Optimizing Energy Efficiency for a High Rise Office Tower in Tropics

Driving Running Cost Down > 70% in a High-Rise

Presented by: Yong Kong, nyk@bezaire.com.my

Lead Author: CK Tang, ck@ckatwork.com

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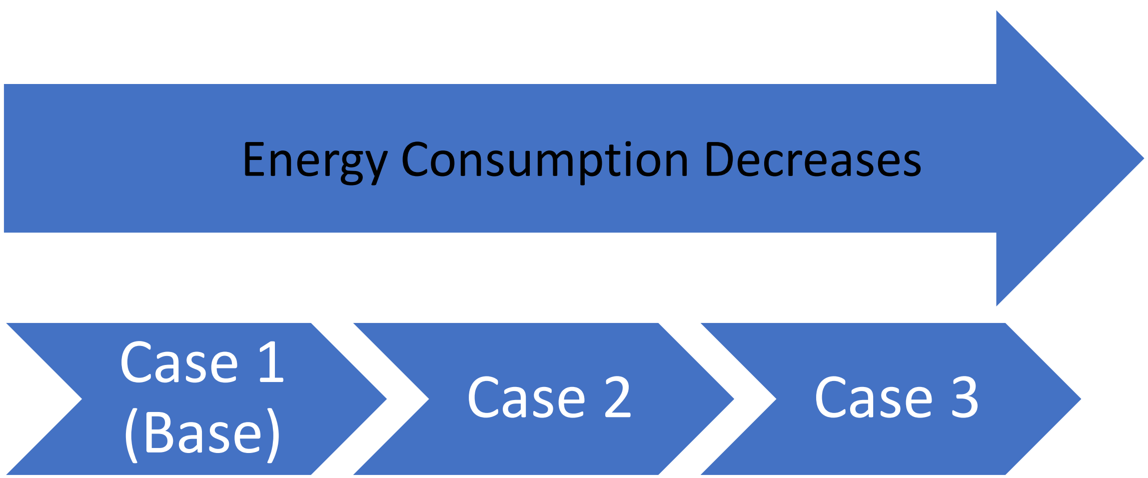
Background

- 27 office levels
- 8 levels of podium
- Completion in Mid-2017
- Located in Johor Bharu, Malaysia. Just north of Singapore.
- Multi-tenanted office tower.
- Owners pay running cost for whole building Air-Conditioning and Common Area spaces.
- Building Energy Simulation Study Conducted to optimize building.

Study Concept

- Energy consumed by the Tower over 48 different simulation cases
- Analyze energy (BEI) and air conditioning Peak Cooling Load
- Each case brings improvement to passive and active systems



Computational Simulation Tool

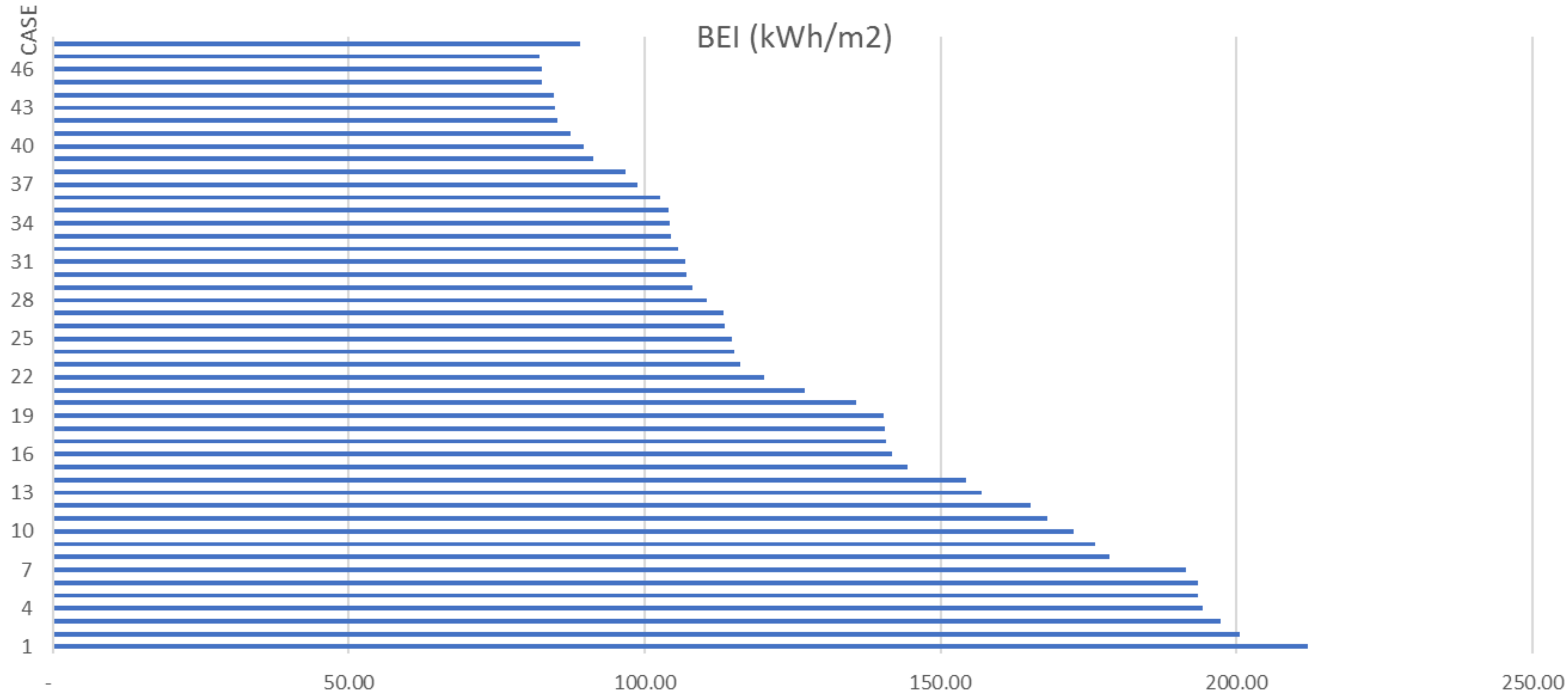
- Integrated Environment Solutions Virtual Environment (IES VE) software
- Simulate sun position, cloud cover, shading, internal heat gain and M&E systems.
- Dynamic simulation model = Time varying model.

Simulation Cases and Results

Case	Descriptions	100% Occupancy					
		Total Energy per year (MWh)	BEI (kWh/m2)	Total Energy Cost per year (RM)	Energy per year by Owner (MWh)	Energy Cost per year by Owner (RM)	Peak Cooling Load (kW)
1	Base Building	8,146.80	212.08	2,851,379	5,717.62	2,001,168	7,394.06
2	Daylight Implementation in Offices (3 meter Depth)	7,706.85	200.63	2,697,396	5,586.20	1,955,170	7,260.99
3	Daylight Implementation in Offices (4 meter Depth)	7,576.80	197.24	2,651,882	5,547.28	1,941,548	7,220.21
4	Daylight Implementation in Offices (5 meter Depth)	7,463.13	194.28	2,612,097	5,513.00	1,929,550	7,182.19
5	Roof Insulation (No insulation to 50mm insulation)	7,430.69	193.44	2,600,742	5,480.56	1,918,195	7,148.49
6	Roof Insulation (50mm insulation to 100mm insulation)	7,430.88	193.44	2,600,808	5,480.74	1,918,261	7,152.80
7	Wall insulation (No insulation to 25mm rockwool)	7,354.56	191.46	2,574,096	5,404.42	1,891,548	7,012.29
8	Glazing (All glass from conventional to Low-E)	6,858.71	178.55	2,400,550	4,908.58	1,718,002	6,239.73
9	Glazing (Light coloured glass to Double Glz Low-E)	6,765.74	176.13	2,368,010	4,815.61	1,685,462	6,141.19

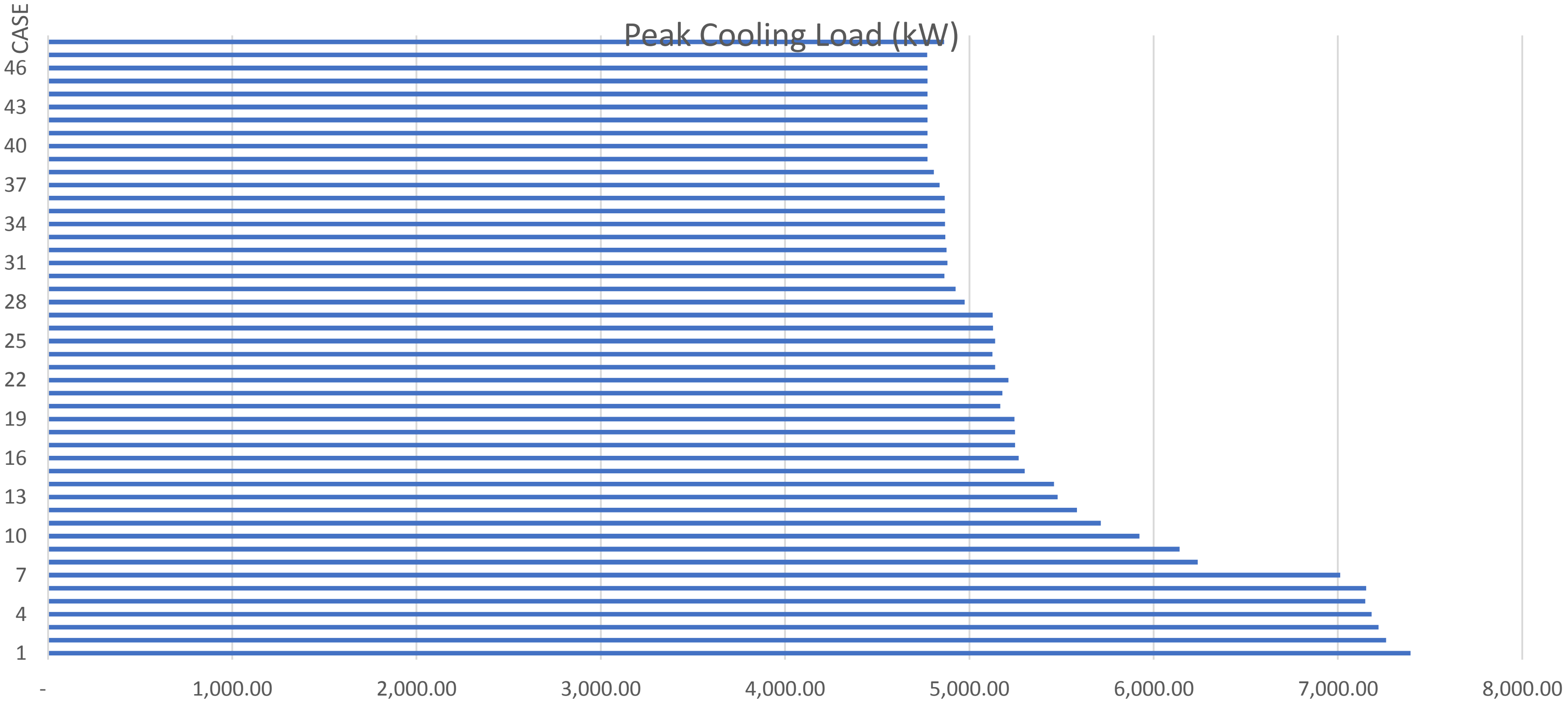
Simulation Cases and Results

Building Energy Intensity (BEI) of each Case



Simulation Cases and Results

Peak Cooling Load of each Case



Analysis

Case 1: Base Building

Construction Material	
Typical Flat Roof – No insulation	U-value = 3.759
Standard Glazing	U-value = 4.825
Standard External Wall	U-value = 1.794
Lighting Power Density (MS 1525)	
Lobby / Walkway	20 W/m2
Office	15 W/m2
Observatory	15 W/m2
Pantry	15 W/m2
Staircase	15 W/m2
Toilet	10 W/m2
Common Area Night Light	50% switched on
Building Air Tightness	
Infiltration	0.5 ACH
Daylight Sensor	None
Light Shelves	None

Analysis

Case 1: Base Building cont.

Air Conditioning System	
Air side	Constant Air Volume (CAV)
Chiller	Constant speed
Chilled / Condenser Water Pump	Constant speed
Duct Static Pressure	1300 Pa
Fan Motor Efficiency	61.2%
Fresh Air CO2 sensor	None
Heat Recovery System	None
Chilled Water Delta T	12 F
Chilled Water Pump Pressure	40m
Chilled Water Pump Efficiency	63%
Chiller COP	5.5
Chilled Water Delta T	12 F
Chilled Water Pump Pressure	40m
Chilled Water Pump Efficiency	63%
Cooling Tower Efficiency	0.0463 kWe per HRT

Analysis

Case 1: Base Building

- BEI = 212.08 kWh/m2
- Peak Cooling Load = 7,394.06 kW

Analysis

Case 2, Case 3 and Case 4: Daylight Implementation

<u>Design Improvement</u>

- Daylight Sensor & light shelves at perimeter office areas up to 3m, 4m and 5m.

<u>Results</u>

- BEI = 194 kWh/m2
- Peak cooling load = 7,182 kW

Analysis

Case 5 and Case 6: Roof Insulation

<u>Design Improvement</u>

- Case 5: 50mm roof polystyrene insulation
- Case 6: 100mm roof polystyrene insulation

<u>Results</u>

- BEI = 193 kWh/m2
- Peak cooling load = 7,152 kW

Analysis

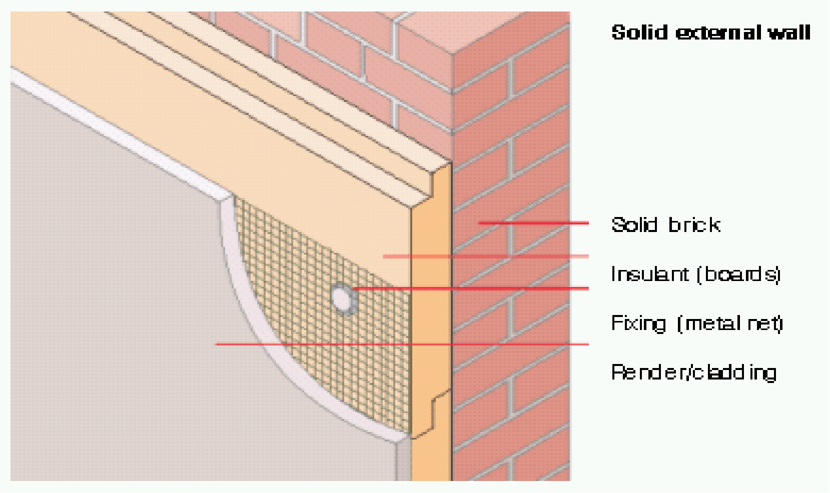
Case 7: Wall Insulation

Design Improvement

- 25mm rockwool insulation to external walls

Results

- BEI = 191 kWh/m2
- Peak cooling load = 7,012 kW



Analysis

Case 8, Case 9 and Case 10: Glazing

<u>Design Improvement</u>

- Case 8: All glazing single glazed, low-E. U-value = 3.806
- Case 9: Light green glazing double glazed low-E. U-value = 1.951.
- Case 10: All glazing double glazed, low-E. U-value = 1.951.

<u>Results</u>

- BEI = 172 kWh/m2 (18.7% lower than base case)
- Peak cooling load = 5,923 kW (19.9% lower than base case)

Analysis

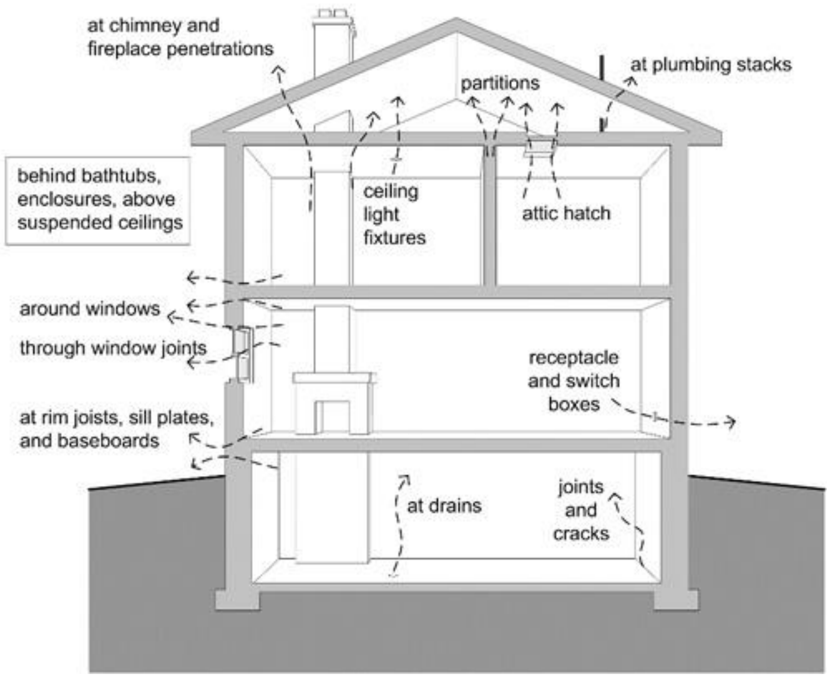
Case 11 and Case 12: Air Tightness

<u>Design Improvement</u>

- Case 11: Infiltration = 0.25 ACH
- Case 12: Infiltration = 0.10 ACH

<u>Results</u>

- BEI = 165 kWh/m2
- Peak cooling load = 5,583 kW

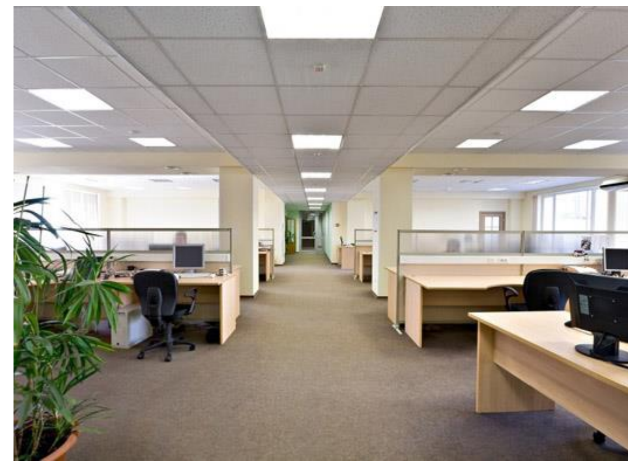


Analysis

Case 13 and Case 14: Office Lighting Power Density

<u>Design Improvement</u>

- Optimize lighting design layout for office areas
- Case 13: 9 W/m2
- Case 14: 7 W/m2



<u>Results</u>

- BEI = 154 kWh/m2
- Peak cooling load = 5,458 kW

Analysis

Case 15 and Case 16: Walkway / Lift Lobby Lighting Power Density

Design Improvement

- Optimize lighting design layout
- Case 13: 9 W/m2
- Case 14: 7 W/m2

Results

- BEI = 141 kWh/m2
- Peak cooling load = 5,267 kW

Analysis

Case 17: Walkway / Lift Lobby Night Light

<u>Design Improvement</u>

- Reduce night time light to 33%

<u>Results</u>

- BEI = 140 kWh/m2
- Peak cooling load = 5,248 kW

Analysis

Case 18: Toilet Lighting Power Density

Design Improvement

- Reduce toilet lighting power density to 7 W/m2

Results

- BEI = 140 kWh/m2
- Peak cooling load = 5,248 kW

Analysis

Case 19: Toilet Occupancy Sensor

Design Improvement

- Occupancy sensor to further reduce lighting to 3.5 W/m2

Results

- BEI = 140 kWh/m2
- Peak cooling load = 5,244 kW

Analysis

Case 20: Staircase Lighting Power Density

Design Improvement

- Reduce staircase lighting power density from 15 W/m2 to 3 W/m2

Results

- BEI = 135 kWh/m2
- Peak cooling load = 5,168 kW

Analysis

Case 21: Air Conditioning Air Side

Design Improvement

- Implement Variable Air Volume (VAV) system
- Variable speed AHU, VAV boxes
- Supply air regulated to occupancy needs

Results

- BEI = 127 kWh/m2
- Peak cooling load = 5,178 kW

Analysis

Case 22 and Case 23: Duct Static Pressure

Design Improvement

- Optimize duct size, reduce tees, bends etc.
- Case 22: Total pressure = 900 Pa
- Case 23: Total pressure = 650 Pa

Results

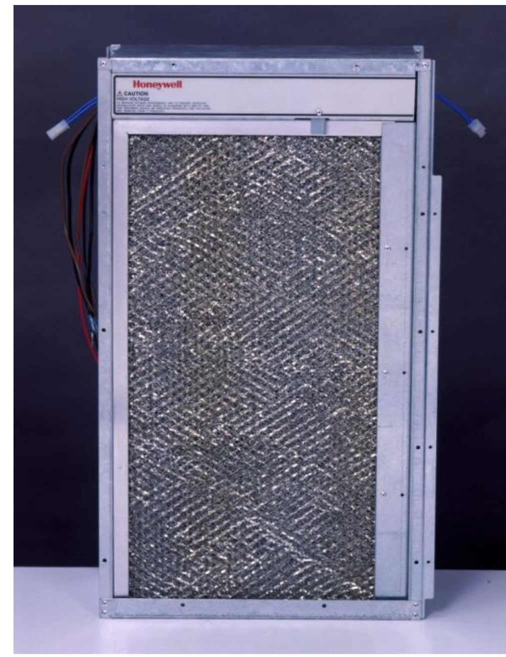
- BEI = 120 kWh/m2
- Peak cooling load = 5,140 kW

Analysis

Case 24 and Case 25: AHU Air Filter

<u>Design Improvement</u>

- Improve air filter for all AHUs
- Case 24: High grade air filter, total pressure = 580 Pa
- Case 25: Electronic air filter, total pressure = 550 Pa



<u>Results</u>

- BEI = 114 kWh/m2
- Peak cooling load = 5,140 kW

Analysis

Case 26 and Case 27: Fan Efficiency

<u>Design Improvement</u>

- Improve all fan efficiency
- Case 26: air foil type fan, total efficiency = 70.2%
- Case 27: IE3 fan motor, total efficiency = 71.8%

<u>Results</u>

- BEI = 113 kWh/m2
- Peak cooling load = 5,127 kW

Analysis

Case 28: CO2 Sensor

Design Improvement

- Introduce CO2 sensors to regulate fresh air intake based on occupants need for fresh air
- CO2 sensor set to 900 ppm

Results

- BEI = 110 kWh/m2
- Peak cooling load = 4,973 kW

Analysis

Case 29: Heat Recovery System

<u>Design Improvement</u>

- Introduce heat recovery wheel to the fresh air intake

<u>Results</u>

- BEI = 108 kWh/m2
- Peak cooling load = 4,924 kW

Analysis

Case 30 and Case 31: Chilled Water Delta T

Design Improvement

•Increase chilled water delta T from 12 °F to 16 °F thus decreasing chilled water flow rate

•Case 30: Supply and return temperature = 42 °F and 58 °F

•Case 31: Supply and return temperature = 44 °F and 60 °F

Results

•BEI = 106 kWh/m2

•Peak cooling load = 4,880 kW. Peak cooling load does not show much decrease from here on. Active system improvement does not have much impact on cooling load.

Analysis

Case 32 and Case 33: Chilled Water Pump Pressure

Design Improvement

- Decrease pump pressure by optimizing pipe size, reduce bends, tees, etc.
- Case 32: Pump pressure = 30m
- Case 33: Pump pressure = 20m

Results

- BEI = 104 kWh/m2
- Peak cooling load = 4,869 kW.

Analysis

Case 34 and Case 35: Chilled Water Pump Efficiency

Design Improvement

- Improve pump efficiency
- Case 34: High efficiency pump, total efficiency 72%
- Case 33: IE3 motor, total efficiency = 74.4%

Results

- BEI = 104 kWh/m2 (marginal)
- Peak cooling load = 4,868 kW.

Analysis

Case 36: Variable Primary Chilled Water Pump

Design Improvement

- Specify pump with VSD. Improves performance at part load

Results

- BEI = 102 kWh/m2
- Peak cooling load = 4,866 kW.

Analysis

Case 37 and Case 38: Chiller Coefficient of Performance (COP)

Design Improvement

- Specify high efficiency chiller
- Case 37: COP = 6.2
- Case 38: COP = 6.6

Results

- BEI = 96 kWh/m2
- Peak cooling load = 4,807 kW.

Analysis

Case 39: Variable Speed Chiller

<u>Design Improvement</u>

- Specify chiller with VSD compressors. Gives better part load efficiency.

<u>Results</u>

- BEI = 91 kWh/m2
- Peak cooling load = 4,772 kW.

Analysis

Case 40: Condenser Water Delta T

<u>Design Improvement</u>

•Design a higher condenser water delta T of 12 °F hence decreasing flowrate

<u>Results</u>

•BEI = 89 kWh/m2

•Peak cooling load = 4,772 kW.

Analysis

Case 41 and Case 42: Condenser Pump Pressure

<u>Design Improvement</u>

- Decrease pump pressure by optimizing pipe size, deduce bends, tees, etc.
- Case 41: Pump pressure = 30m
- Case 42: Pump pressure = 20m

<u>Results</u>

- BEI = 85 kWh/m2
- Peak cooling load = 4,772 kW.

Analysis

Case 43 and Case 44: Condenser Pump Efficiency

Design Improvement

- Improve pump efficiency
- Case 43: High efficiency pump, total efficiency 72%
- Case 44: IE3 motor, total efficiency = 74.4%

Results

- BEI = 84 kWh/m2
- Peak cooling load = 4,772 kW.

Analysis

Case 45: Cooling Tower Efficiency

Design Improvement

- Select cooling tower with high efficiency. Efficiency decreased form 0.0463 kW/HRT to 0.0275 kW/HRT

Results

- BEI = 82 kWh/m2
- Peak cooling load = 4,772 kW.

Analysis

Case 46: Variable Speed Cooling Tower

Design Improvement

- Specifying a cooling tower with variable speed fan

Results

- BEI = 82 kWh/m2
- Peak cooling load = 4,772 kW.

Analysis

Case 47: Oversized Cooling Tower

Design Improvement

•Design return temperature from 29.4 °C to 28.5 °C/95 or 94 F

Results

•BEI = 82 kWh/m2

•Peak cooling load = 4,772 kW.

Analysis

Case 48: Faulty Daylight Sensors

Design Improvement

- This case does not improve on the design. Considers situation when daylight sensors are not functioning. Hence all office lights are switched on.

Results

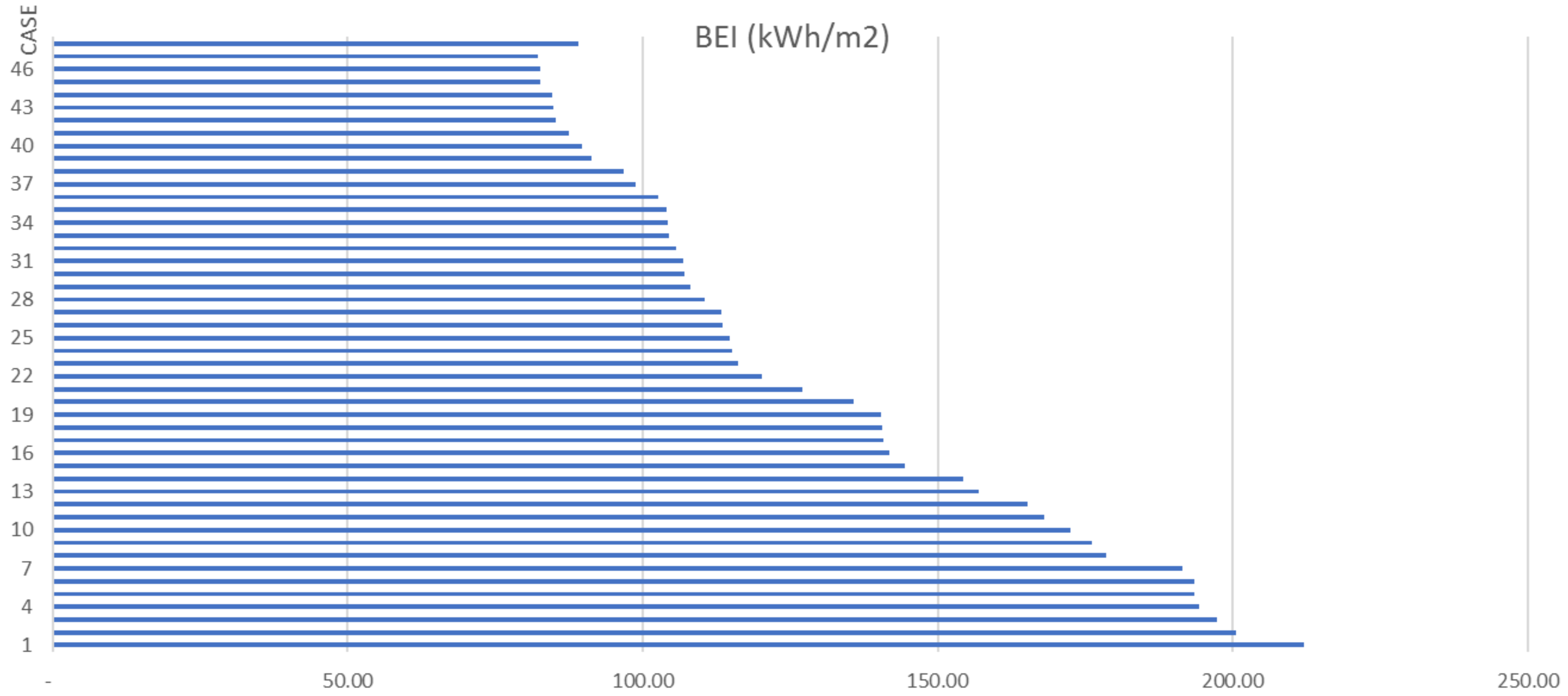
- BEI = 89 kWh/m2
- Peak cooling load = 4,862 kW

Conclusion

- Each small improvement contribute to substantial overall savings.
  - Base building BEI = 212.08 kWh/m2
  - Final BEI (Case 47) = 82.25 kWh/m2. A decrease of **61%** **(building overall)**
- Energy by owner.
  - Base building energy = 5,717 MWh (RM 2,001,168) per year.
  - Final energy (Case 47) = 1,510 MWh (RM 528,666) per year. A decrease of **73%** **(owner's running cost)**
- Peak air cond load.
  - Base building load = 7,394 kW
  - Final load (Case 48) = 4,862 kW. A decrease of **34%** **(capital cost reduction)**

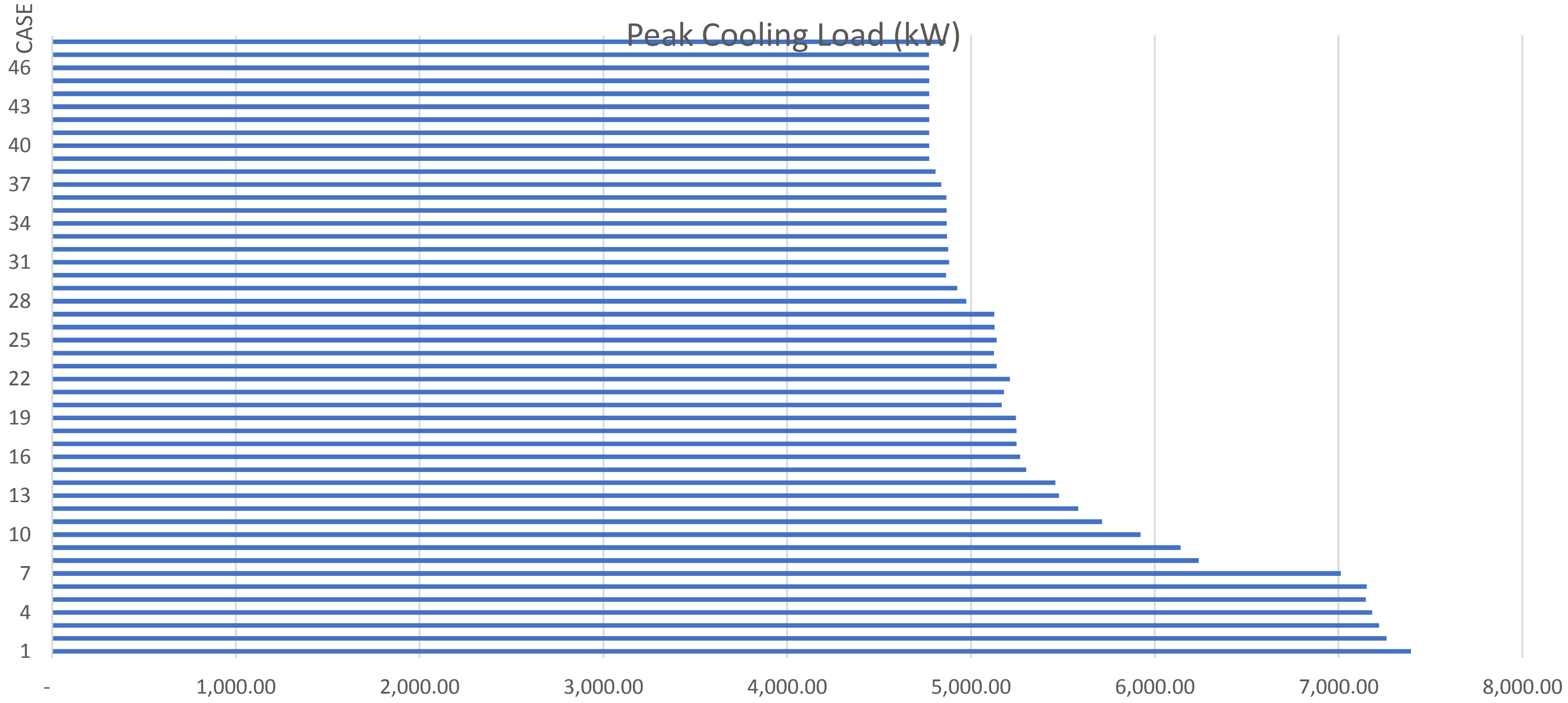
Conclusion

Building Energy Intensity (BEI) of each Case



Conclusion

Peak Cooling Load of each Case



Summary

- Achieving very high energy efficiency requires the building to capitalize on every opportunity that increases efficiency on the building.
  - Each energy efficiency feature provides savings in the region of 1%~2% gains.
- Peak cooling load reduction is even smaller per feature, ranging from 0.5% ~ 1%.
  - But a combination of features will provide up to 34% peak cooling load reduction.

Thank you