Optimizing Energy Efficiency for a High Rise Office Tower in Tropics

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

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Background

- 27 office levels
- 8 levels of podium
- Completion in Mid-2017
- 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

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

Building Energy Intensity (BEI) of each Case
Simulation Cases and Results

Peak Cooling Load of each Case

CASE

Peak Cooling Load (kW)
## Analysis

### Case 1: Base Building

<table>
<thead>
<tr>
<th>Construction Material</th>
<th>U-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Flat Roof – No insulation</td>
<td>3.759</td>
</tr>
<tr>
<td>Standard Glazing</td>
<td>4.825</td>
</tr>
<tr>
<td>Standard External Wall</td>
<td>1.794</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lighting Power Density (MS 1525)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lobby / Walkway</td>
<td>20 W/m²</td>
</tr>
<tr>
<td>Office</td>
<td>15 W/m²</td>
</tr>
<tr>
<td>Observatory</td>
<td>15 W/m²</td>
</tr>
<tr>
<td>Pantry</td>
<td>15 W/m²</td>
</tr>
<tr>
<td>Staircase</td>
<td>15 W/m²</td>
</tr>
<tr>
<td>Toilet</td>
<td>10 W/m²</td>
</tr>
</tbody>
</table>

**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.

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

Design Improvement

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

Results

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

Case 5 and Case 6: Roof Insulation

Design Improvement
• Case 5: 50mm roof polystyrene insulation
• Case 6: 100mm roof polystyrene insulation

Results
• 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

Design Improvement

• 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.

Results

• 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

Design Improvement
• Case 11: Infiltration = 0.25 ACH
• Case 12: Infiltration = 0.10 ACH

Results
• BEI = 165 kWh/m²
• Peak cooling load = 5,583 kW
Analysis

Case 13 and Case 14: Office Lighting Power Density

Design Improvement

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

Results

- 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

Design Improvement
- Reduce night time light to 33%

Results
- 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

Design Improvement

• 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

Results

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

Case 26 and Case 27: Fan Efficiency

Design Improvement

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

Results

• 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

Design Improvement

• Introduce heat recovery wheel to the fresh air intake

Results

• 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

Design Improvement

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

Results

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

Case 40: Condenser Water Delta T

Design Improvement

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

Results

• BEI = 89 kWh/m²
• Peak cooling load = 4,772 kW.
Analysis

Case 41 and Case 42: Condenser Pump Pressure

Design Improvement

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

Results

- 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 from 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