• Structural – Finite Element Analysis
• Lighting – Natural / Glare Analysis
• Mechanical – Energy Analysis

• Tools
  • US DOE comparison of tools:
  • http://www.eere.energy.gov/buildings/tools_directory
Design Optimization Techniques

Analytical Tools – Lighting & Visualization

Visualization

Day-Lighting
Notes

- The NRB facility (highlighted in red) will be generally unobstructed by adjacent site buildings in regard to solar exposure. The link partially obscures the west wing in the morning and the east wing in the afternoon.
Notes

- While a large, un-shaded area of glazing provides ample illumination of the interior, the brightest (red) interior surfaces are in stark contrast to the darkest areas. The result is glare. Occupants at the perimeter will tend to close the shades, thereby reducing available light throughout.
OVERAL ENERGY MODELING STRATEGY
• The Case Study Model is intended to demonstrate a variety of exposure and configuration variations in a single example.
• Simplicity is preferred, in the interest of facilitating experimentation.
• The Curtain Wall and windows are modeled using the basic Revit tools.

• The skylights and atrium roof are modeled as a “sloped glazing” roof type.
The Heating/Cooling Load Calculation took about 15 seconds. It includes this Room Summary as well as detail for each of the rooms.

This calculation and report took approximately 20 seconds to compute.

<table>
<thead>
<tr>
<th>Name</th>
<th>Area</th>
<th>Airflow</th>
<th>Cooling Load (Total)</th>
<th>Heating Load (Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Punch Corner</td>
<td>522 SF</td>
<td>756 CFM</td>
<td>17573.9 Btu/h</td>
<td>17050.1 Btu/h</td>
</tr>
<tr>
<td>2. Punch Deep</td>
<td>259 SF</td>
<td>324 CFM</td>
<td>7612.1 Btu/h</td>
<td>7485.2 Btu/h</td>
</tr>
<tr>
<td>3. Punch Square</td>
<td>533 SF</td>
<td>634 CFM</td>
<td>14977.9 Btu/h</td>
<td>14425.5 Btu/h</td>
</tr>
<tr>
<td>4. Punch Wide</td>
<td>1082 SF</td>
<td>1262 CFM</td>
<td>29668.0 Btu/h</td>
<td>28572.9 Btu/h</td>
</tr>
<tr>
<td>5. Punch Atrium</td>
<td>533 SF</td>
<td>656 CFM</td>
<td>15419.0 Btu/h</td>
<td>16022.8 Btu/h</td>
</tr>
<tr>
<td>6. Punch Sky Deep</td>
<td>305 SF</td>
<td>375 CFM</td>
<td>8826.3 Btu/h</td>
<td>8692.7 Btu/h</td>
</tr>
<tr>
<td>7. Punch Sky Square</td>
<td>533 SF</td>
<td>634 CFM</td>
<td>14982.4 Btu/h</td>
<td>14441.1 Btu/h</td>
</tr>
<tr>
<td>8. Punch Sky Wide</td>
<td>1082 SF</td>
<td>1254 CFM</td>
<td>29906.3 Btu/h</td>
<td>28612.4 Btu/h</td>
</tr>
<tr>
<td>9. Punch Sky Corner</td>
<td>522 SF</td>
<td>694 CFM</td>
<td>16214.9 Btu/h</td>
<td>17134.8 Btu/h</td>
</tr>
<tr>
<td>10. CW Corner</td>
<td>560 SF</td>
<td>1222 CFM</td>
<td>27719.0 Btu/h</td>
<td>23354.4 Btu/h</td>
</tr>
<tr>
<td>11. CW Deep</td>
<td>268 SF</td>
<td>386 CFM</td>
<td>8982.1 Btu/h</td>
<td>9307.3 Btu/h</td>
</tr>
<tr>
<td>12. CW Square</td>
<td>552 SF</td>
<td>738 CFM</td>
<td>17254.2 Btu/h</td>
<td>17787.1 Btu/h</td>
</tr>
<tr>
<td>13. CW Wide</td>
<td>1120 SF</td>
<td>1466 CFM</td>
<td>34334.3 Btu/h</td>
<td>35100.7 Btu/h</td>
</tr>
<tr>
<td>14. CW Atrium</td>
<td>576 SF</td>
<td>963 CFM</td>
<td>22114.9 Btu/h</td>
<td>18763.9 Btu/h</td>
</tr>
<tr>
<td>15. CW Sky Deep</td>
<td>316 SF</td>
<td>452 CFM</td>
<td>10513.5 Btu/h</td>
<td>12025.6 Btu/h</td>
</tr>
<tr>
<td>16. CW Sky Square</td>
<td>552 SF</td>
<td>738 CFM</td>
<td>17248.4 Btu/h</td>
<td>17824.8 Btu/h</td>
</tr>
<tr>
<td>17. CW Sky Wide</td>
<td>1120 SF</td>
<td>1470 CFM</td>
<td>34423.7 Btu/h</td>
<td>36222.9 Btu/h</td>
</tr>
<tr>
<td>18. CW Sky Corner</td>
<td>580 SF</td>
<td>1066 CFM</td>
<td>24282.8 Btu/h</td>
<td>23424.1 Btu/h</td>
</tr>
<tr>
<td>19. Sky Corridor</td>
<td>553 SF</td>
<td>691 CFM</td>
<td>16257.5 Btu/h</td>
<td>15824.8 Btu/h</td>
</tr>
<tr>
<td>20. Corridor</td>
<td>670 SF</td>
<td>833 CFM</td>
<td>19607.6 Btu/h</td>
<td>18973.9 Btu/h</td>
</tr>
<tr>
<td>21. Atrium</td>
<td>2664 SF</td>
<td>3228 CFM</td>
<td>76541.8 Btu/h</td>
<td>69600.9 Btu/h</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>14884 SF</td>
<td>19852 CFM</td>
<td><strong>464660.7 Btu/h</strong></td>
<td><strong>449624.8 Btu/h</strong></td>
</tr>
</tbody>
</table>
### ORIENTATION VARIATIONS

- **By changing the orientation of the model in Revit and re-running the energy analysis, it was easy to compare the effect of altering Curtain Wall exposure.**

- **This Technique allow one to optimize the orientation.**

<table>
<thead>
<tr>
<th>Orientation of CW</th>
<th>Cooling Loads</th>
<th>Heating Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>457,334</td>
<td>310,774</td>
</tr>
<tr>
<td>South</td>
<td>480,024 104.96%</td>
<td>310,774 100.00%</td>
</tr>
<tr>
<td>East</td>
<td>580,565 126.95%</td>
<td>310,774 100.00%</td>
</tr>
<tr>
<td>West</td>
<td>583,873 127.67%</td>
<td>310,774 100.00%</td>
</tr>
<tr>
<td>NNE - 10 deg</td>
<td>470,868 102.96%</td>
<td>310,774 100.00%</td>
</tr>
<tr>
<td>NE - 45 deg</td>
<td>550,594 120.39%</td>
<td>310,774 100.00%</td>
</tr>
<tr>
<td>NW - 45 dge</td>
<td>519,812 113.66%</td>
<td>310,774 100.00%</td>
</tr>
<tr>
<td>NNW - 10 deg</td>
<td>455,443 99.69%</td>
<td>310,774 100.00%</td>
</tr>
</tbody>
</table>
Design Optimization Techniques

Project Case Study

Diagram showing a system with labels such as 'Operable Windows/Louvers', 'Evaporative Cooling', 'Reflecting Pool', 'Thermal Siphon', 'Hybrid HVAC', 'Fresh Air Intake', 'Natural Ventilation', and 'Underground Cooling Ducts'.
Design Optimization Techniques

Project Case Study
Design Optimization Techniques

Project Case Study

A

7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM

B

7:00 AM 8:00 AM 9:00 AM 10:00 AM 11:00 AM

C

12:00 PM 1:00 PM 2:00 PM 3:00 PM 4:00 PM

D

1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM

E

1:00 PM 2:00 PM 3:00 PM 4:00 PM 5:00 PM

North Elevation:
Vertical Shading turned 90° 30 degrees
Shade angle: 45°
Shift angle: 45°

South Elevation:
Vertical Shading turned 90° 30 degrees
Shade angle: 45°
Shift angle: 45°

East Elevation:
Horizontal Shading
Shade angle: 45°
Shift angle: 45°

West Elevation:
Horizontal Shading
Shade angle: 45°
Shift angle: 45°
Design Optimization Techniques

No Sunshades
Design Optimization Techniques

Project Case Study

- Vegetation reduces urban heat island effect.
- Soil mass insulates and creates thermal lag.
- Soil retains stormwater, releasing it slowly over time.
- Plants improve air quality at HVAC intakes.
- Aesthetic benefits for occupants of surrounding buildings.
- Biofiltration improves water quality, eliminating bioretention cells.

- Gravel and drains at roof perimeter.
- Green roof system.
- Gravel at roof penetrations.
- Rooftop mechanical equipment in well.
- Drain with inspection chamber.
- Gravel vegetation-free zone at perimeter and roof penetrations.
- Soil and plant material.
- Sheet drain/retention mat and filter fabric.
- Insulation.
- Root barrier, protection board, and roof membrane.
- Concrete roof deck with 2% slope.
Design Optimization Techniques

Project Case Study

**Concrete Structure**
- 3x3x3 concrete castings in steel cage
- Max: 3000 lb.
- Stacked

**Labyrinth**
- Service tunnel

**Section**
- Airflow

**Schematic Section**
- Zink pipe "Earth tubes" 2" I.D.
- Slope towards and connect to manholes
- 2 ducts under ground floor slab to shafts (similar to labyrinth scheme)

**Schematic Plan**
- Manholes, approx. 12' x 6' x 24' deep
Design Optimization Techniques

ASHRAE 55 comfort chart (pg 7)
- **Green** – ASHRAE comfort boundary
- **Red** – conventional HVAC design boundary

Tight Environmental Control

Clean Rooms  Workplaces  Transitory Spaces (hallways)  Atria  Outdoor Shelters  Outdoors

No Control
Design Optimization Techniques

Winter Wind Rose

Summer Wind Rose

<table>
<thead>
<tr>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUNE</th>
<th>JULY</th>
<th>AUG</th>
<th>SEPT</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
<th>YEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.0</td>
<td>3.9</td>
<td></td>
<td>3.5</td>
<td>3.9</td>
<td></td>
<td></td>
<td>32</td>
</tr>
<tr>
<td>2.7</td>
<td>2.8</td>
<td>3.7</td>
<td>3.8</td>
<td>3.5</td>
<td>3.9</td>
<td>3.4</td>
<td>3.2</td>
<td>3.3</td>
<td>3.2</td>
<td>4.0</td>
<td>3.2</td>
<td>40.2</td>
</tr>
</tbody>
</table>

Washington D.C. monthly average precipitation
Design Optimization Techniques

Washington D.C. Hourly Temperature Distribution
Design Optimization Techniques

Project Case Study

Temperature °F

Time of Day (July 25)

Pressure

Operative Temperature °F

Percent Dissatisfied (%)
Design Optimization Techniques

![Bar chart showing annual atrium energy cost by optimization technique.](chart)

- **Standard Atrium Design**
  - No shading
  - Lights on all day (6am-8pm)
  - Tight temp control (72-75°F, 40-60% RH)

- **With Optimal Shading**
  - Good internal shading on skylights and large glazing walls

- **With Displacement Ventilation**
  - Displacement ventilation system conditioning occupied space only

- **With Radiant Floor Heating**
  - Radiant floor heating

- **Mixed Mode Natural Vent, Tight Control**
  - Lights dim in response to ambient daylight in space
  - Temp and humidity control: 68°F to 70°F
  - No air conditioning, heating to 68.

- **With Daylight Dimming Lights**
  - Operable windows open during nice days only, maintaining 72-75°F, 40-60% RH

- **Natural Vent With relaxed Indoor Criteria to ASHRAE limits**
  - No heating or cooling, lighting only