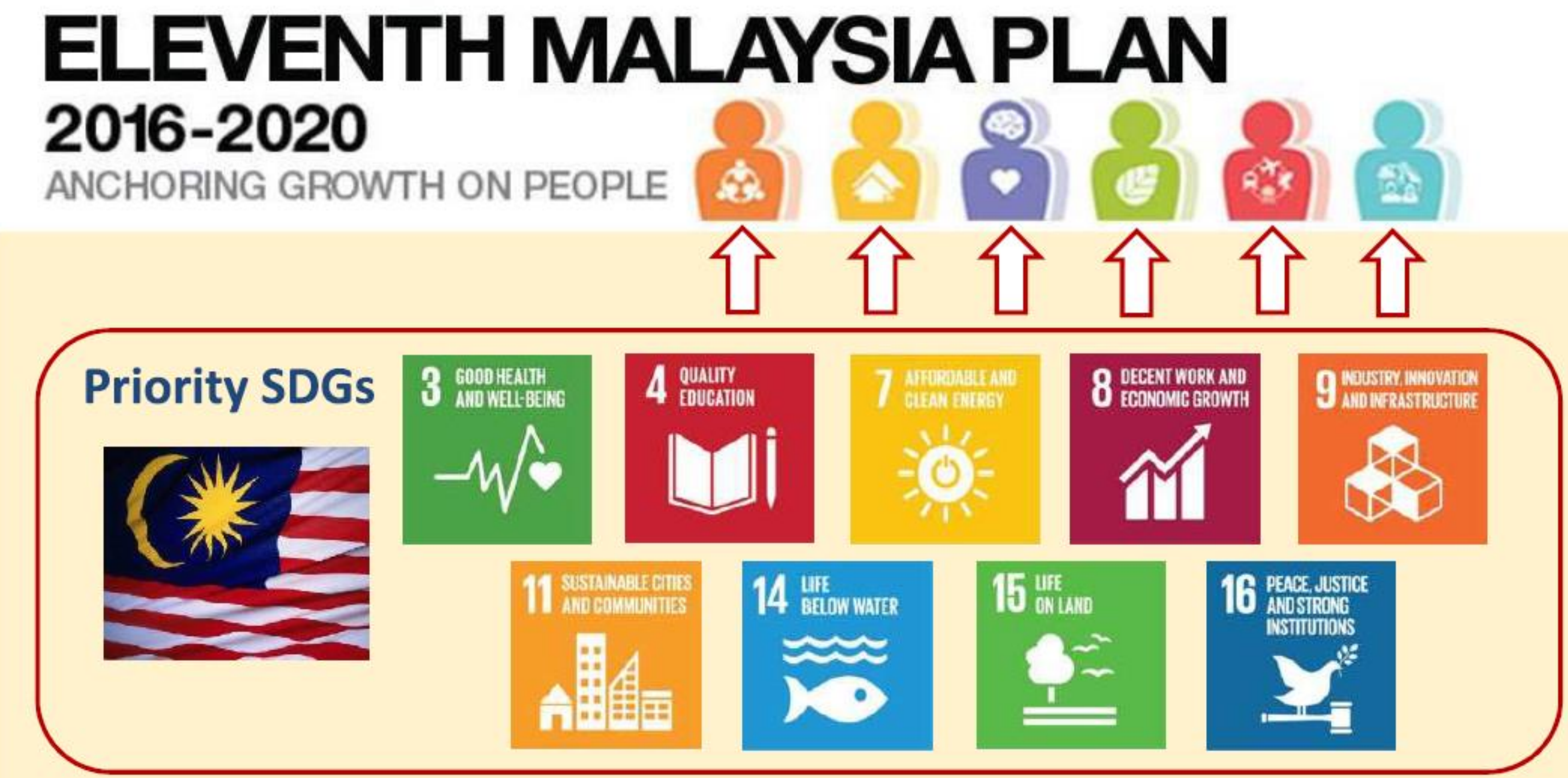


Fossil fuel fraction: 96.5% 0%

PWD /BSEEP in collaboration with the United Nations Development Program (UNDP) has been promoting energy efficiency in buildings in support of the United Nations Sustainable Development Goals (SDG).

17 goals to Transform the World

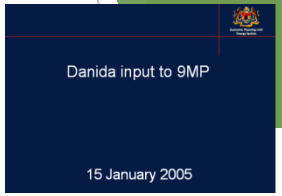
Funding for SDG Programmes and Projects: Through the existing development mechanisms (5-year Malaysia Plans)

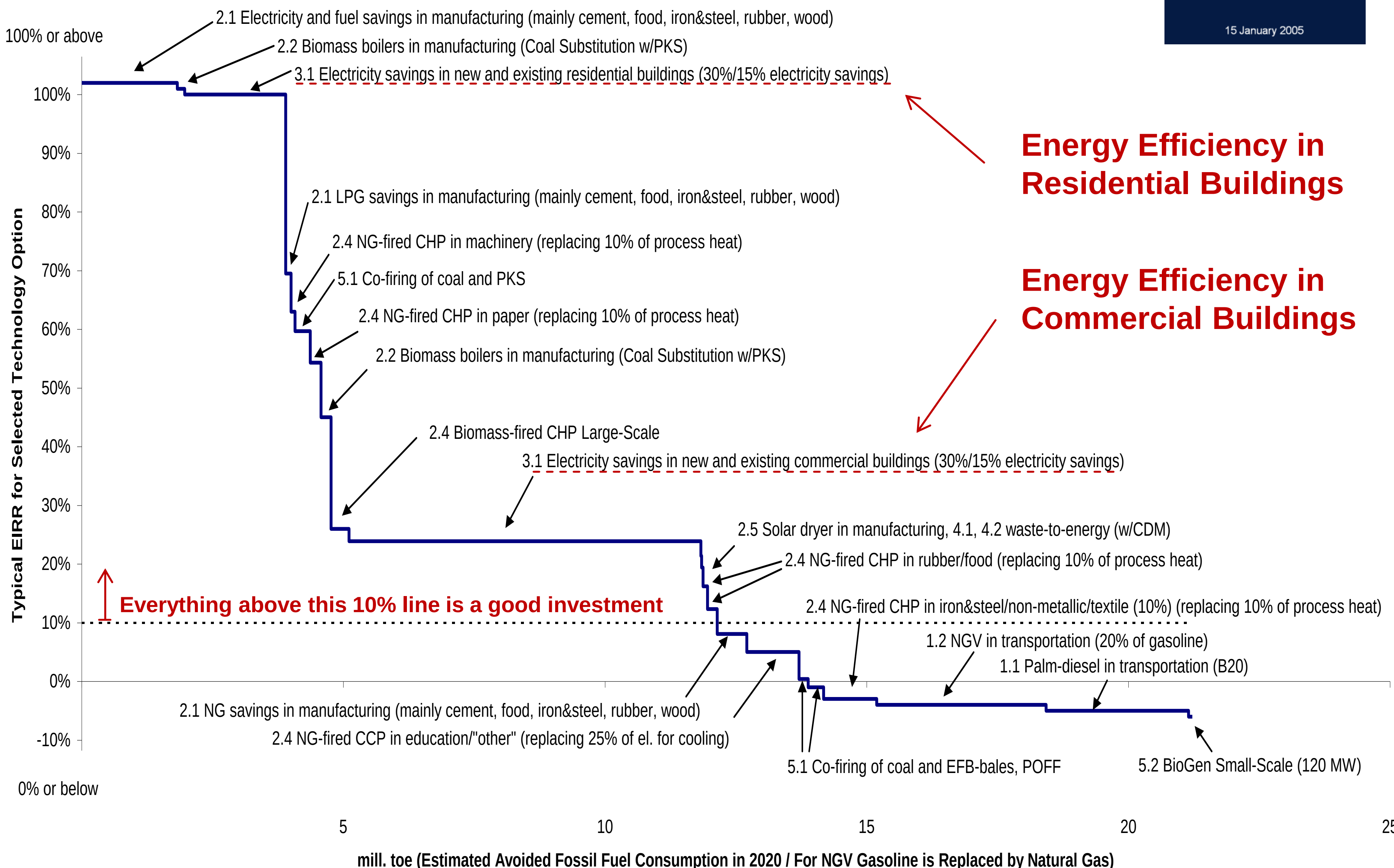


Funds are channelled through the programmes and projects under the 11MP strategic thrusts that fit the SDG goals

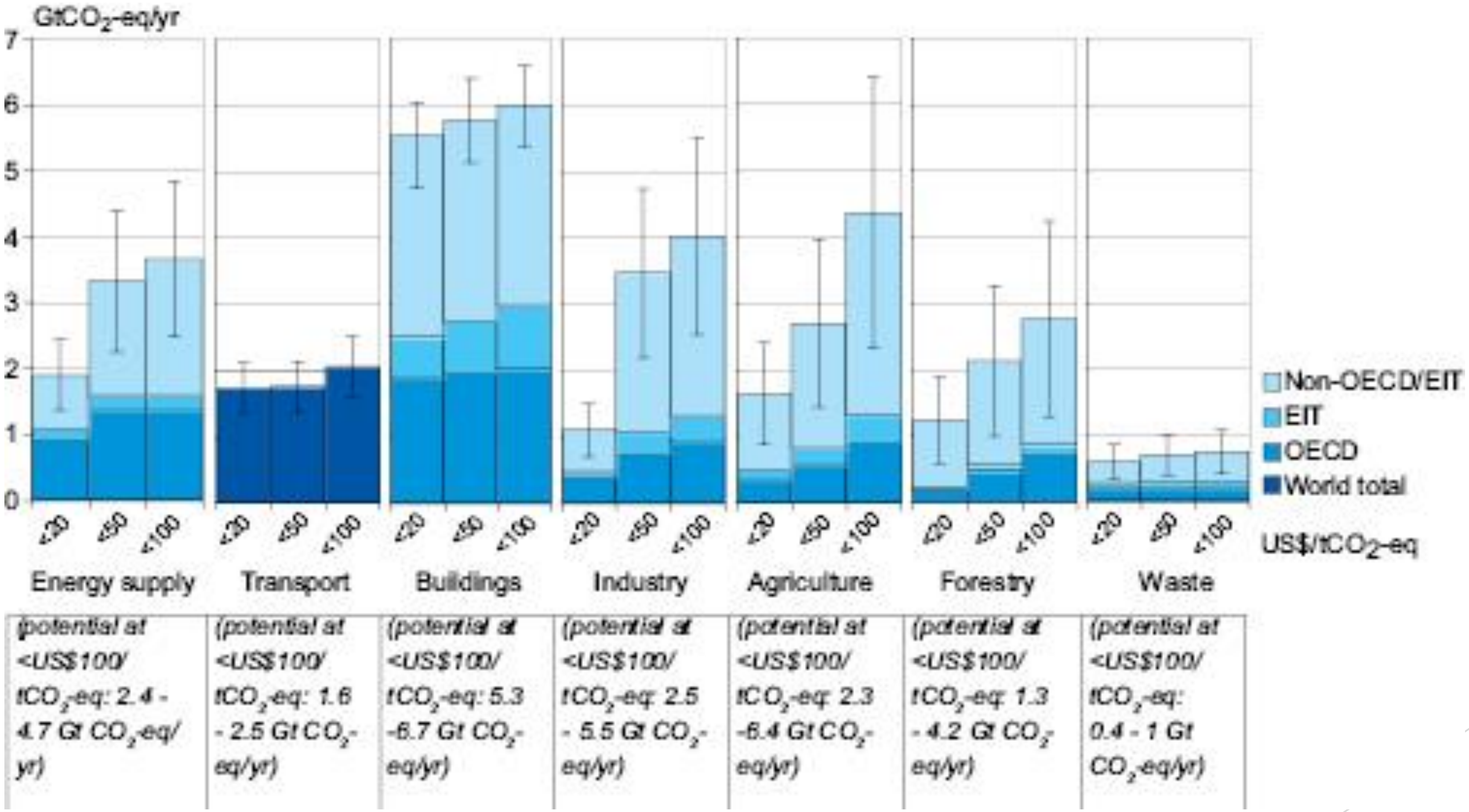
MALAYSIA: Energy Efficiency has a good Economic Internal Rate of Return

(Input to 9th Malaysian Plan by Danida, 2005)





Cheapest Way to reduce carbon footprint.



What is Energy Efficient Building

Introduction of BEI (Building Energy Intensity)

Green Building Index

BEI= ((TBEC-CPEC-DCEC)/(GFA(excluding carpark)-DCA-GLA*FVR))*(52/WHO)

Introduction of EUI (Energy Usage Index)

Green Mark

EUI= ((TBEC-DCEC)/(GFA(excluding carpark)-DCA-GLA*FVR))*(52/WHO)

Simplest way to calculate EUI is by use TNB bill total KWH, and divide by Building GFA.

BIL ELEKTRIK DAN INVOIS CUKAI

TENAGA NASIONAL

SALINAN

Jumlah Perlu Dibayar RM 484,400.50 | **Tarikh Bil : 02.11.2017** | **Bil : LPC**

		Amaun	Bayar Sebelum		
Tunggakan	RM	473,060.60	Segera		
Caj Semasa	RM	11,339.88	02.12.2017		
Penggenapan	RM	0.02			
Jumlah Bil	RM	484,400.50			
Bil Terdahulu	RM	0.00	Bayaran Akhir (01.11.2017)	RM	636.00

Jenis Bacaan	: Bacaan Sebenar
Tempoh Bil	: 13.01.2017 - 31.01.2017 (19 Hari)
Tarif	: C1:Perdagangan

Blok Tarif (kWh/kW)	Kegunaan (kWh/kW)	Kadar(RM)	Amaun(RM)
Kegunaan	21,666.00	0.3650	7,908.09
Kehendak Maksima	154.00	30.3000	2,955.26

Untuk maklumat bil dan bayaran terdahulu, sila layari- http://www.mytnb.com.my atau hubungi Hotline TNB 1 300 88 5454
Untuk gangguan bekalan atau kerosakan lampu jalan TNB sila hubungi melalui telefon/SMS: 15454

Untuk pertanyaan, sila hubungi:

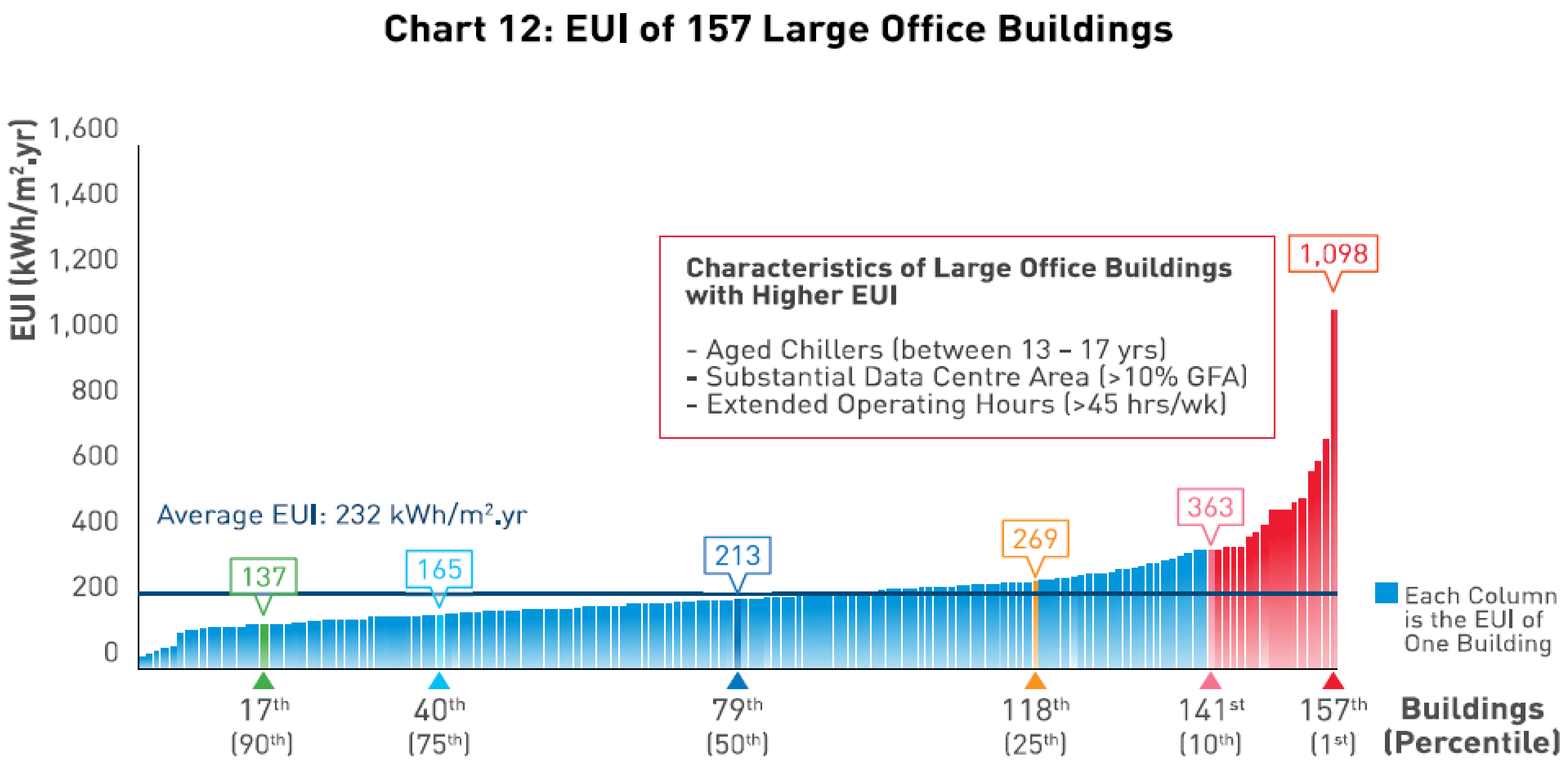
TNB KUALA LUMPUR - PUSAT

Energy Efficient Building Benchmarking

Reference:
https://www.bca.gov.sg/GreenMark/others/BCA_BEBR_Abridged_FA_2016.pdf

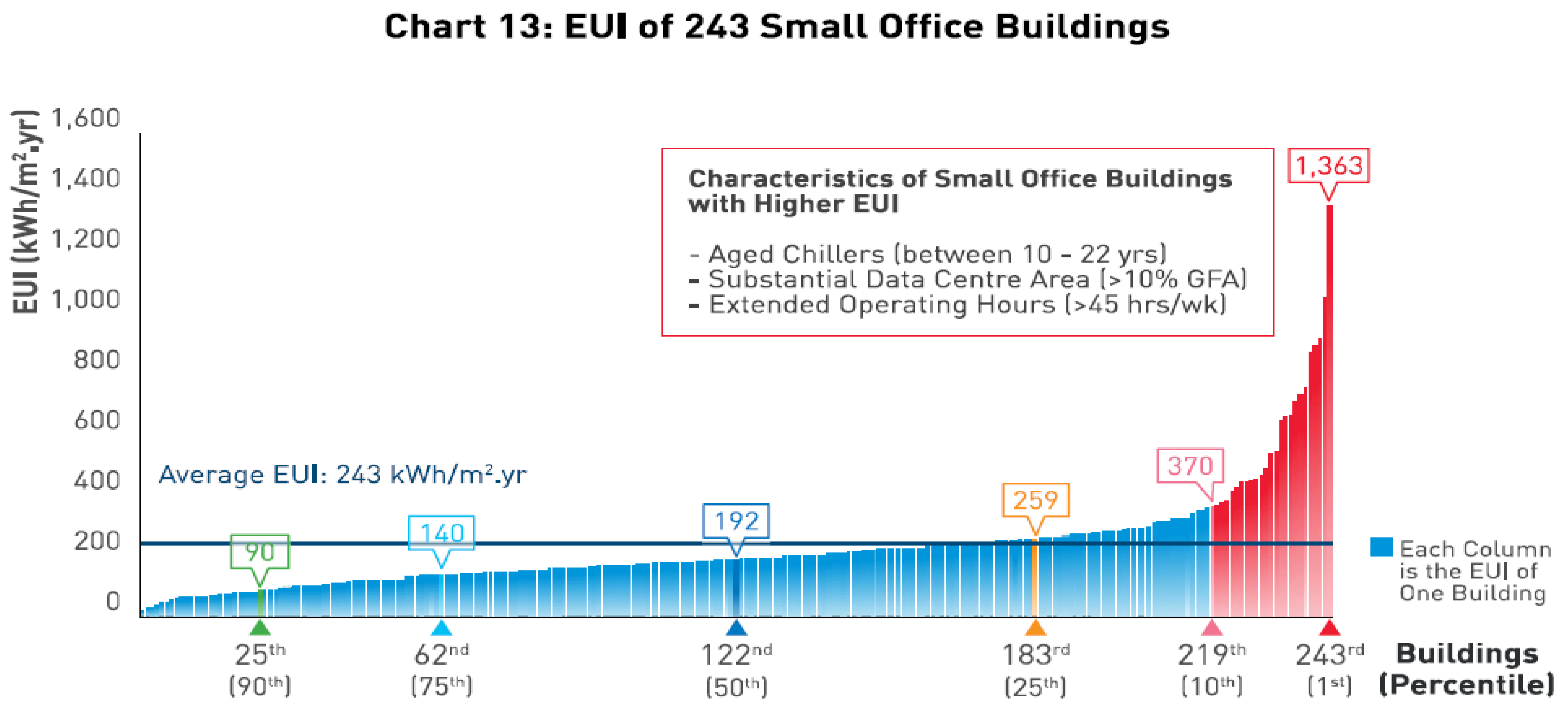
Energy Use Intensity (EUI) of Office Buildings

Large Office Buildings (GFA ≥15,000 m²)



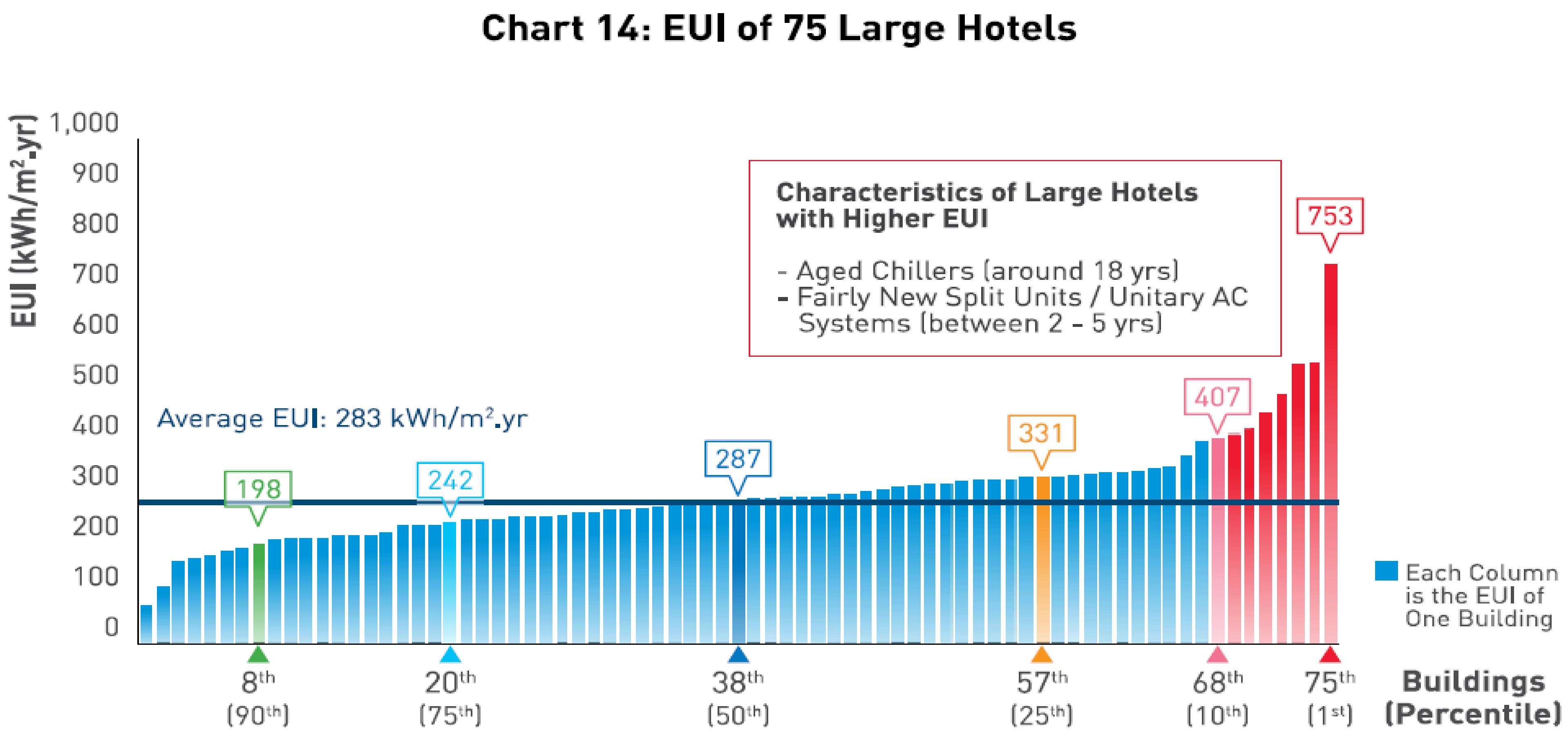
Energy Use Intensity (EUI) of Office Buildings

Small Office Buildings (GFA <15,000 m²)



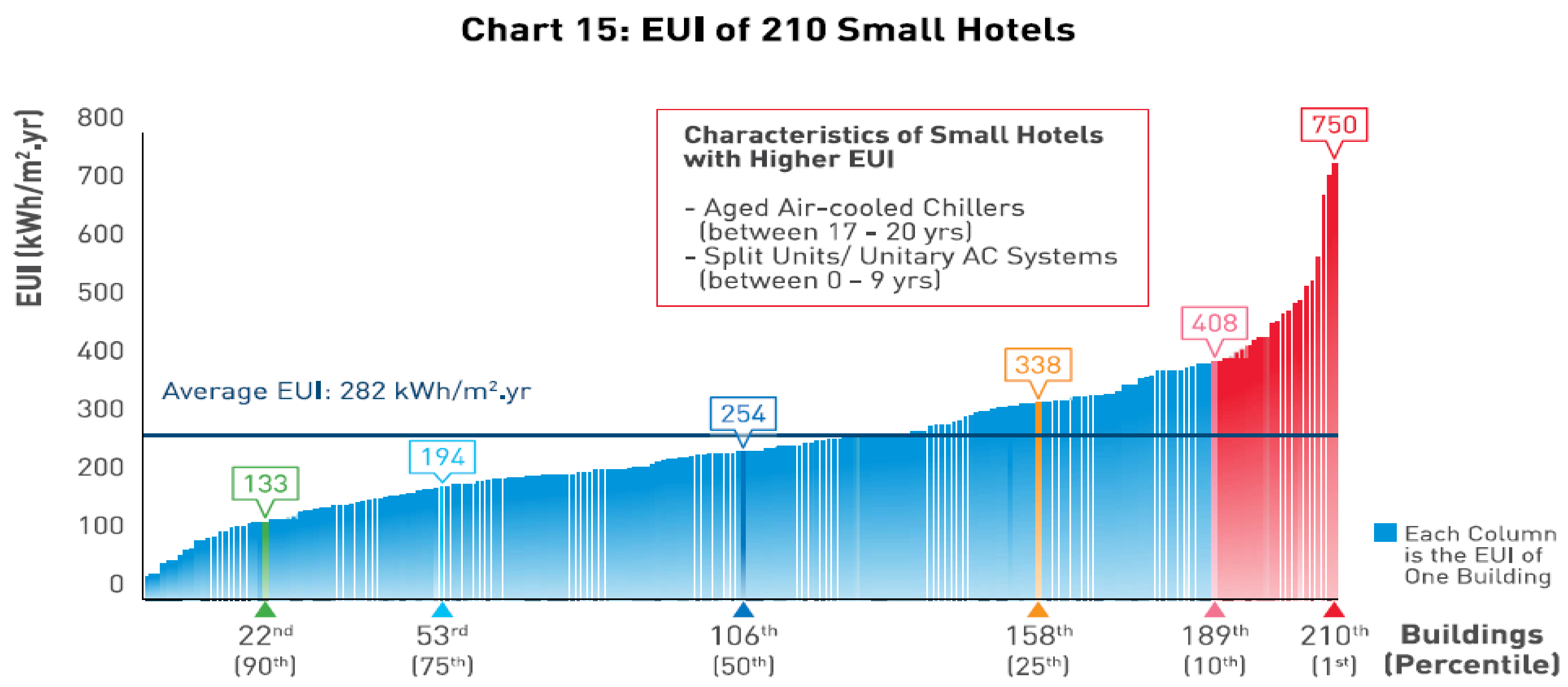
Energy Use Intensity (EUI) of Hotels

Large Hotels (GFA ≥7,000 m²)

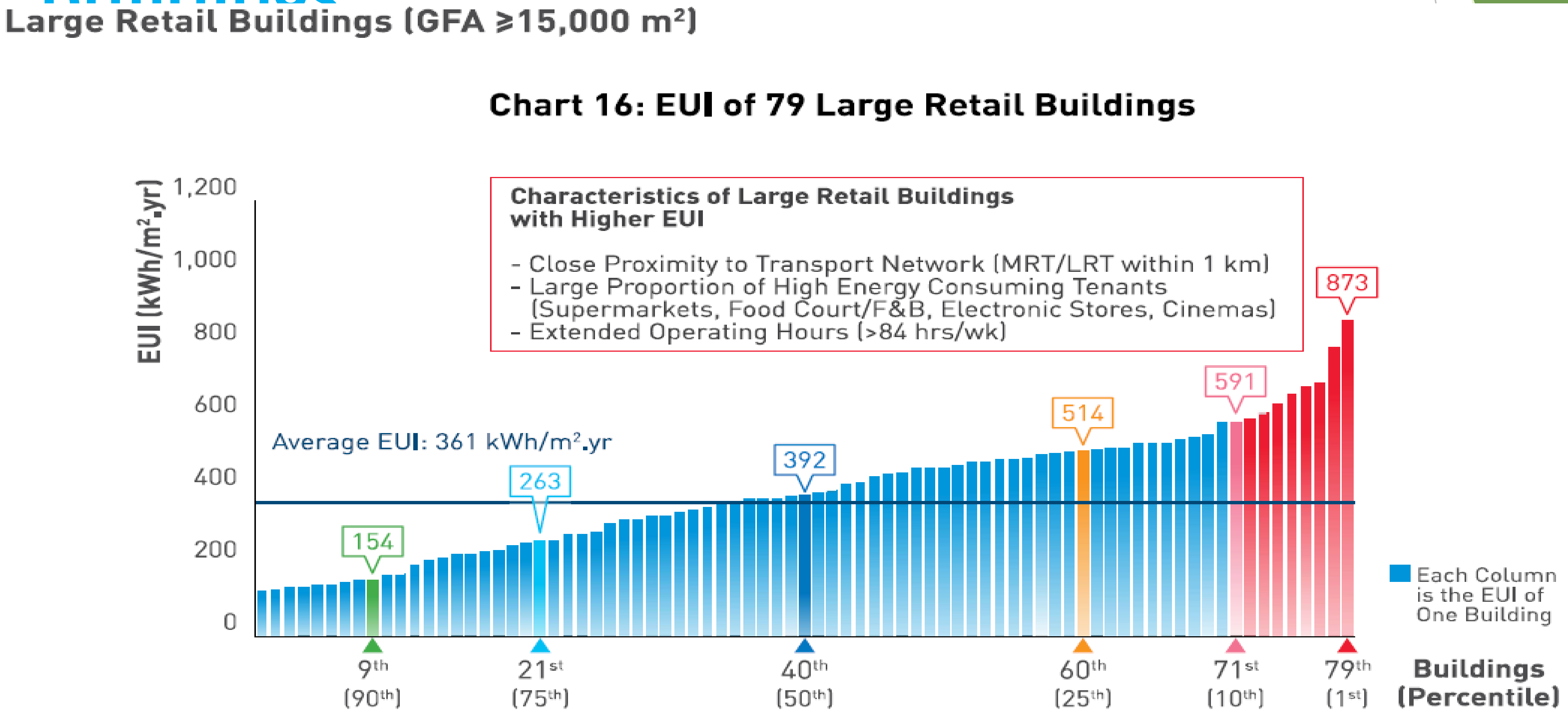


Energy Use Intensity (EUI) of Hotels

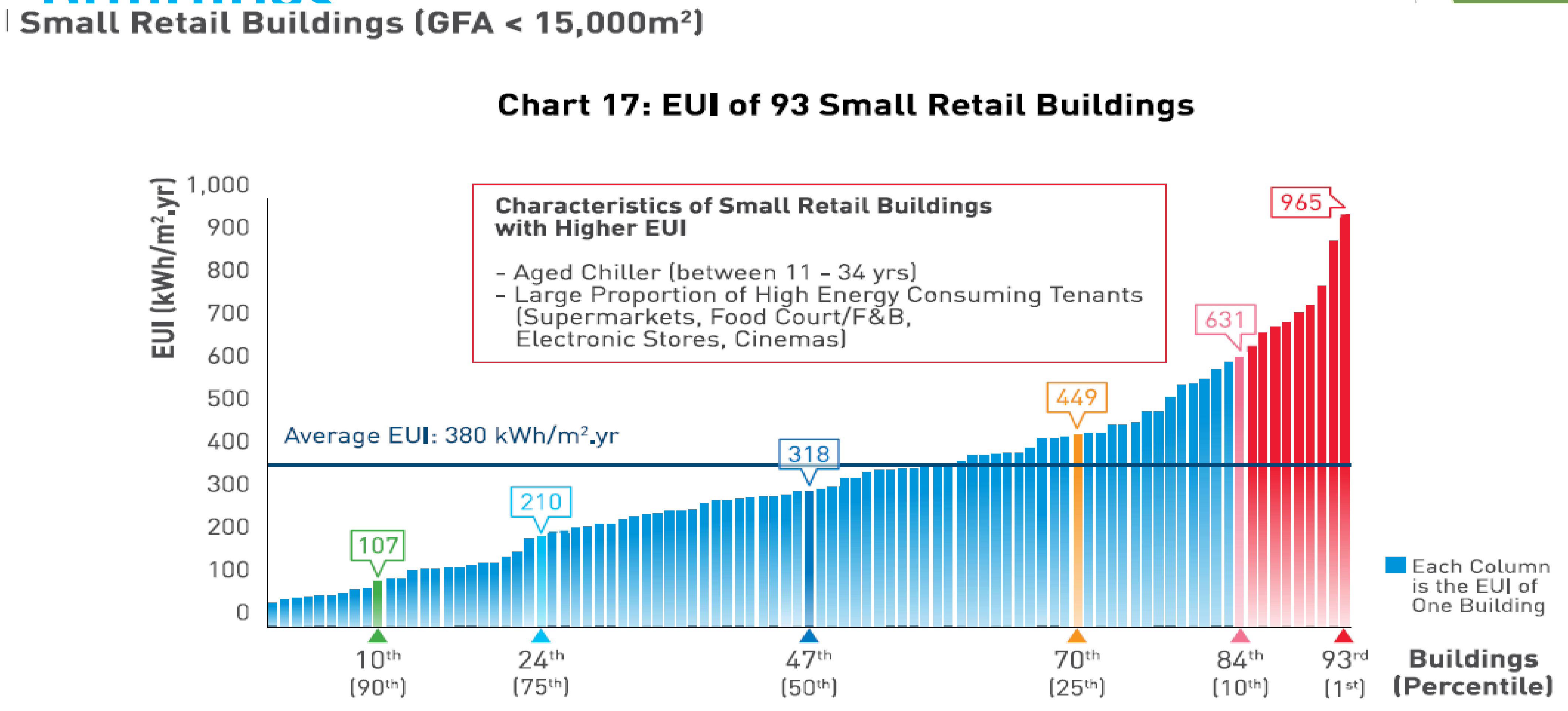
Small Hotels (GFA <7,000 m²)



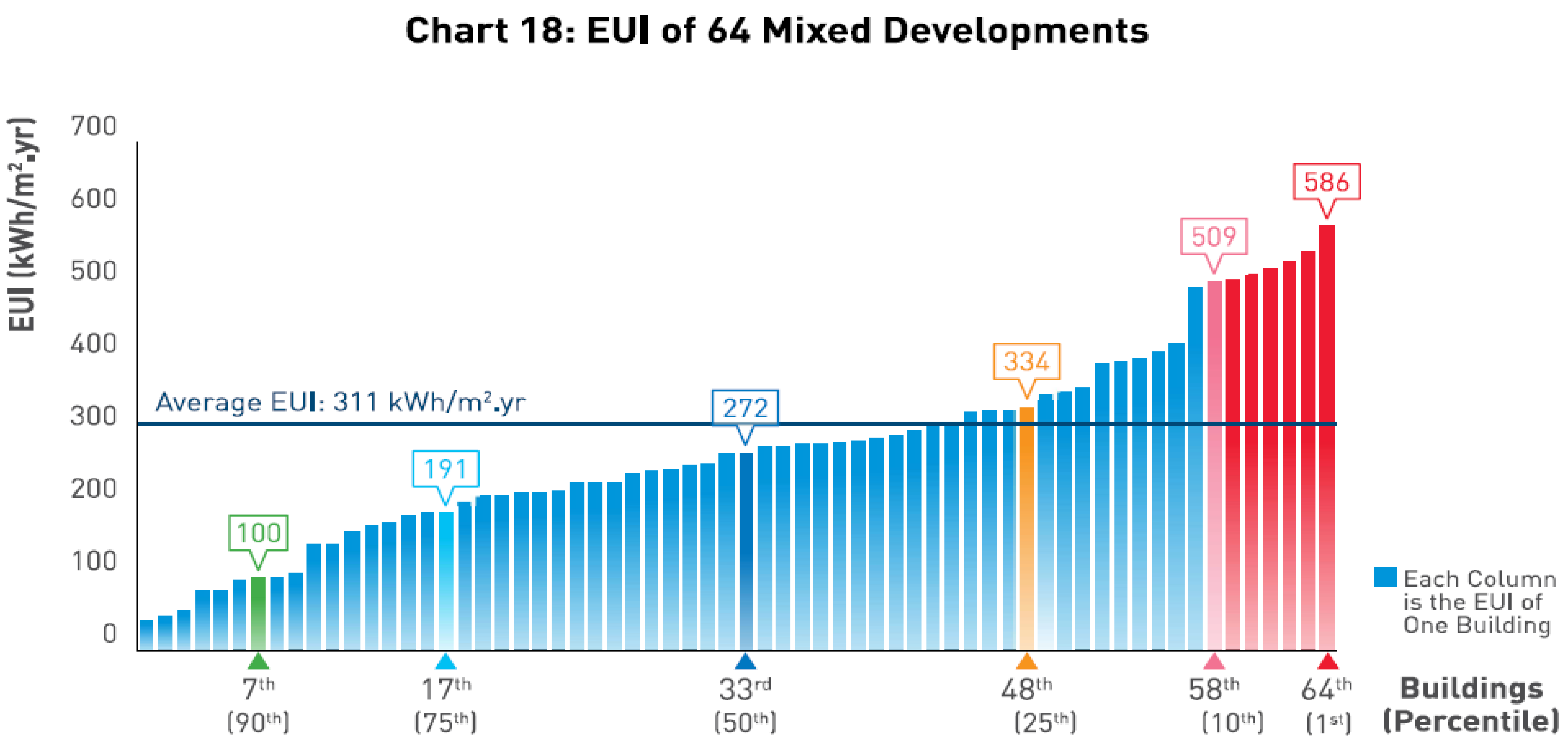
Energy Use Intensity (EUI) of Retail Buildings



Energy Use Intensity (EUI) of Retail Buildings

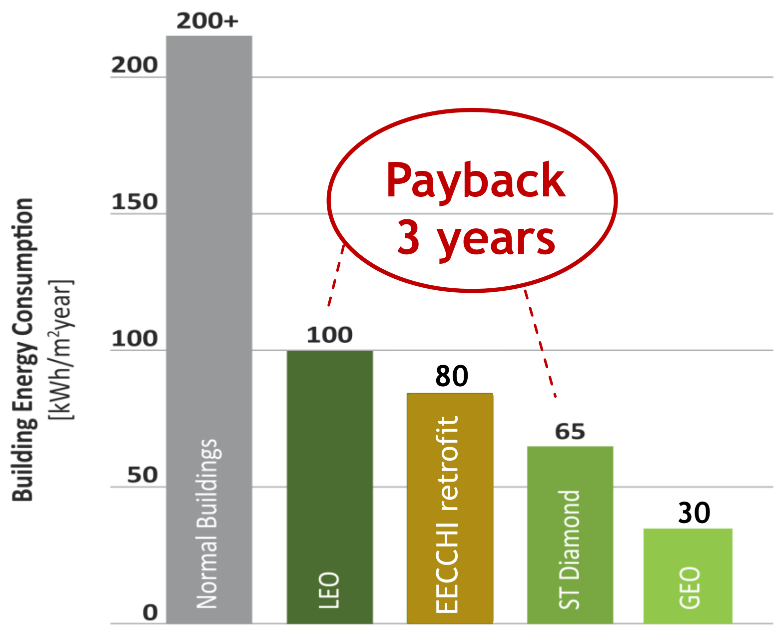


Energy Use Intensity (EUI) of Mix Developments



Energy Efficient Buildings in South-East Asia

LEO Building | GEO Building | ST Diamond Building | EECCHI retrofit



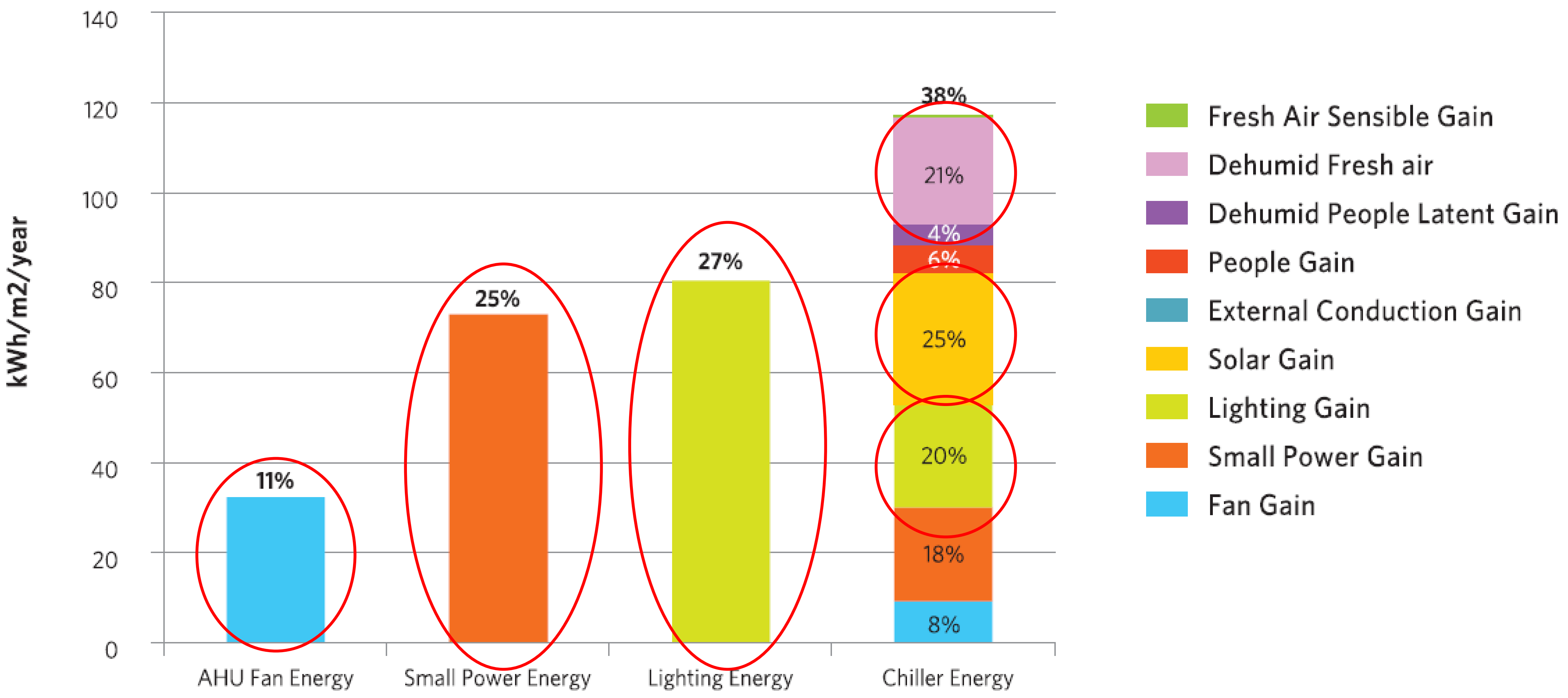
Completion year | - | 2004 | 2010 | 2010 | 2007

Expensive
not to be energy efficient

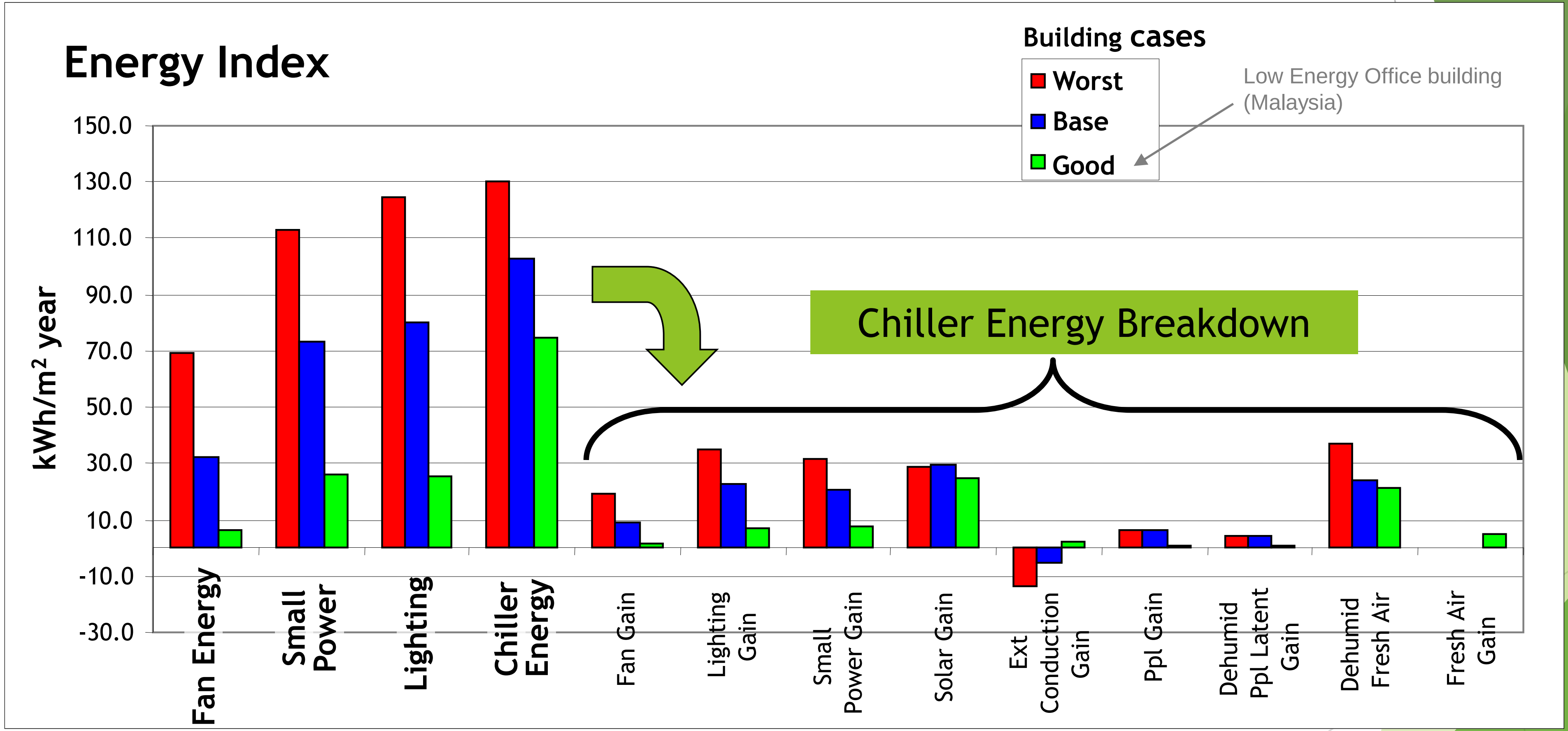
Buildings by
by IEN Consultants

I E N CONSULTANTS

CHART 1.1 | TYPICAL ENERGY BREAKDOWN IN A BUILDING



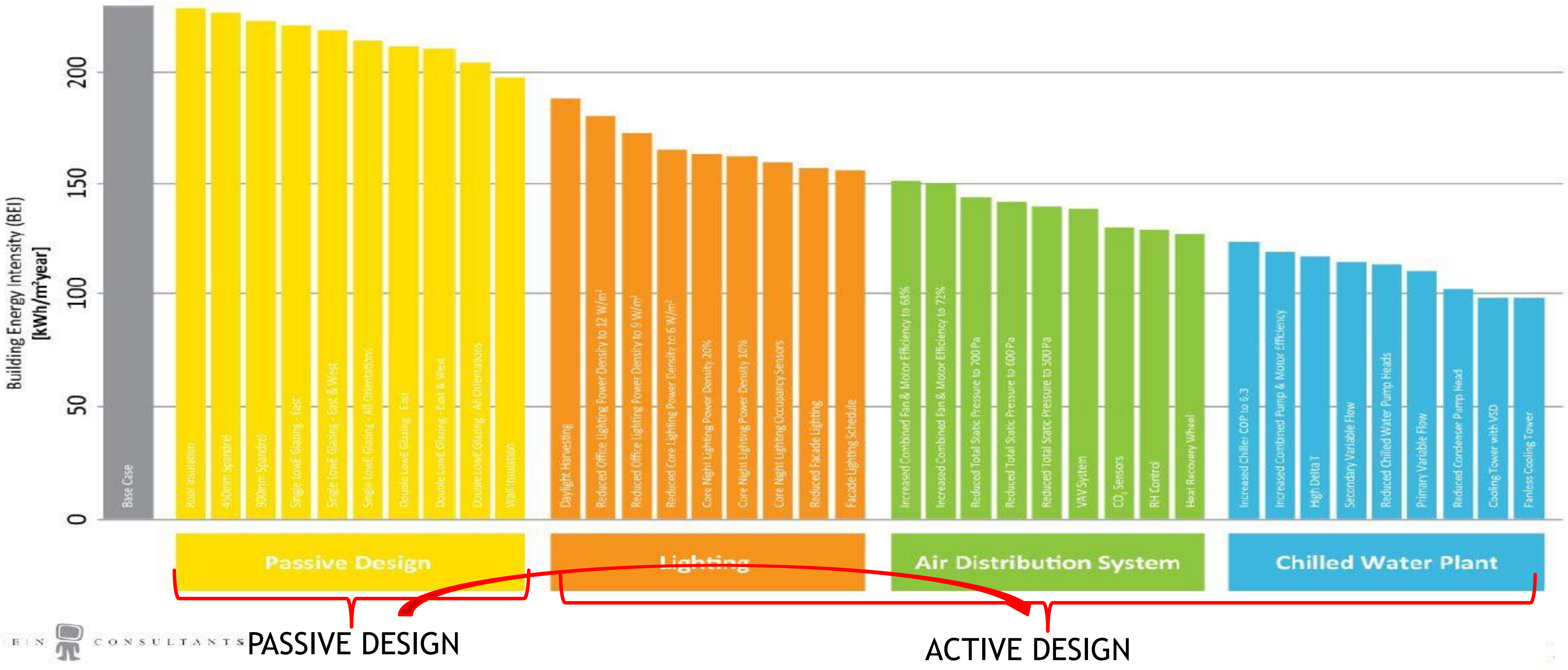
Building Energy Analysis with Computer Simulation



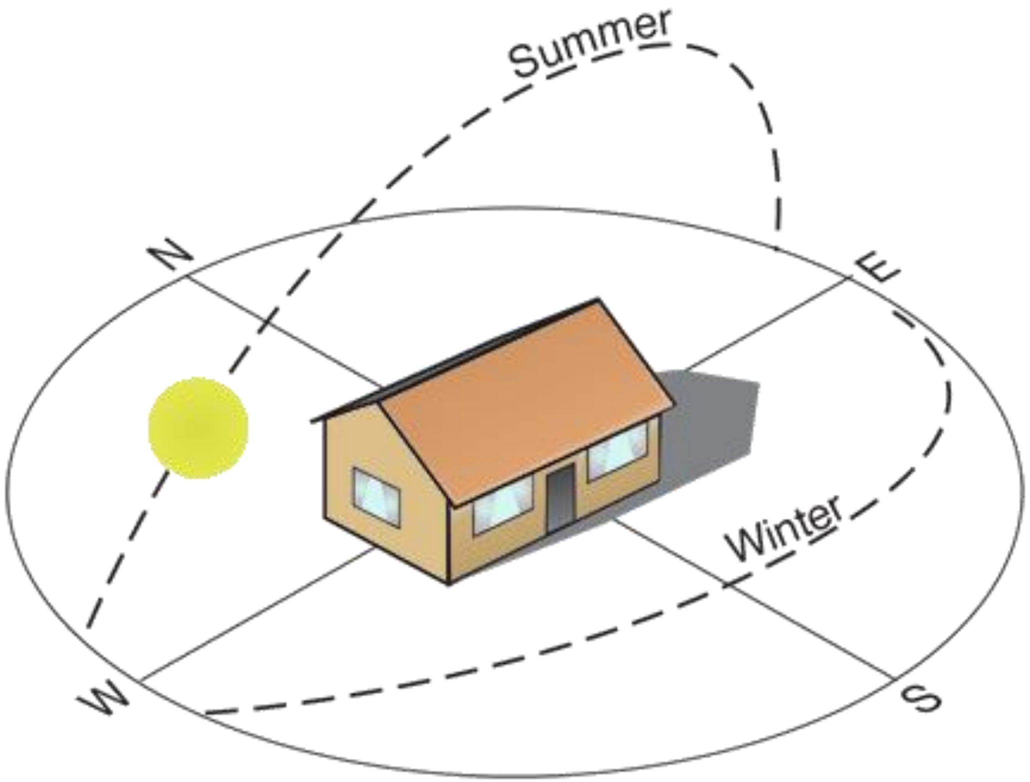
Energy Efficient Building Strategies

Energy Optimisation

Simulation steps and improvements



I E N CONSULTANTS



PASSIVE DESIGN

OTTV = Overall Thermal Transfer Value

OTTV is a measure of the average heat gain into a building through the building envelope.

MS 1525:2007 requirement :
OTTV ≤ 50 W/m^2

OTTV CONCEPT

OTTV CALCULATION:

$15a(1 - WWR)U_w$	+	$6(WWR)U_f$	+	$194xCFxWWRxSC$		
0.2%-5%		**10%-20%**		**70%-85%**	≤	50 W/m²
Heat Conduction through Walls	+	Heat Conduction Through Windows	+	Solar Heat Gain through Windows		

α= solar absorptivity of the opaque wall

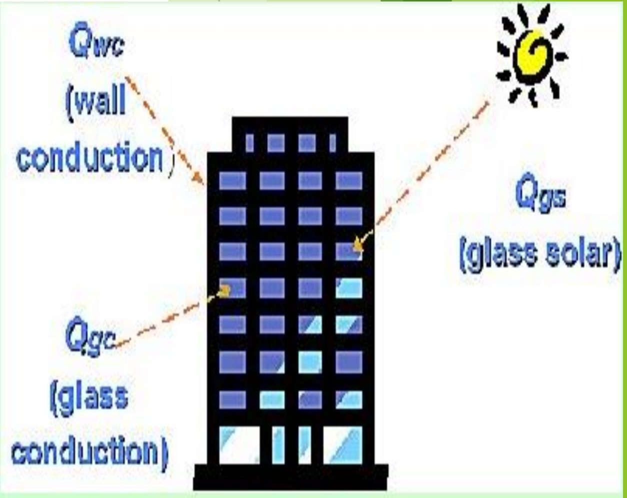
WWR = Window to wall ratio

U_w= Themal Transmittance of opaque wall W/m^2K

U_f= Themal Transmittance of fenestration system W/m^2K

CF =Solar Correction factor

SC = Shading coefficient of the fenestration system



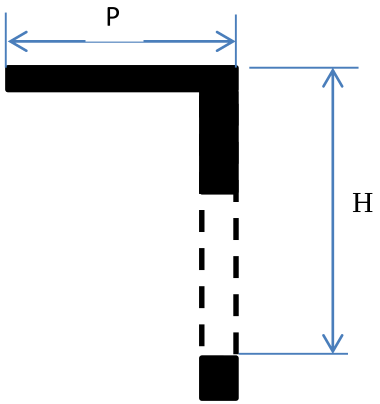
Correction Factor : (MS1525:2007)

Orientation	CF
North	0.9
Northeast	1.09
East	1.23
Southeast	1.13
South	0.92
Southwest	0.9
West	0.94
Northwest	0.9

Shading Coefficient (SC)

SC = SC1 x SC2
SC 1 = Glass Shading Coefficient
SC 2 = External Shading Coefficient

External Shading Coefficient



$$R1 = \frac{P}{H}$$

SC2 Refer to Table 5 MS1525:2007

Strategy Reducing OTTV

Make sure the most determining variables is low enough:

All Variables are below:

1. CF
2. WWR
3. Uw
4. Uf
5. SC

Summary:

- Minimize WWR, especially at East ,NorthEast, SouthEast
- Minimize SC
  -SC of Glass
  -SC of sunshade

Example of East Façade OTTV

Base Case

Window: 50% of total façade

Window: Single Glaze Tinted

Opaque Façade: Opaque façade is made from brickwall + plaster

α Value: 0.8

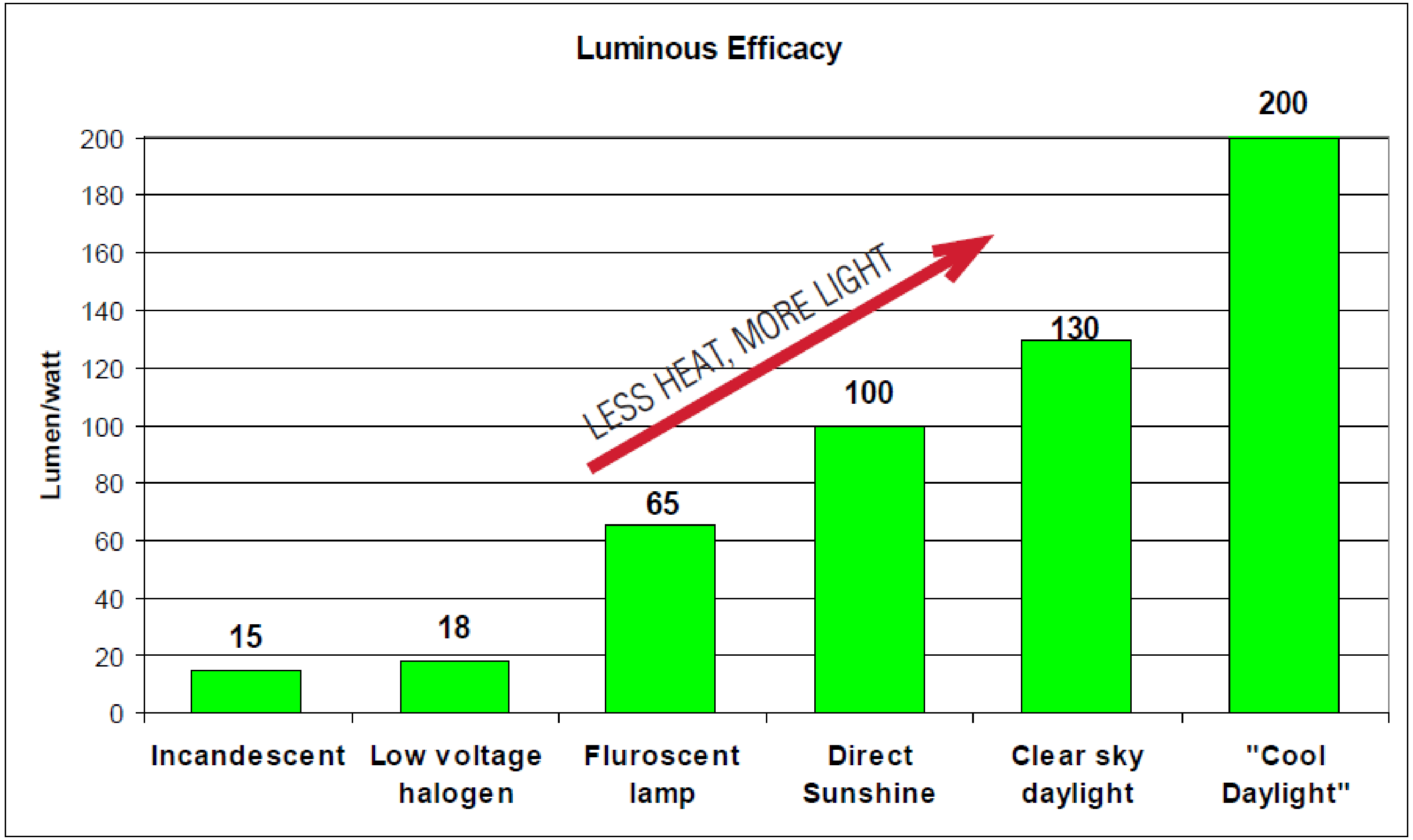
WWR	Uw	Uf	CF	SC
0.5	2.44	5.7	1.23	0.7

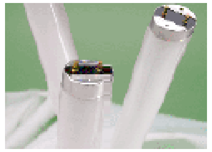
15xα x (1-WWR) x UW	6 x (WWR) x Uf	194 x (WWR) x SC x CF	OTTV
14.64	17.1	83.52	115.26

	WWR	Uw	Uf	CF	SC	OTTV	OTTV Reduction
Base	0.5	2.44	5.7	1.23	0.7	115.26	
Step 1	0.4	2.44	5.7	1.23	0.7	98.06	15%
Step 2	0.4	0.55	5.7	1.23	0.7	84.45	14%
Step 3	0.4	0.55	5.7	1.23	0.539	69.09	18%
Step 4	0.4	0.55	1.6	1.23	0.27	33.52	51%

Efficient Lighting Design Strategies

COMMON MISCONCEPTION - SUNLIGHT IS "HOTTER" THAN ELECTRIC LIGHTS

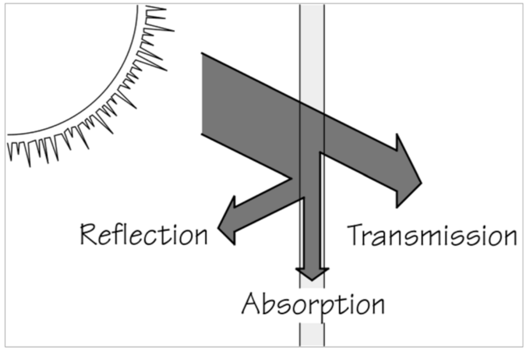




Daylighting Harvesting

- Daylight through normal glazing is **2.6 times cooler** than people think
- Daylight through high performance glazing is **4.9 times cooler** than people think

Solar Light interacting with Glazing



Reflection(%) + Transmission(%) + Absorption(%) = 100%

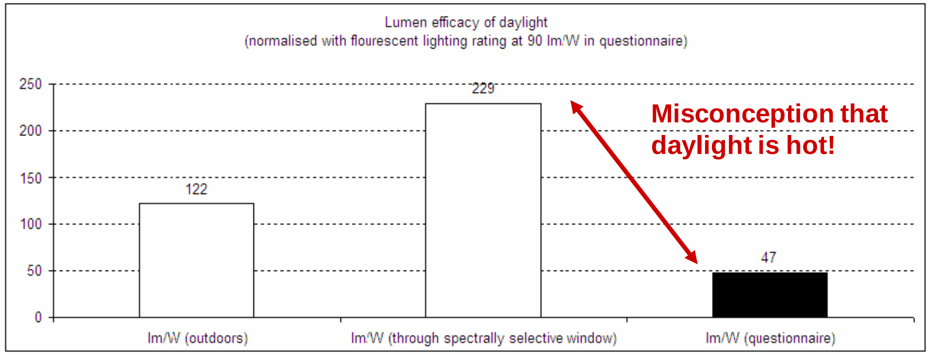
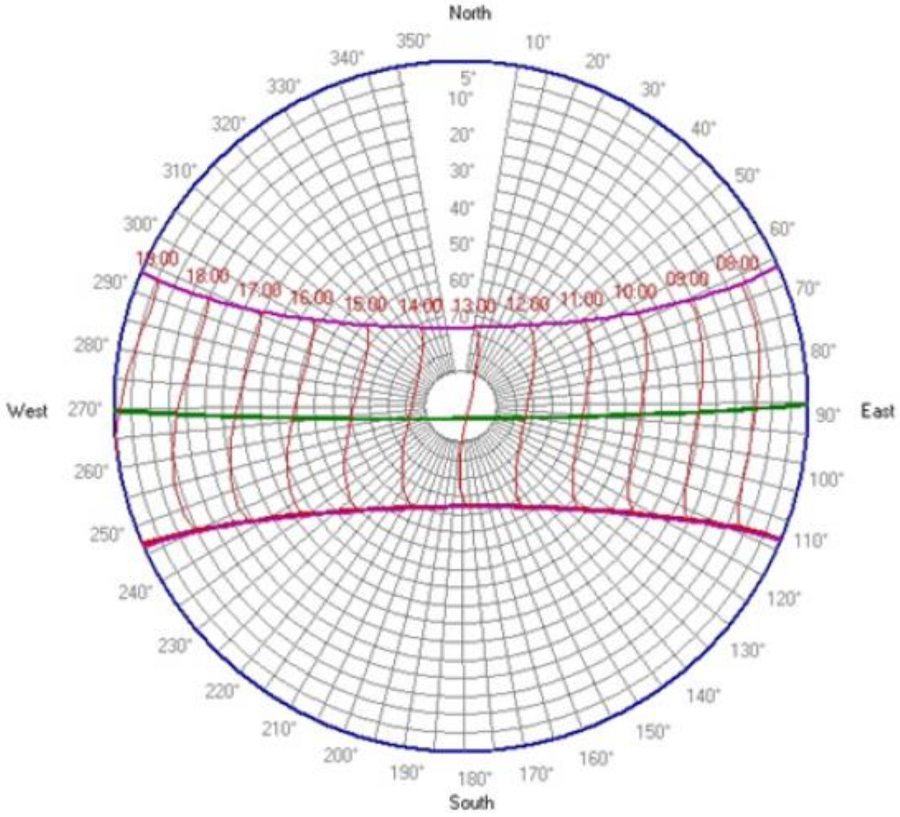


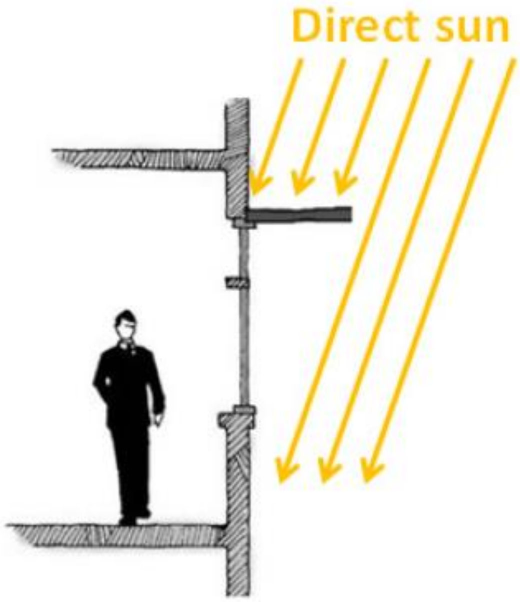
Figure 4.15: Misconception of lumen efficacy of daylight. If fluorescent light is assumed to have a lumen efficacy of 90 lm/W then the lumen efficacy of daylight was set to 47 lm/W, while in reality it is 160% higher at 122 lm/W (outdoors) or almost 400% higher at 229 lm/W when coming through a spectrally selective window.

Survey among 46 building professionals in Singapore (by Gregers Reimann)

ORIENTATION MATTERS



Sunpath diagram for Malaysia



North & South windows can easily be shaded from direct sun by horizontal overhangs

Lighting Power Density of MS 1525

Type of Usage	Max. lighting power W/m^2
Restaurants	15
Offices	15
Classrooms/ Lecture Theatres	15
Auditoriums/ Concert Halls	15
Hotel/ Motel Guest Rooms	15
Lobbies/ Atriums/ Concourse	20
Supermarkets/ Department Stores/ Shops	25
Stores/ Warehouses/ Stairs/ Corridors/ Lavatories	10
Car Parks	5

Recommended Lux Value in MS 1525

Task	Illuminance (Lux)	Example of Applications
Lighting for infrequently used area	20	Minimum service illuminance
	100	Interior walkway and car-park
	100	Hotel bedroom
	100	Lift interior
	100	Corridor, passageways, stairs
	150	Escalator, travellator
	100	Entrance and exit
	100	Staff changing room, locker and cleaner room, cloak room, lavatories, stores.
	100	Entrance hall, lobbies, waiting room
	300	Inquiry desk
	200	Gate house
Lighting for working interiors	200	Infrequent reading and writing
	300 – 400	General offices, shops and stores, reading and writing
	300 – 400	Drawing office
	150	Restroom
	200	Restaurant, Canteen, Cafeteria
	150 – 300	Kitchen
	150	Lounge
	150	Bathroom
	100	Toilet
	100	Bedroom
	300 – 500	Class room, Library
	200 – 750	Shop / Supermarket/Department store
	300	Museum and gallery
Localised lighting for exacting task	500	Proof reading
	1000	Exacting drawing
	2000	Detailed and precise work

Case study

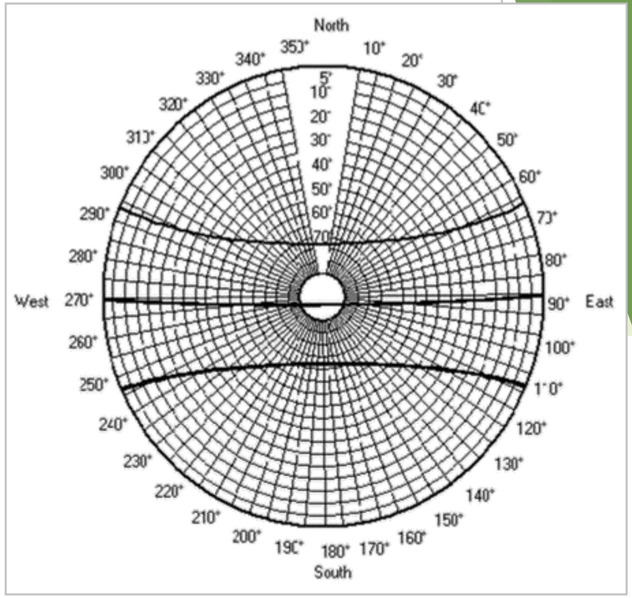
GEO Building

(Malaysia. formerly ZEO Building, 2007)

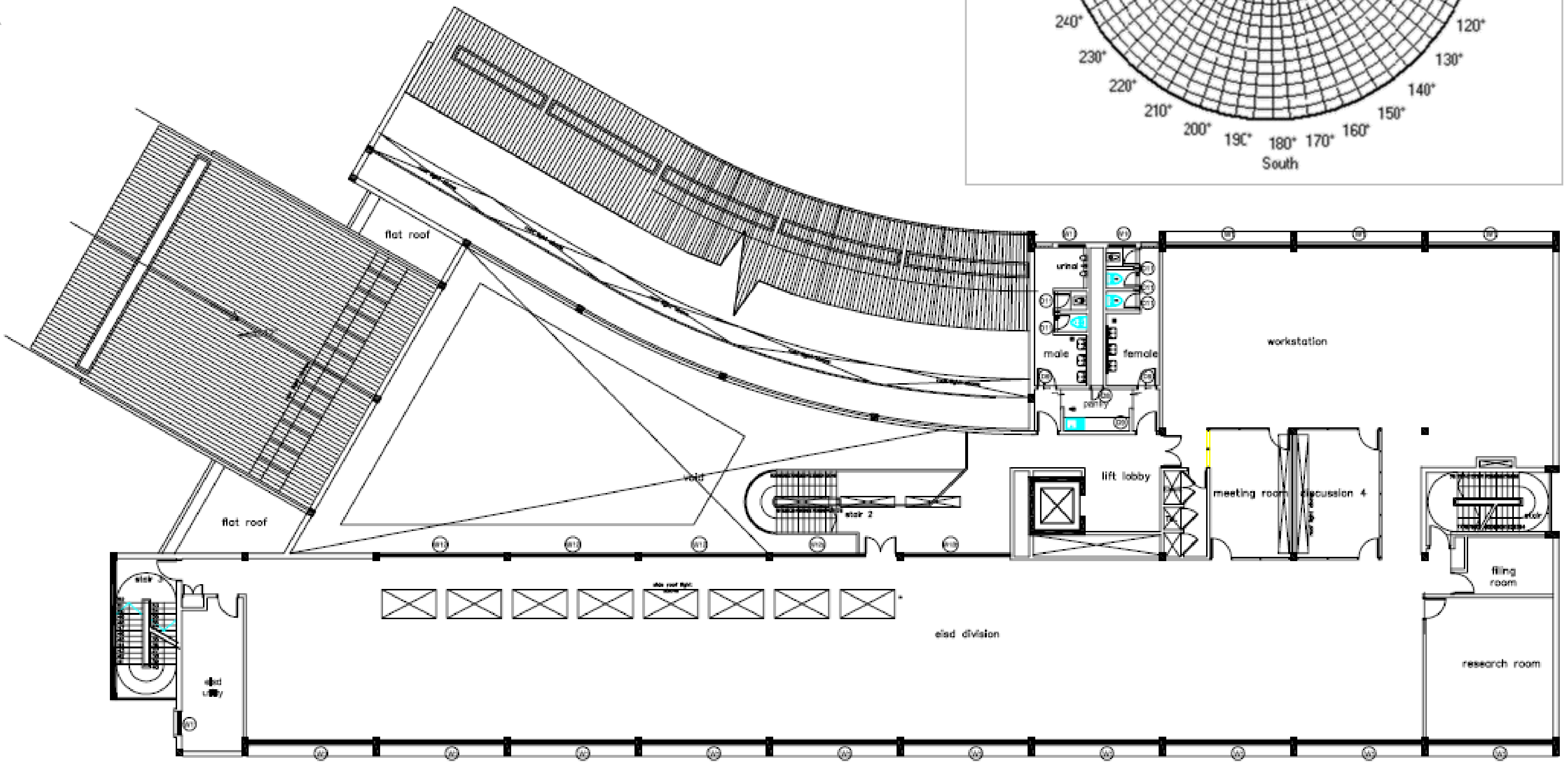
Daylighting case study

Good Orientation for Daylighting

Solar chart for Kuala Lumpur (3.15° North)

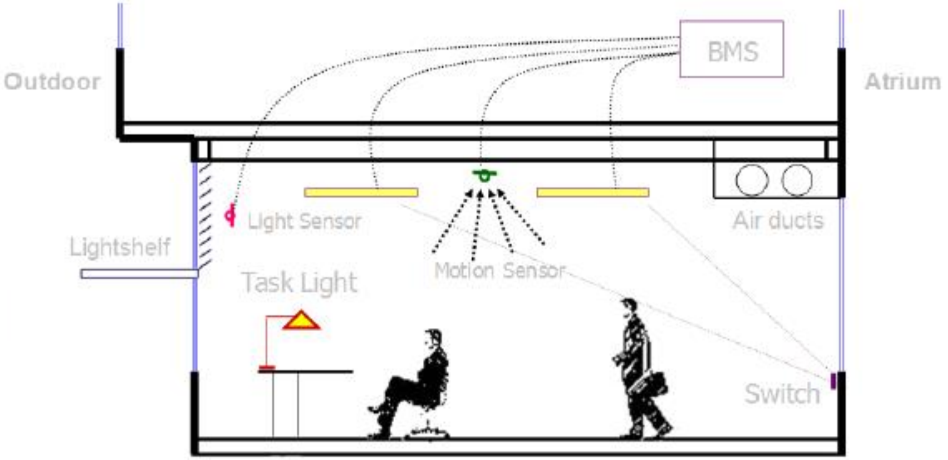


N



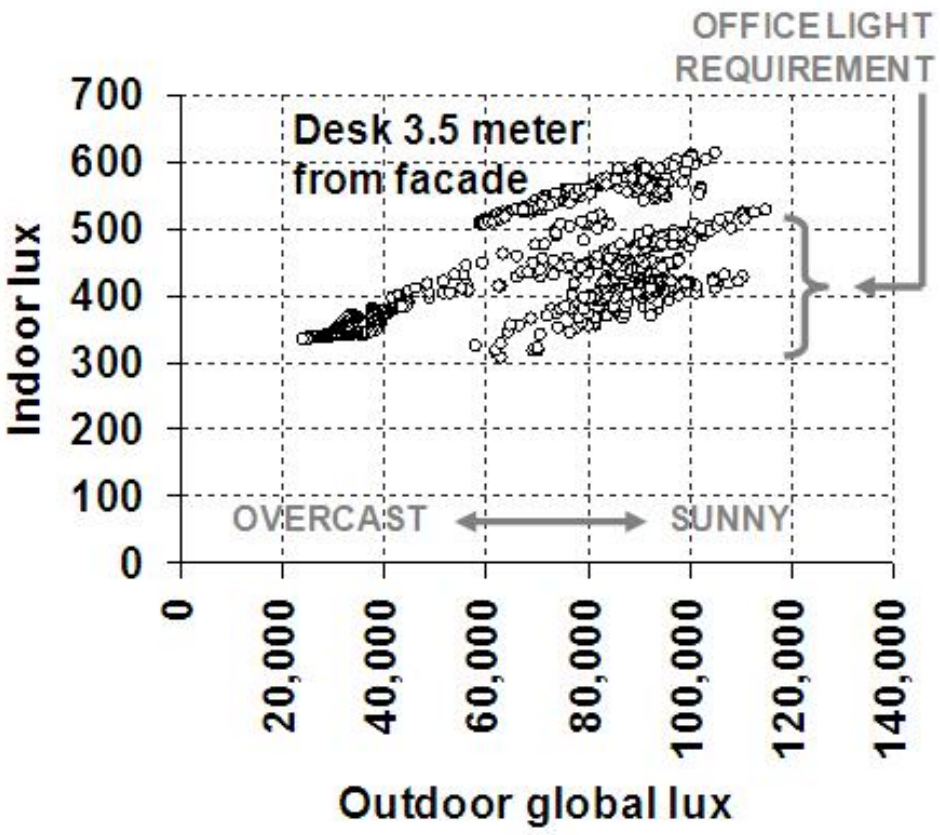
SUCCESS STORIES - GREEN ENERGY OFFICE (GEO) BUILDING, BANGI

Split Window Design



Daylight Responsive Lighting

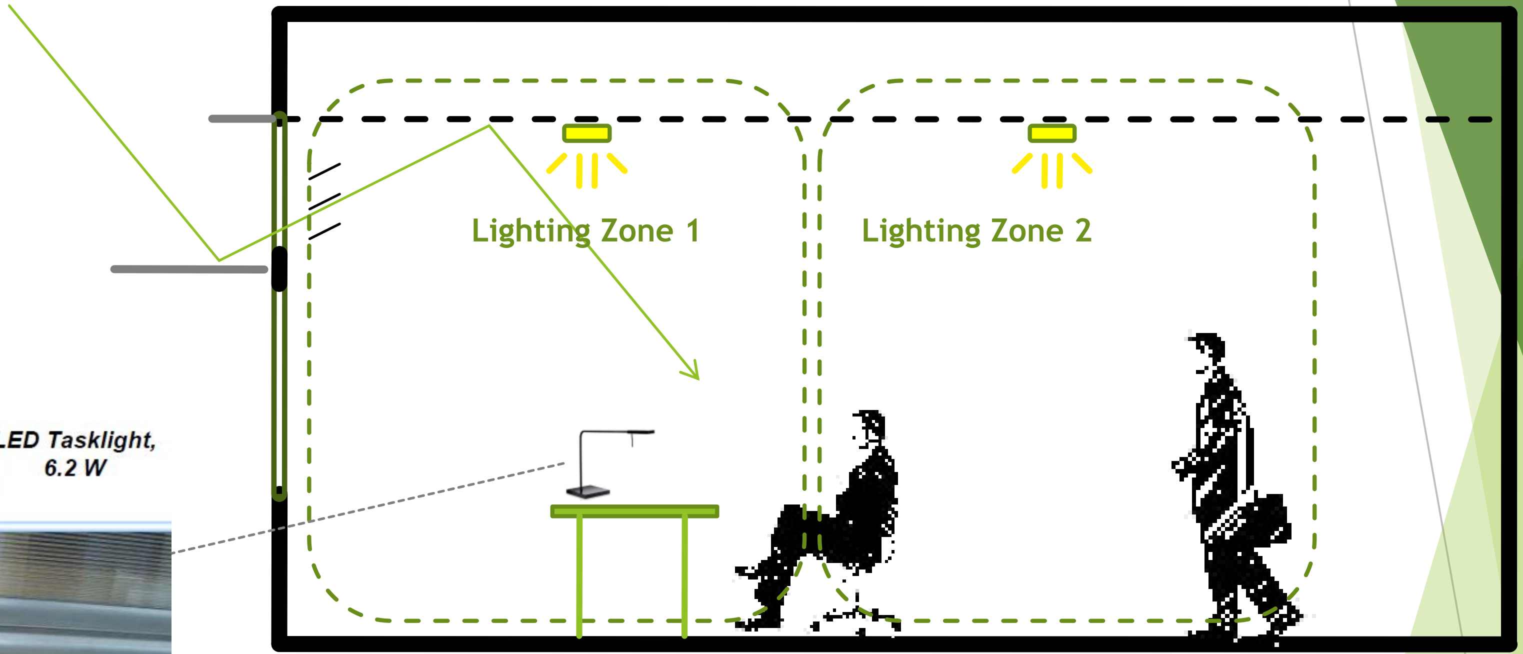
Daylight Measurements



- Lighting consumption: 0.56 W/m^2
- Code requirement: 15 W/m^2

25 times more efficient

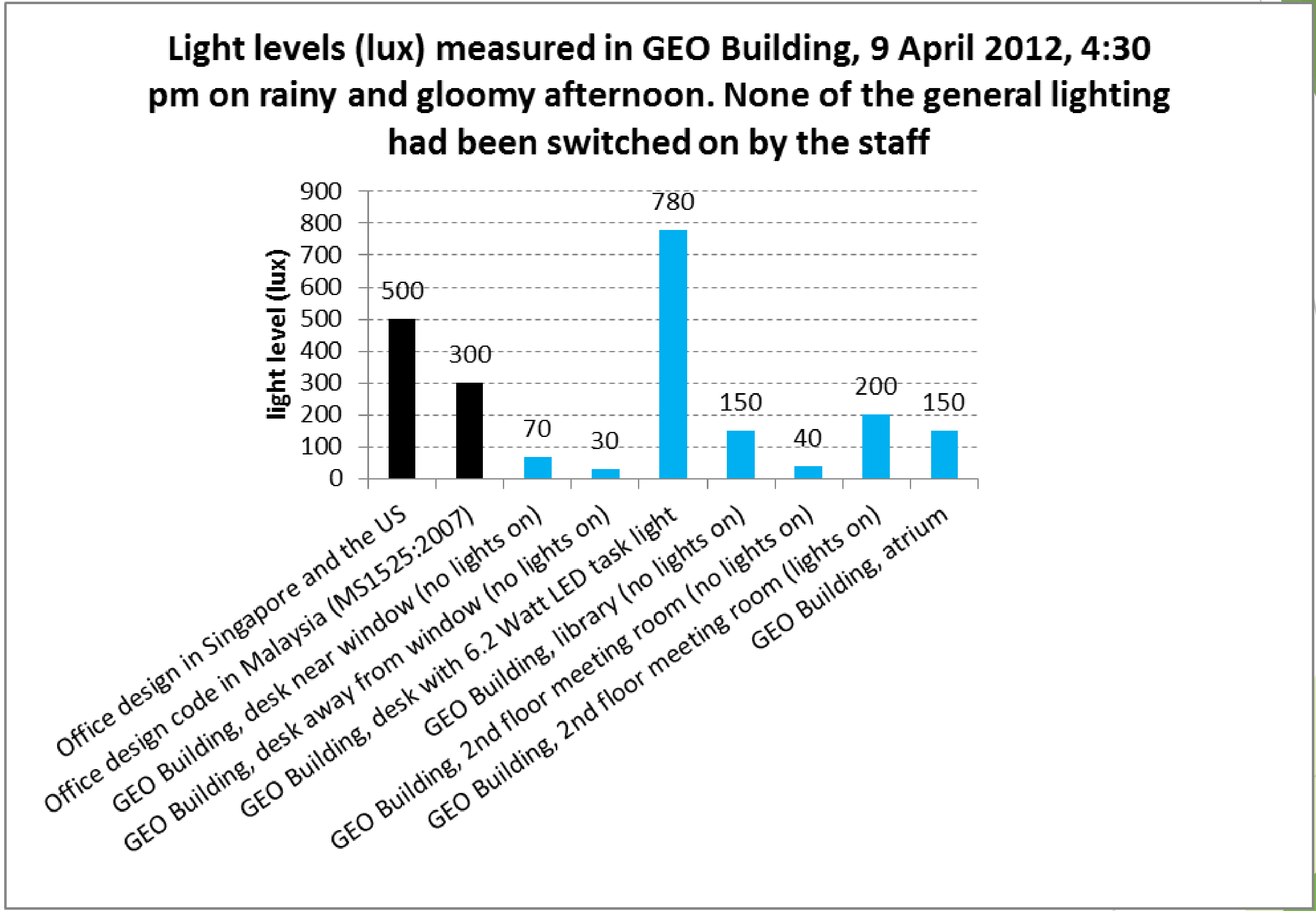
Daylight Responsive Lighting



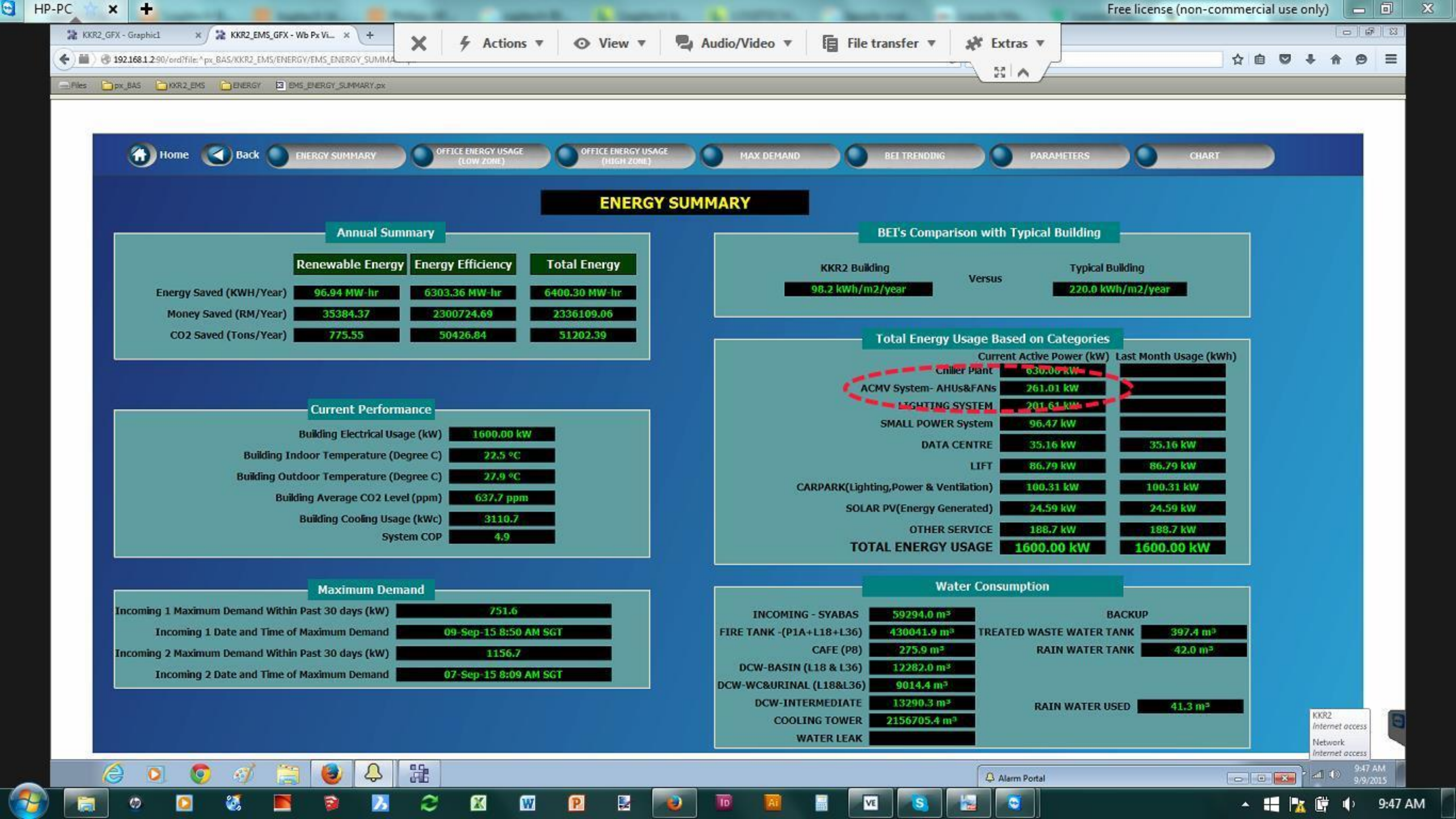
Lighting Control

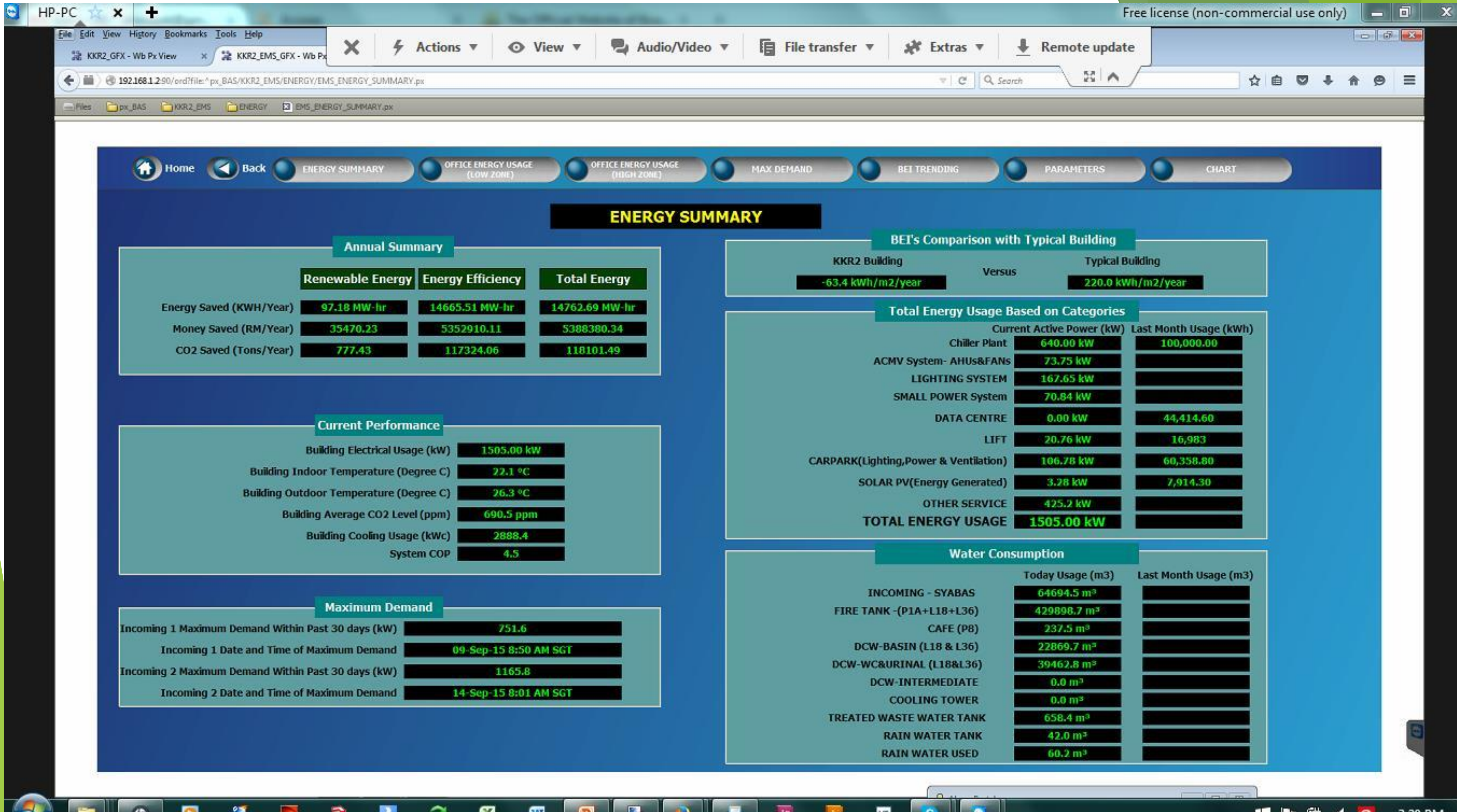
- Automatic off (light sensor and/or occupancy sensor)
- Manual on (people press the wall switch)
- Use task light (table lamp)

GEO Building Daylight Measurements



Air Distribution System


Home
Back
ENERGY SUMMARY
OFFICE ENERGY USAGE (LOW ZONE)
OFFICE ENERGY USAGE (HIGH ZONE)
MAX DEMAND
BEI TRENDING
PARAMETERS
CHART
ENERGY SUMMARY
Annual Summary
Renewable Energy
Energy Efficiency
Total Energy
Energy Saved (KWH/Year) 96.94 MW-hr 6303.36 MW-hr 6400.30 MW-hr
Money Saved (RM/Year) 35384.37 2300724.69 2336109.06
CO2 Saved (Tons/Year) 775.55 50426.84 51202.39
BEI's Comparison with Typical Building
KKR2 Building
98.2 kWh/m2/year
Versus
Typical Building
220.0 kWh/m2/year
Total Energy Usage Based on Categories
Current Active Power (kW)
Last Month Usage (kWh)
Chiller Plant 630.00 kW
ACMV System- AHUs&FANs 261.01 kW
LIGHTING SYSTEM 201.61 kW
SMALL POWER System 96.47 kW
DATA CENTRE 35.16 kW 35.16 kW
LIFT 86.79 kW 86.79 kW
CARPARK(Lighting,Power & Ventilation) 100.31 kW 100.31 kW
SOLAR PV(Energy Generated) 24.59 kW 24.59 kW
OTHER SERVICE 188.7 kW 188.7 kW
TOTAL ENERGY USAGE 1600.00 kW 1600.00 kW
Current Performance
Building Electrical Usage (kW) 1600.00 kW
Building Indoor Temperature (Degree C) 22.5 °C
Building Outdoor Temperature (Degree C) 27.9 °C
Building Average CO2 Level (ppm) 637.7 ppm
Building Cooling Usage (kWc) 3110.7
System COP 4.9
Maximum Demand
Incoming 1 Maximum Demand Within Past 30 days (kW) 751.6
Incoming 1 Date and Time of Maximum Demand 09-Sep-15 8:50 AM SGT
Incoming 2 Maximum Demand Within Past 30 days (kW) 1156.7
Incoming 2 Date and Time of Maximum Demand 07-Sep-15 8:09 AM SGT
Water Consumption
INCOMING - SYABAS 59294.0 m³
FIRE TANK -(P1A+L18+L36) 430041.9 m³
CAFE (P8) 275.9 m³
DCW-BASIN (L18 & L36) 12282.0 m³
DCW-WC&URINAL (L18&L36) 9014.4 m³
DCW-INTERMEDIATE 13290.3 m³
COOLING TOWER 2156705.4 m³
WATER LEAK
BACKUP
TREATED WASTE WATER TANK 397.4 m³
RAIN WATER TANK 42.0 m³
RAIN WATER USED 41.3 m³


HP-PC
Free license (non-commercial use only)
Actions
View
Audio/Video
File transfer
Extras
Remote update
KKR2_GFX - Wb Px View
KKR2_EMS_GFX - Wb Px
Home
Back
ENERGY SUMMARY
OFFICE ENERGY USAGE (LOW ZONE)
OFFICE ENERGY USAGE (HIGH ZONE)
MAX DEMAND
BEI TRENDING
PARAMETERS
CHART
ENERGY SUMMARY
Annual Summary
Renewable Energy
Energy Efficiency
Total Energy
Energy Saved (KWH/Year)
97.18 MW-hr
14665.51 MW-hr
14762.69 MW-hr
Money Saved (RM/Year)
35470.23
5352910.11
5388380.34
CO2 Saved (Tons/Year)
777.43
117324.06
118101.49
Current Performance
Building Electrical Usage (kW)
1505.00 kW
Building Indoor Temperature (Degree C)
22.1 °C
Building Outdoor Temperature (Degree C)
26.3 °C
Building Average CO2 Level (ppm)
690.5 ppm
Building Cooling Usage (kWc)
2888.4
System COP
4.5
Maximum Demand
Incoming 1 Maximum Demand Within Past 30 days (kW)
751.6
Incoming 1 Date and Time of Maximum Demand
09-Sep-15 8:50 AM SGT
Incoming 2 Maximum Demand Within Past 30 days (kW)
1165.8
Incoming 2 Date and Time of Maximum Demand
14-Sep-15 8:01 AM SGT
BEI's Comparison with Typical Building
KKR2 Building
-63.4 kWh/m2/year
Versus
Typical Building
220.0 kWh/m2/year
Total Energy Usage Based on Categories
Current Active Power (kW)
Last Month Usage (kWh)
Chiller Plant
640.00 kW
100,000.00
ACMV System- AHUs&FANs
73.75 kW
LIGHTING SYSTEM
167.65 kW
SMALL POWER System
70.84 kW
DATA CENTRE
0.00 kW
44,414.60
LIFT
20.76 kW
16,983
CARPARK(Lighting,Power & Ventilation)
106.78 kW
60,358.80
SOLAR PV(Energy Generated)
3.28 kW
7,914.30
OTHER SERVICE
425.2 kW
TOTAL ENERGY USAGE
1505.00 kW
Water Consumption
Today Usage (m3)
Last Month Usage (m3)
INCOMING - SYABAS
64694.5 m³
FIRE TANK -(P1A+L18+L36)
429898.7 m³
CAFE (P8)
237.5 m³
DCW-BASIN (L18 & L36)
22869.7 m³
DCW-WC&URINAL (L18&L36)
39462.8 m³
DCW-INTERMEDIATE
0.0 m³
COOLING TOWER
0.0 m³
TREATED WASTE WATER TANK
658.4 m³
RAIN WATER TANK
42.0 m³
RAIN WATER USED
60.2 m³

Air Distribution System

- MS 1525 Motor Efficiency

Table 15. Class definition for 4-pole motors

Motor Capacity (kW)	Motor Efficiency (%)	
	Motor Class Eff2	Motor Class Eff1
1.1	≥ 76.2	≥ 83.8
1.5	≥ 78.5	≥ 85.0
2.2	≥ 81.0	≥ 86.4
3	≥ 82.6	≥ 87.4
4	≥ 84.2	≥ 88.3
5.5	≥ 85.7	≥ 89.2
7.5	≥ 87.0	≥ 90.1
11	≥ 88.4	≥ 91.0
15	≥ 89.4	≥ 91.8
18.5	≥ 90.0	≥ 92.2
22	≥ 90.5	≥ 92.6
30	≥ 91.4	≥ 93.2
37	≥ 92.0	≥ 93.6
45	≥ 92.5	≥ 93.9
55	≥ 93.0	≥ 94.2
75	≥ 93.6	≥ 94.7
90	≥ 93.9	≥ 95.0

Table 16. Class definition for 2-pole motors

Motor Capacity (kW)	Motor Efficiency (%)	
	Motor Class Eff2	Motor Class Eff1
1.1	≥ 76.2	≥ 82.8
1.5	≥ 78.5	≥ 84.1
2.2	≥ 81.0	≥ 85.6
3	≥ 82.6	≥ 86.7
4	≥ 84.2	≥ 87.6
5.5	≥ 85.7	≥ 88.6
7.5	≥ 87.0	≥ 89.5
11	≥ 88.4	≥ 90.5
15	≥ 89.4	≥ 91.3
18.5	≥ 90.0	≥ 91.8
22	≥ 90.5	≥ 92.2
30	≥ 91.4	≥ 92.9
37	≥ 92.0	≥ 93.3
45	≥ 92.5	≥ 93.7
55	≥ 93.0	≥ 94.0
75	≥ 93.6	≥ 94.6
90	≥ 93.9	≥ 95.0

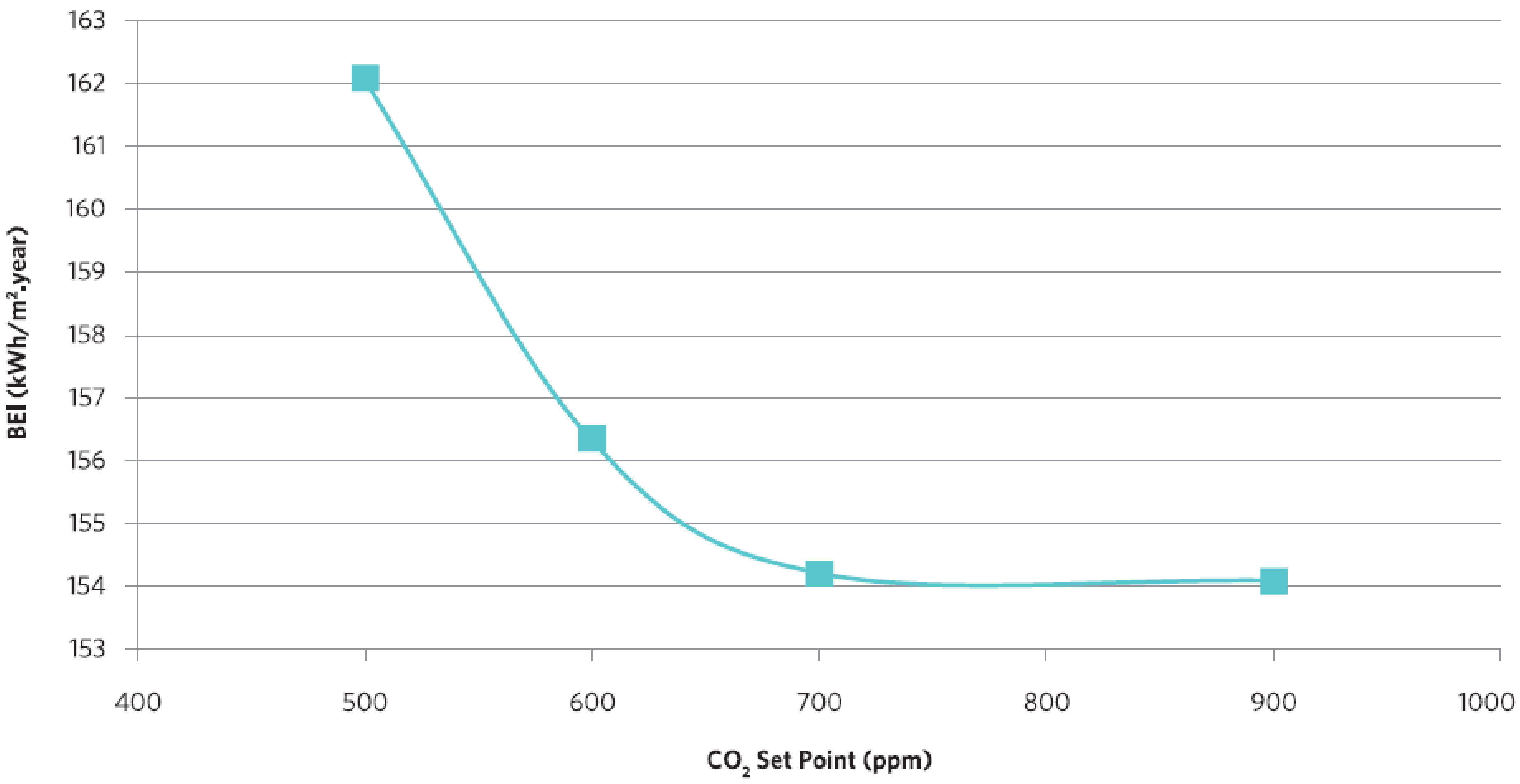
Fresh Air Demand Control Using CO2 Sensors

- ASHRAE 62.1 state need of Fresh air intake for indoor environment.
- However Hot Outdoor air will increase heat load of building.
- Therefore, use of CO2 sensor to regulate the fresh air intake.

TABLE 7.5 | BUILDING PEAK COOLING LOAD REDUCTION DUE TO THE USE OF CO_2 DEMAND CONTROLLED FRESH AIR VENTILATION STRATEGY

Description	Peak cooling load (W/m^2)
No CO_2 sensor	167.0
With CO_2 sensor, Set point 900 ppm	164.7
Difference	2.3

FIGURE 7.16 | IMPACT ON BEI BASED ON CO_2 SET POINT IN A SPARSELY OCCUPIED BUILDING (40% DESIGN OCCUPANCY)



Chilled Water Plant

Equipment	Size	*COP @, 100% Load Conditions		*COP @ NPL V Conditions	
		Minimum COP	**Maximum kWe/RT**	**Minimum COP**	**Maximum kWe/RT**
Air cooled, with condenser	< 105 kWr (30RT)	2.6	1.36	2.8	1.26
	≥ 105 kWr and < 530 kWr (150RT)	2.7	1.30	2.8	1.26
	≥ 530 kWr and < 1060 kWr (300RT)	2.8	1.26	2.9	1.21
	≥ 1060 kWr (300RT)	2.9	1.21	3.0	1.18
Water cooled, positive displacement (Reciprocating and Scroll)	All capacities	3.9	0.90	4.0	0.88
Water cooled, positive Displacement (Rotary Screw)	< 530 kWr (150RT)	4.0	0.88	4.2	0.84
	≥ 530 kWr and < 1060 kWr (300RT)	4.4	0.80	4.7	0.75
	≥ 1060 kWr (300RT)	5.4	[illegible]	[illegible]	0.61
Water cooled, centrifugal	< 1060 kWr (300RT)	[illegible]	0.68	4.7	0.75
	≥ 1060 kWr (300RT)	5.7	0.62	5.2	0.68

What is COP stand for?

Coefficient of Performance (COP). A ratio of the cooling capacity in watts [kW] to the Total Power Input, in watts [kW] at any given set of Rating Conditions, expressed in kilowatts/kilowatt [kW/kW].

3.37 COP = 1kW/(3.37kW/3.5172) = 1.044kW/Ton

Equipment	Size	*COP @, 100% Load Conditions		*COP @ NPLV Conditions	
		Minimum COP	Maximum kWe/RT	Minimum COP	Maximum kWe/RT
Air cooled, with condenser	< 105 kWr (30RT)	2.6	1.36	2.8	1.26
	≥ 105 kWr and < 530 kWr (150RT)	2.7	1.30	2.8	1.26
	≥ 530 kWr and < 1060 kWr (300RT)	2.8	1.26	2.9	1.21
	≥ 1060 kWr (300RT)	2.9	1.21	3.0	1.18
Water cooled, positive displacement (Reciprocating and Scroll)	All capacities	3.9	0.90	4.0	0.88
Water cooled, positive Displacement (Rotary Screw)	< 530 kWr (150RT)	4.0	0.88	4.2	0.84
	≥ 530 kWr and < 1060 kWr (300RT)	4.4	0.80	4.7	0.75
	≥ 1060 kWr (300RT)	5.4	0.65	5.8	0.61
Water cooled, centrifugal	< 1060 kWr (300RT)	5.2	0.68	4.7	0.[illegible]5
	≥ 1060 kWr (300RT)	5.7	0.62	5.2	0.68

300RT & Above
0.617kW/Ton or better

Chilled Water and Condenser Pump Efficiency

Benchmark criteria: SS553

10.5.1.1 Hydronic Variable Flow Systems

The pump power limitation for chilled water systems shall be 349 $kW/m^3/s$. The pump power limitation for condensing water systems is 301 $kW/m^3/s$.

Cooling Tower Efficiency

ASHRAE 90.1

Table 3 – Performance requirements for heat rejection equipment

Equipment type	Total system heat rejection capacity at rated conditions	Subcategory or rating condition	Performance required[a]	Test procedure
Propeller or axial fan cooling towers	All	35 °C Entering water 29 °C Leaving water 24 °C wb Outdoor air	≥ 3.23 L/s.kW	CTI ATC-105
Centrifugal fan cooling towers	All	35 °C Entering water 29 °C Leaving water 24 °C wb Outdoor air	≥ 1.7 L/s.kW	CTI ATC-105

[a] For the purpose of this table,

- cooling tower performance is defined as the maximum flow rating of the tower divided by the nameplate rated motor power
- air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the nameplate rated motor power

For cooling tower flowrate = 3GPM per Ton
= 0.1893 litre per sec per ton
With every 3.23 L/s, we can remove 23 Ton
Therefore with every 1kW we remove 23Ton
Thus, minimum requirement = (1/23) x (1 + 1 / Chiller COP)

Plantroom Efficiency Baseline Reference

	Benchmark Reference	kW/Ton	COP
Chiller (Centrifugal > 300RT)	MS1525	0.617	
Chilled Water Pumps	SS553	0.0529	
Condenser Water Pumps	SS553	0.0457	
Cooling Towers	ASHRAE 90.1	0.055	
Total Plantroom System		**0.77**	**4.7**

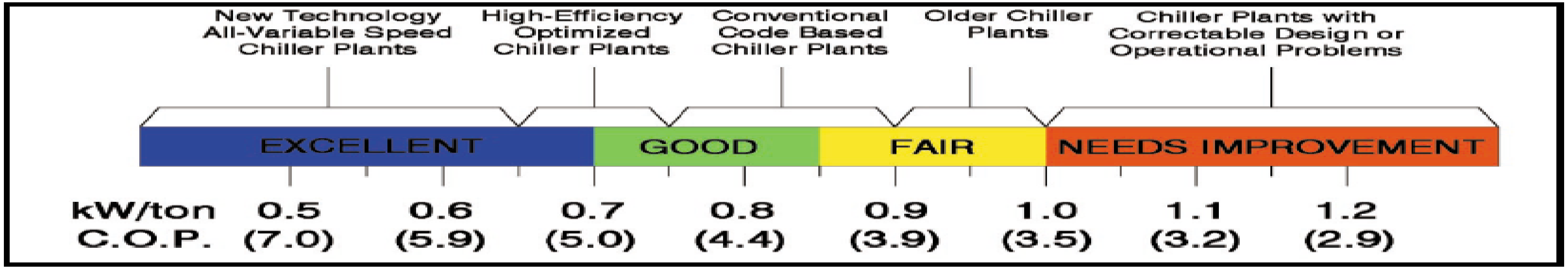


Figure 5: Average annual chiller plant efficiency in kW/ton (COP). Input energy includes chillers, condenser pumps and tower fans, based on electrically driven centrifugal chiller plants in comfort conditioning applications with 42°F (5.6°C) nominal chilled water supply temperature and open cooling towers sized for 85°F (29.4°C) maximum entering condenser water temperature. Local climate adjustment for North America climates is ±0.05 kW/ton.

VRF Minimum Efficiency by ASHRAE 90.1

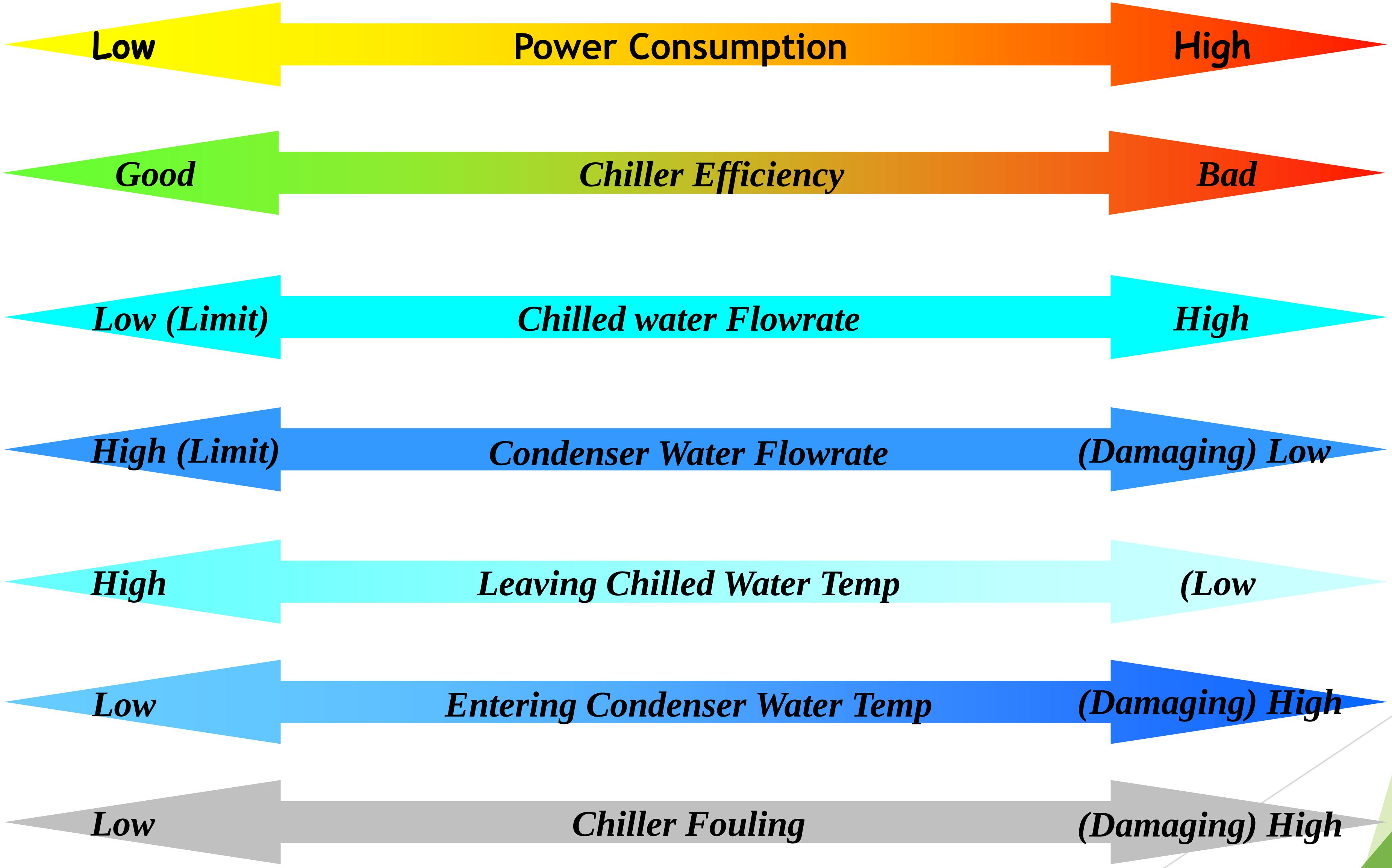
TABLE 6.8.1J Electrically Operated Variable Refrigerant Flow Air-to-Air and Applied Heat Pumps—Minimum Efficiency Requirements *(continued)*

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency	Test Procedure
VRF Ground source (cooling mode)	<40 kW	All	VRF Multisplit System 25°C entering water	3.93 COP_C	AHRI 1230
	<40 kW	All	VRF Multisplit System with Heat Recovery 25°C entering water	3.87 COP_C	
	≥40 kW	All	VRF Multisplit System 25°C entering water	3.22 COP_C	
	≥40 kW	All	VRF Multisplit System with Heat Recovery 25°C entering water	3.16 COP_C	

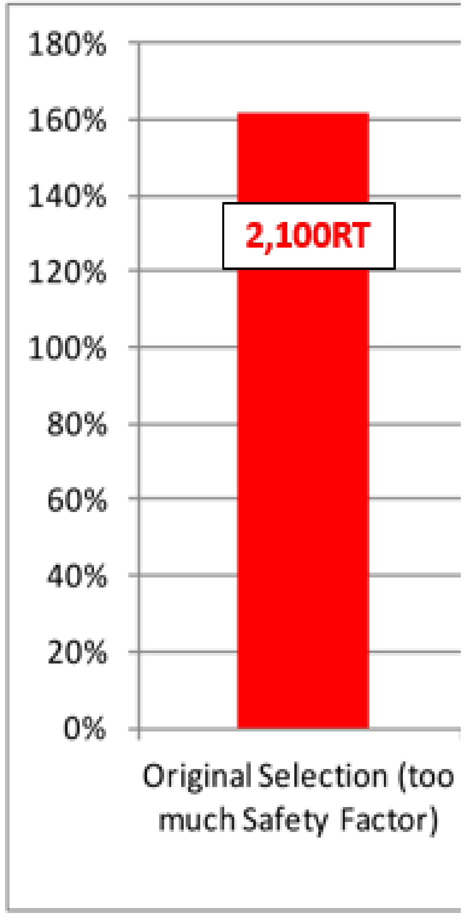
CHILLER:

- ✓ **To configure Chiller Plant in a way that it operates at most efficient zone at most time;**
- ✓ **Design parameters should allow for low compressor head capability, increase evaporator mean saturated temp/pressure by variable flow thus improve chiller efficiency and prevent pipe freeze;**
- ✓ **Off-peak operating chiller should provide flexibility with load fluctuation and yet maintain good efficiency**
- ✓ **Chiller should also comes with good motor efficiency and power factor**

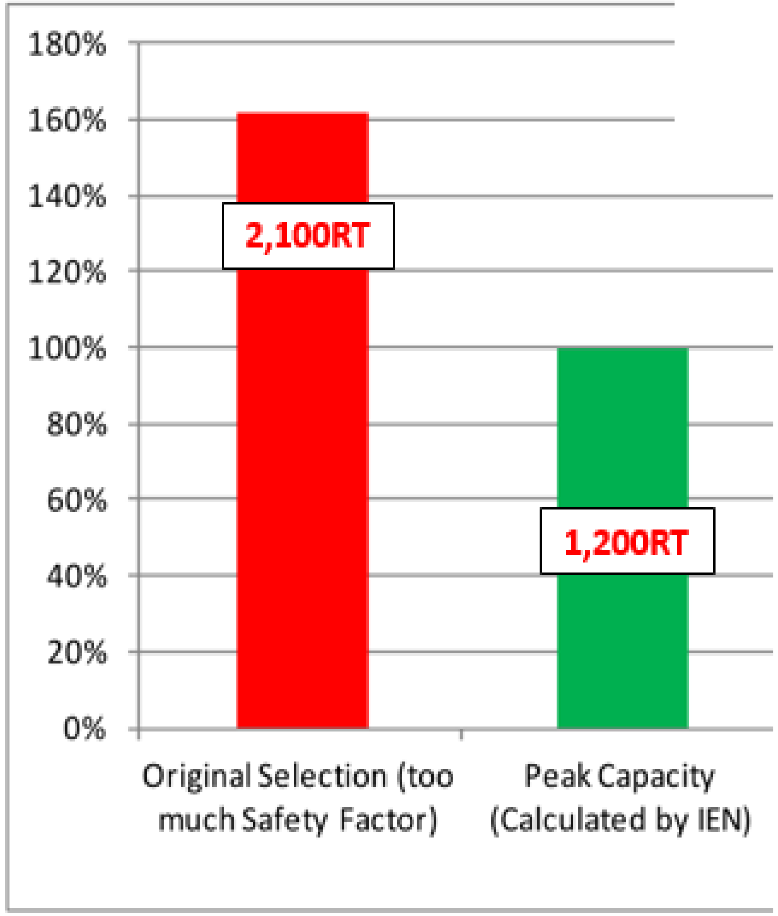
Good Chiller Performance



Our simulations showed that Chiller Plant could be downsized

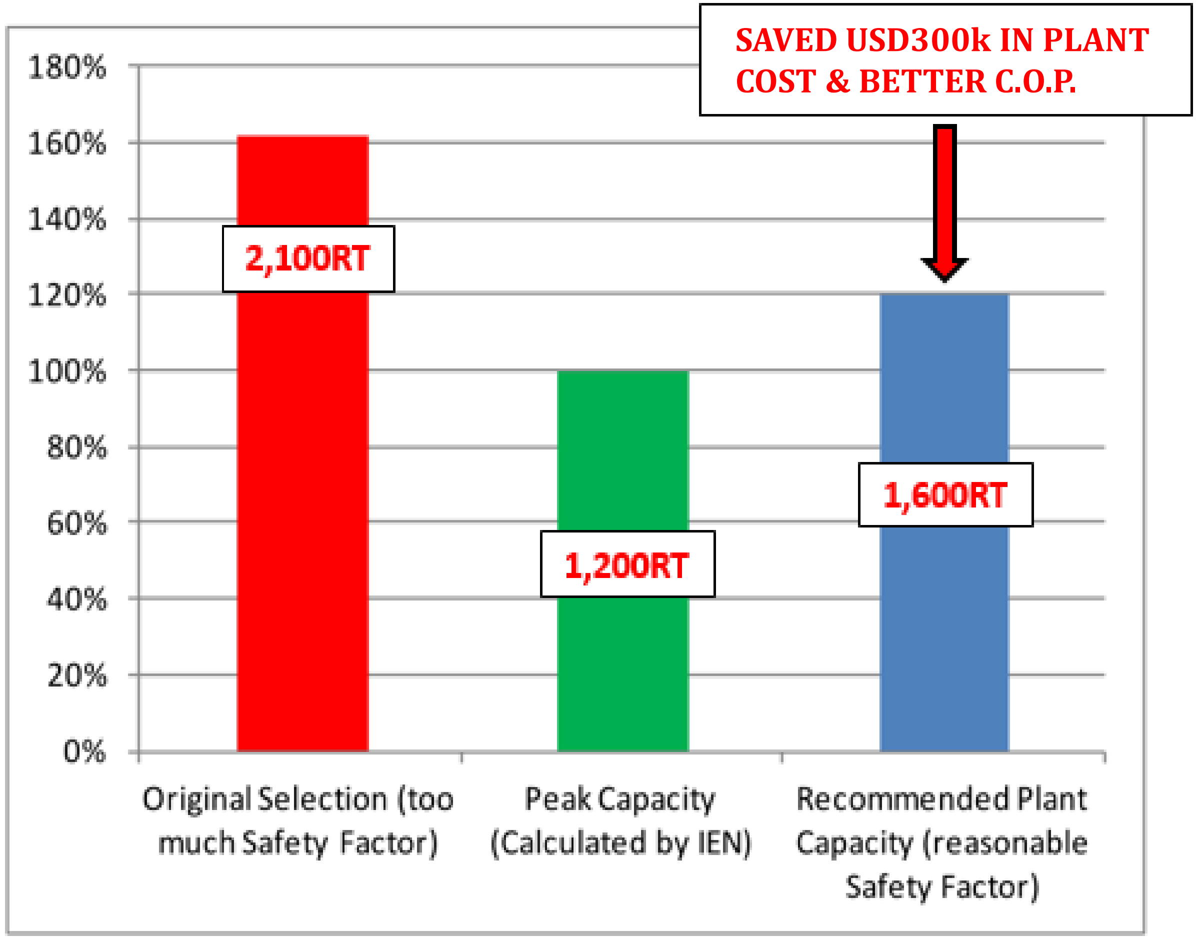


Our simulations showed that Chiller Plant could be downsized



I|E|N CONSULTANTS

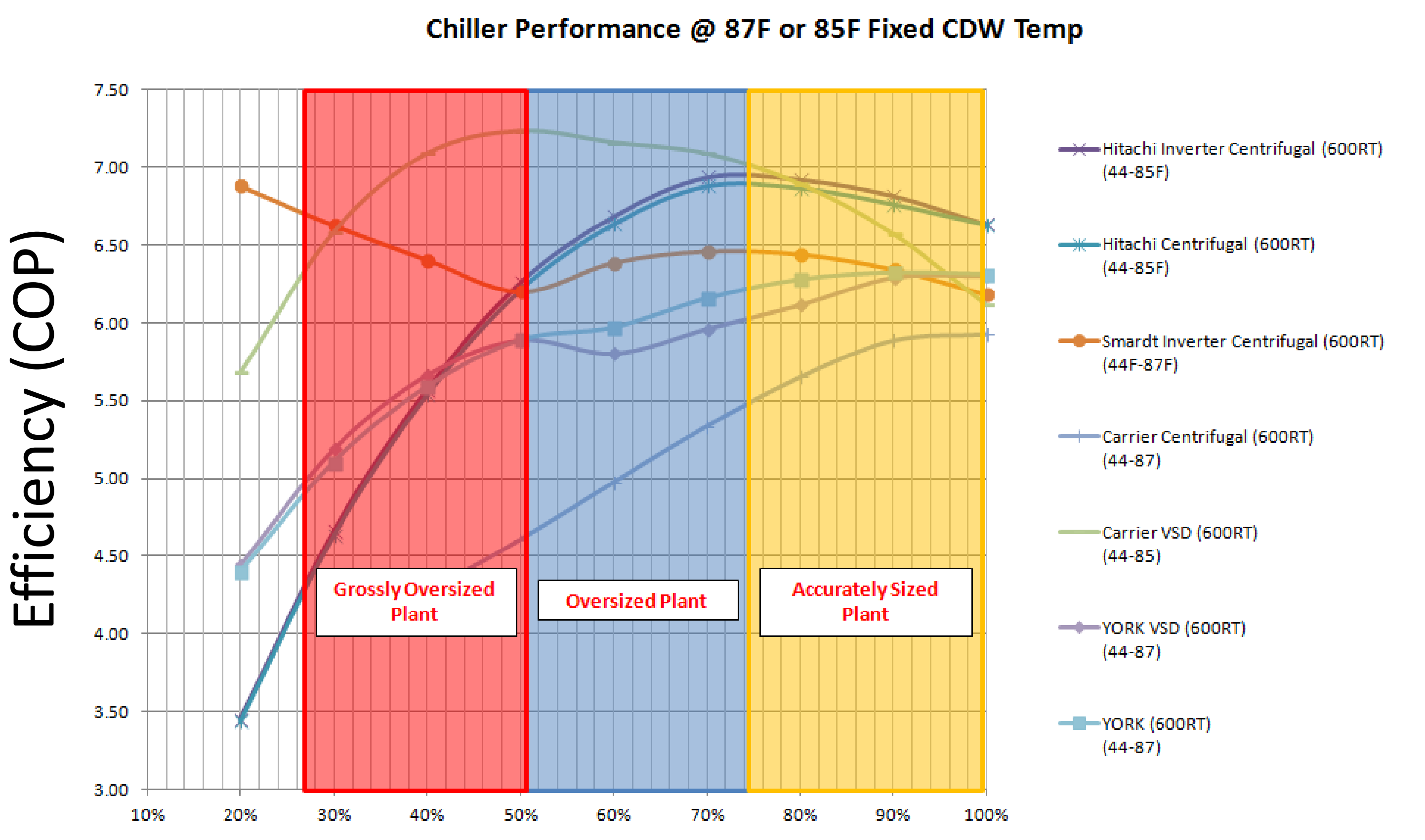
Our simulations showed that Chiller Plant could be downsized



The Double-Penalty of Oversizing the Cooling Plant

High CAPEX **+** **High OPEX**

USD500,000 **USD2,000,000 per year**

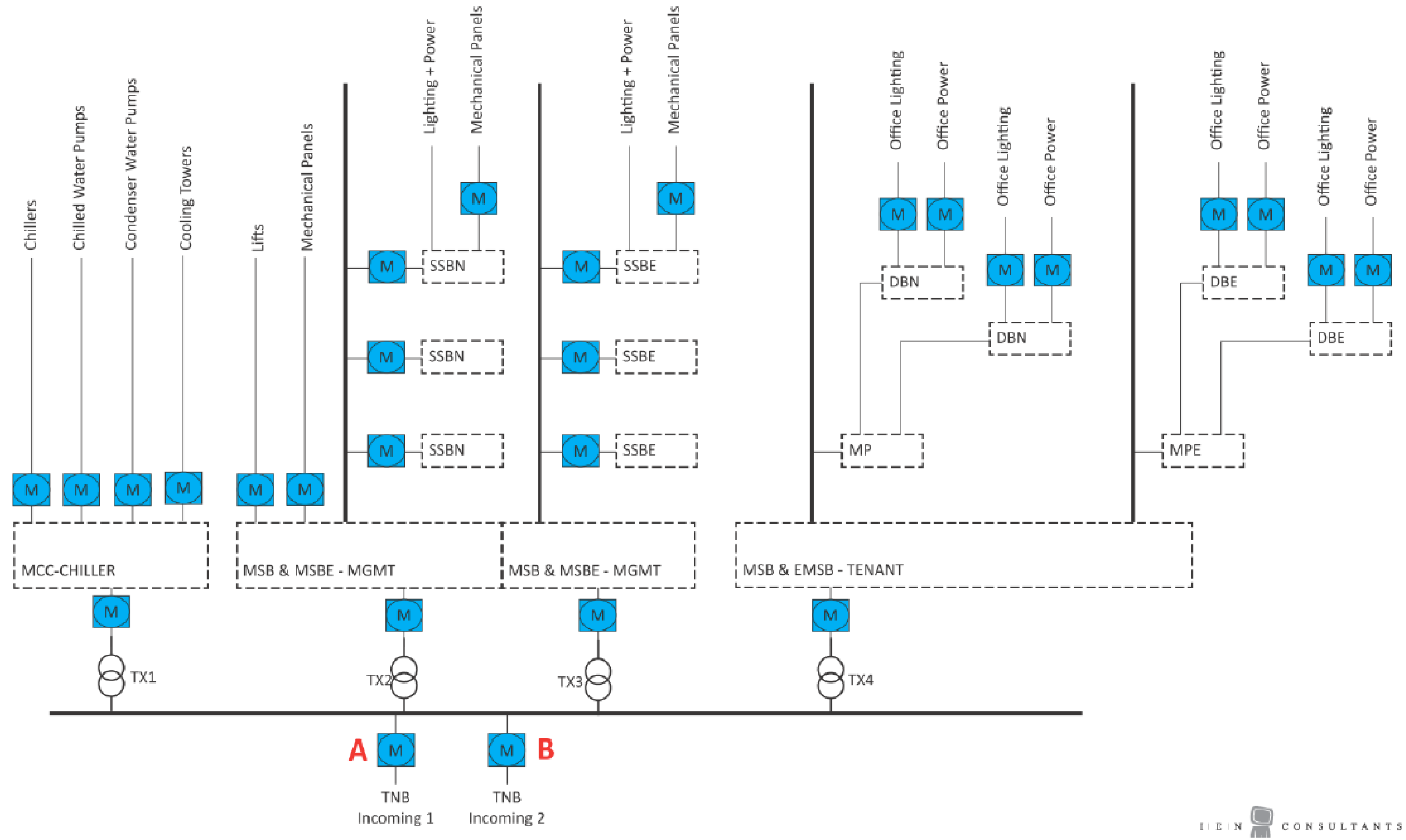


ENERGY METERING PROPOSAL

Notes
1. All digital power meters shall be linked to the BMS/EMS System

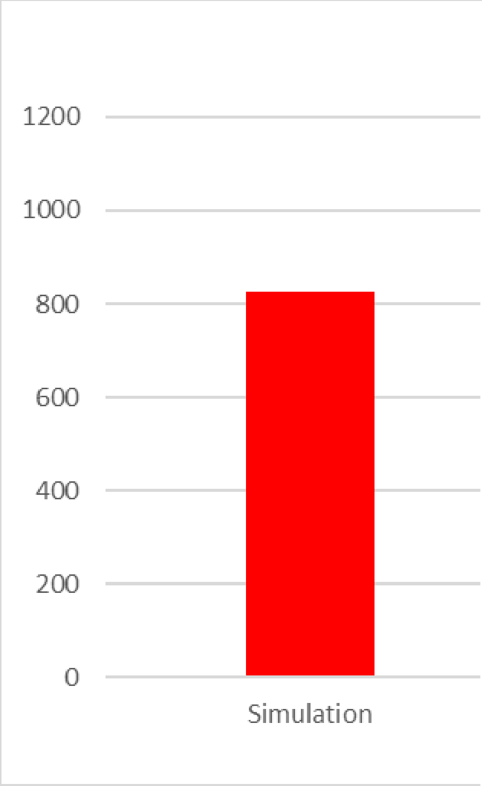
2. All digital power meters shall at minimum provide information on kWH and kW

Legend
M Compulsory Digital Power Meters

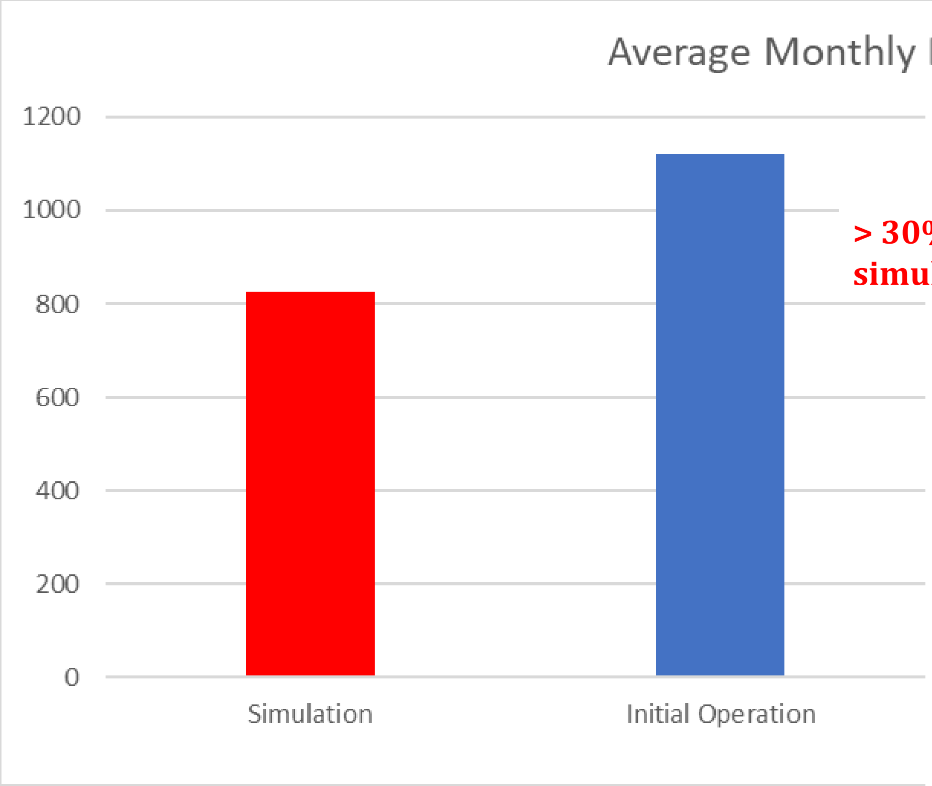


Actual Building vs design case study

Verification & Fine Tuning – Comparing Simulations against Actual Operations



Verification & Fine Tuning – Comparing Simulations against Actual Operations

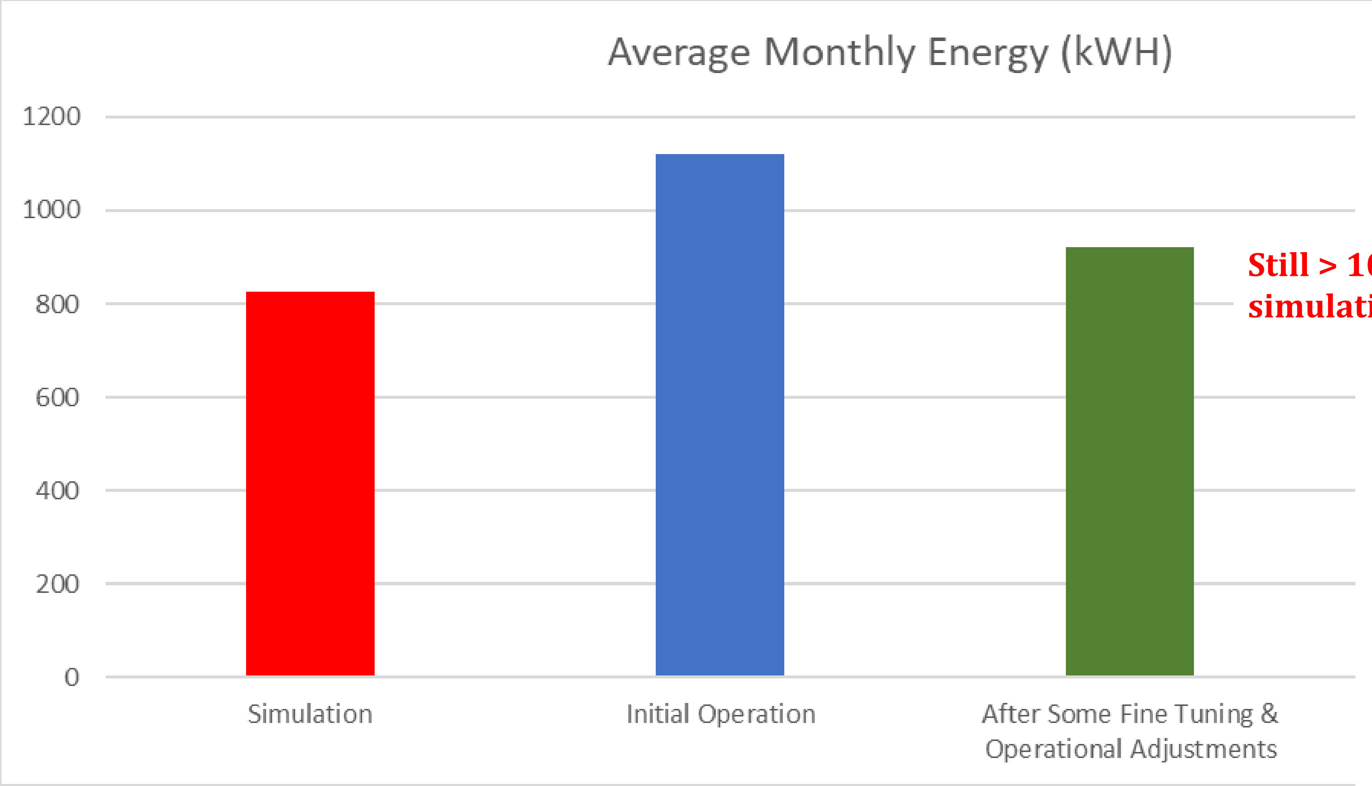


> 30% Higher than simulated energy usage!

Remedial Actions

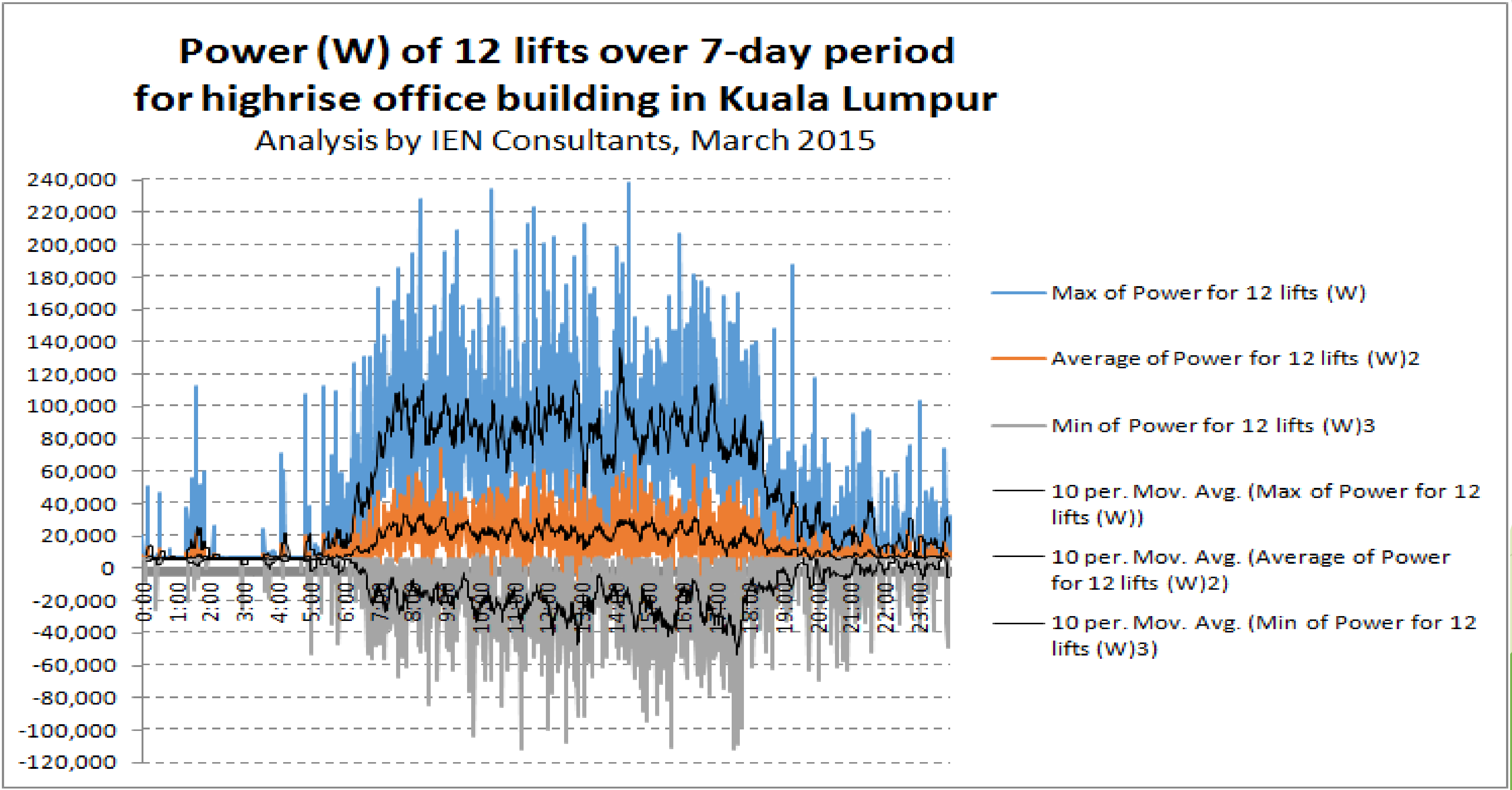
1. Checked BMS schedules
2. Checked and adjusted setpoints
3. Checked BMS control logics
4. Checked chiller plant efficiency & equipment performance

Verification & Fine Tuning – Comparing Simulations against Actual Operations



Still > 10% higher than simulation

Other Energy Efficient features: Regenerative Lift



CONCLUDING REMARK
Buildings are Like a Leaky Bucket

with lots of unnecessary wastages

Plug the holes, and you are well on the way to a green inexpensive buildings that people appreciate to use

Recommendation for Reading

Available at :
http://bseep.gov.my/publications/

Thanks You

By Tan Chin Hong
chinhong@ien.com.my
+60174145928