160 Ann Street, Brisbane, Australia

1. INTRODUCTION

PROJECT SUMMARY
- **Year of construction** – 1972

SPECIAL FEATURES
- **Building retrofitting methodology** through calibrated building energy modeling, to meet NABERS 4 star rating scheme. Three orders of decisions were developed:
  i. Control of internal loads,
  ii. Control of Environmental loads,
  iii. HVAC improvements.

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IEA – SHC Task 47
Renovation of Non-Residential Buildings towards Sustainable Standards
2. CONTEXT AND BACKGROUND

BACKGROUND
- Building is located in the CBD of Brisbane, Australia, in a warm sub-tropical climate, approx. 27° S, densely populated with medium to high rise buildings adjacent to Brisbane river.
- It is a 23-storey tower with NLA: 15,877 m²; 820 m² each floor, being internal load dominant.
- Whole building energy rating is between 2 – 2.5 stars.
- Total energy consumption is 270 Kwh/m²/a
- Tenants and HVAC are 126 and 147 KWh/m².annum

OBJECTIVES OF THE RENOVATION
- Meet Queensland Emission reduction targets, energy performance improvements to accomplish:
  - 4 stars NABERS rating of 182 KWh/m².annum
  - Operational energy footprint for the whole building

SUMMARY OF THE RENOVATION
- Step 1 - Internal load controls – using non-technological & technological strategies
- Step 2 - Environmental load controls – using technological strategies
- Step 3 - System improvements – using non-technological & Technological strategies to upgrade the HVAC system
3. DECISION MAKING PROCESSES

- Project initiated by Prof. Richard Hyde at University of Queensland under research named “Exploring Synergies with Innovative Green Technologies: Redefining Bioclimatic Principles for Multi Residential Buildings and Offices in Hot and Moderate Cimates”.

- This building was considered as a “Critical Case” representing common physical and operational characteristics of typical high rise office buildings in Australia.

- Public funding program: ARC (Australia Research Council)

Timeline for the decision making process:

1. Idea was born
   - 2006
2. First brief project description completed
   - 2008
3. Detailed project description completed
   - 2010
4. Tendering process started
   - TBA
5. Signing of contract with main contractor
   - TBA
6. Start renovation
   - TBA
7. Renovation completed
   - TBA
8. Evaluation among occupants
   - TBA

Modeling methodology:

1. Critical Case
2. Critical Case Input Model - CCIM
3. Critical case load analysis
4. Forward Building Input Model - FBIM
5. Run simulation and analyze results
6. Check validity criteria of FSIM
7. Criteria adequate → Refine
8. Forward Simulation Model - FSM
9. Calibration for Summer and Winter
   - FSSM
   - Summer Model
   - Winter Model
9a. FSWM
10. Statistical energy load analysis
11. Prioritize retrofit design strategies
12. Application of retrofitting solution/sets
13. Data Driven Simulation Model - DDSM
4. BUILDING ENVELOPE

**Roof construction**: U-value: 2.3 W/m².K
- **Materials** (Interior to exterior):
  - RCC concrete (existing): 250 mm
  - Pure Bitumen (existing): 20 mm
  - Total (existing): 285 mm

**Wall construction**: U-value: 2.7 W/m².K
- **Materials** (Interior to exterior):

**Slab construction**: U-value: 3.0 W/m².K
- **Materials** (Interior to exterior):

**Windows**: U-value: 2.63 W/m².K
- **Double-glazing** (existing)
  - Clear glass: 6 mm
  - Cavity with venetian blinds: 50 mm
  - Bronze tinted glass: 6 mm

**Thermal bridge avoidance**:
- **Airtightness** (existing): 1.0 ach/h
- **Airtightness** (new): 0.5 ach/h
- 0.11 ach/h??

**Summary of U-values [W/m²K]**

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After (1)</th>
<th>After (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor/slab</td>
<td>3.0</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Walls</td>
<td>2.7</td>
<td>0.565</td>
<td>0.143</td>
</tr>
<tr>
<td>Roof</td>
<td>2.3</td>
<td></td>
<td>0.095</td>
</tr>
<tr>
<td>Windows</td>
<td>2.63</td>
<td>0.76</td>
<td></td>
</tr>
</tbody>
</table>

**BCA 2009**, External wall –
- U=0.565, R=1.8 (1)

**ASHRAE Budget model**
- U=0.673, R=1.5 (2)
- Same material layering with 29mm Expanded Polystyrene (Standard)

**PassiveHaus**, External wall –
- U=0.143, R=7 (3)
5. BUILDING SERVICES SYSTEM

OVERALL DESIGN STRATEGY

STEP 1 (FIRST ORDER)
Controls to internal heat loads
- Before (CCIM) 273 KWh/m²/a
- After 163 KWh/m²/a

LIGHTING SYSTEM
Reduction of power density load
- Before 12 W/m²
- After 9 W/m²

STEP 2 (SECOND ORDER)
Controls environmental heat loads
- Before 163 KWh/m²/a
- After 155 KWh/m²/a

VENTILATION/INFILTRATION
- Before 1.0ach.h
- After 0.5ach.h

INSULATION (see page 4)

STEP 3
HVAC improvements
- Before 155 KWh/m²/a
- After 111 KWh/m²/a

HVAC SYSTEM
- Before COP 2.5
- After COP 5.0

INTERNAL TEMPERATURE SETPOINT
- Before 21.5°C
- After 24°C
6. ENERGY PERFORMANCES

Queensland Emission reduction targets
- 4 star energy efficiency rating for commercial buildings by 2010
- Carbon neutral government office buildings by 2020

Retrofit scenarios satisfies the 2010 emission reduction targets
- 1383713 KWh per annum, 87 KWh/m².annum
- By 2020 – 3.9% increase in energy usage due to climate change.
- Green Power requirement (Whole building)
  - 1437768 KWh per annum
  - 90 KWh/m²/annum

To achieve near carbon neutral status
- Green power to move from improved energy efficiency status to near carbon neutral status (Step 4)

**For internal load control**

*Using technological and non-technological interventions*

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>BCA, PH and ASHRAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FSM + Operational and occupancy profile</td>
<td>for BCA only</td>
</tr>
<tr>
<td>2</td>
<td>(1) + Efficient appliances (plug loads)</td>
<td>for BCA, PH and ASHRAE</td>
</tr>
<tr>
<td>3</td>
<td>(02) + Lighting</td>
<td>for BCA, PH and ASHRAE</td>
</tr>
<tr>
<td>3A</td>
<td>(03) + Daylight linear off sensors for artificial light</td>
<td>for BCA, PH and ASHRAE</td>
</tr>
<tr>
<td>3B</td>
<td>(03A) + Window blinds operation with solar sensors</td>
<td>for BCA, PH and ASHRAE</td>
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</tbody>
</table>

**For internal load + environmental load control**

*Using technological interventions*

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>BCA, PH and ASHRAE</th>
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</thead>
<tbody>
<tr>
<td>4</td>
<td>(03B) + Infiltration</td>
<td>for BCA, PH and ASHRAE</td>
</tr>
<tr>
<td>5</td>
<td>(04) + Insulation to external walls</td>
<td>for BCA, PH and ASHRAE</td>
</tr>
<tr>
<td>6</td>
<td>(05) + Insulation to total opaque surfaces</td>
<td>for BCA, PH and ASHRAE</td>
</tr>
<tr>
<td>7</td>
<td>(06) + Solar transmission control to glazing</td>
<td>for BCA, PH and ASHRAE</td>
</tr>
<tr>
<td>8</td>
<td>(07) + Efficient HVAC (increased COP 5)</td>
<td>for BCA, PH and ASHRAE (Summer)</td>
</tr>
<tr>
<td>8A</td>
<td>(08) + Increase of set point temperature by 1 degree C</td>
<td>no heating</td>
</tr>
<tr>
<td>9</td>
<td>(08A) + Mixed mode HVAC system</td>
<td>winter no heating</td>
</tr>
<tr>
<td>10</td>
<td>(10A) + increase of glazing in envelope</td>
<td></td>
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<tr>
<td>11</td>
<td>Scenario 11 for climate change effects 2030</td>
<td></td>
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<tr>
<td>12</td>
<td>(11) + Green power, PV Cells</td>
<td>for BCA, PH and ASHRAE</td>
</tr>
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</table>

**Conceptual thermal behaviour appraisal**

*CLARIFICATION*: the energy calculations and given energy numbers will be according to the national standards which might vary between countries, i.e. numbers are not always comparable.
7. ENERGY PERFORMANCE

Items that could be covered:

Modeling methodology
- Input data collection
- Model development
- Simulation
- Calibration
- Retrofit solution/sets

Simulation Program
Dynamic energy simulation software:
- Design Builder version 2.2.5

Model development involved the following:
- Critical Case Input Model – CCIM
- Forward Simulation Model - FSM
- Model calibration

Building Design Characteristics
- Externalities (building design and microclimate)
- Internalities (occupancy, equipment and systems)

Both affect the heat load profiles and therefore energy performance were the AREAS for retrofitting.

Operational energy consumption – 61.3% (HVAC + Lighting)

- Tenants 46.4%
- HVAC 43.7%
- Lighting 17.6%
- Plug load 28.8%
- Lifts 4.7%
- Unrecorded 5.2%

Total energy usage

% of energy saving

Annual total energy saving (%)

Electricity use (KWh)

SCHE
8. MORE INFORMATION

RENOVATION COSTS
- Specified for individual energy saving measure and expected pay back time if possible
- To achieve a 65% energy cuts in existing buildings, require an economic analysis to justify the retrofitting decisions.

FINANCING MODEL
• Subsidized loans:
• Grants:
• Interest level: Public disclosure
• Public incentives: Government tenancy require 4.5 star
• ESCO contracts: N/A
• Market conditions:

OTHER INTERESTING ASPECTS
Potential for ecological integration

REFERENCES
Hyde et al, Sustainable Retrofitting, 2012, Chapter 2.4 &2.5

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### Energy efficiency scenarios that PASS the economic test

<table>
<thead>
<tr>
<th>SC</th>
<th>Scenario descriptions</th>
<th>Approach 1 Payback (years)</th>
<th>Approach 2 NPV ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC-1</td>
<td>Occupancy and operational profile of BCA</td>
<td>-</td>
<td>506.681</td>
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<td>SC-2</td>
<td>SC-2a Efficient appliances</td>
<td>0,1</td>
<td>967.392</td>
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<td></td>
<td>SC-2b Increase cooling set-point temperature by 1 degree</td>
<td>0,3</td>
<td>187.769</td>
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<tr>
<td></td>
<td>SC-2c Advance computer management system</td>
<td>1,1</td>
<td>881.708</td>
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<td>SC-3</td>
<td>Infiltration improvements</td>
<td>2,8</td>
<td>15.577</td>
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<td>SC-6</td>
<td>Low emission transmission; double glazing</td>
<td>1,4</td>
<td>63.617</td>
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<td>SC-7</td>
<td>Efficient Lighting</td>
<td>-</td>
<td>1.645.415</td>
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<td>SC-9</td>
<td>Efficient chiller system Mixed mode HVAC system with winter no heating</td>
<td>0,8</td>
<td>488.163</td>
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<td>SC-11</td>
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<td>1,7</td>
<td>272.786</td>
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<td>SC-10</td>
<td>Mechanical services (Pumps and lifts)</td>
<td>0,5</td>
<td>722.622</td>
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<tr>
<td>SC-12</td>
<td>HVAC Fans &amp; VAV diffuser system</td>
<td>6,2</td>
<td>791.830</td>
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### Energy efficiency scenarios that FAIL the economic test

<table>
<thead>
<tr>
<th>SC</th>
<th>Scenario descriptions</th>
<th>Approach 1 Payback (years)</th>
<th>Approach 2 NPV ($)</th>
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<tbody>
<tr>
<td>SC-4</td>
<td>Insulate external walls</td>
<td>44</td>
<td>91.054</td>
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<td>SC-5</td>
<td>Insulate total opaque surfaces</td>
<td>2.971</td>
<td>10.264.638</td>
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<tr>
<td>SC-8</td>
<td>SC-8a Daylight linear off sensors</td>
<td>26</td>
<td>12.675</td>
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<tr>
<td>SC-8</td>
<td>SC-8b Window blinds operation with sensors</td>
<td>19</td>
<td>8.691</td>
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