Case Study: Empire State Building

Thoughtful Cooling ToT: Cooling Interiors Efficiently and Sustainably

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General Manager: Energy Efficiency
What about existing buildings?

> Every new building becomes an existing building

> Most buildings are built without air-conditioning and little consideration for passive design or load reduction measures

> Yet, most buildings eventually get air-conditioned
  > Poor envelope characteristics
  > Poor fenestration design and materials
  > High infiltration / air leakage

> An inefficient new building means the poor performance is locked for the life of a building

> Because of frequent interior renovation cycles, there are periodic opportunities for meaningful interventions
Annual Energy Consumption of New and Existing Buildings in India

- New Buildings
- Existing Buildings
Cumulative Energy Consumption of New and Existing Buildings

20 years from now, as we look back, 90% of the total electricity used will be in our existing buildings

Electricity consumed annually by existing buildings today is more than the total electricity that will be consumed by all new buildings constructed over the next 20 years

Embodied energy in new construction could very well be the game-changer here, IF we start considering it
Is there a business case for whole-building energy efficiency retrofits?

Prior to 2008, the Empire State Building’s performance was average compared to most U.S. office buildings.

**Annual utility costs:**
- $11 million ($4/sq. ft.) (Rs. 53 crores)

**Annual CO₂ emissions:**
- 25,000 metric tons (10 kg/sq. ft.)

**Annual energy use:**
- 26 kWh/sq. ft. (280 kWh/sq. m.)

**Peak electric demand:**
- 9.5 MW (3.8 W/sq. ft. inc. HVAC)

Source: Rocky Mountain Institute
Is there a business case for whole-building energy efficiency retrofits?

With a $500 million capital improvement program underway, ESB ownership decided to re-evaluate certain projects with cost-effective energy efficiency and sustainability opportunities in mind.

**Capital Budget Adjustments for Energy Efficiency Projects**

2008 Capital Budget for Energy-Related Projects = $93m + 0% Energy Savings

Sum of adds / changes / deletes = +$13m

New Capital Budget w/ Efficiency Projects = $106m + 38% Energy Savings

Source: Rocky Mountain Institute
Creating a replicable model for whole-building energy efficiency retrofits

ESB ownership wanted to demonstrate how to cost-effectively retrofit a large multi-tenant office building to inspire others to embark on whole-building retrofits.

1. Identify opportunities
   - 60+ energy efficiency ideas were narrowed to 8 implementable projects
   - Team estimated theoretical minimum energy use
   - Developed eQUEST energy model

2. Evaluate measures
   - Net present value
   - Greenhouse gas savings
   - Dollar to metric ton of carbon reduced
   - Calculated for each measure

3. Create packages
   - Maximize net present value
   - Balance net present value and CO₂ savings
   - Maximize CO₂ savings for a zero net present value
   - Maximize CO₂ savings

4. Model iteratively
   - Iterative energy and financial modeling process to identify final eight recommendations

Source: Rocky Mountain Institute
Project Development Process

Determining the optimal package of retrofit projects involved identifying opportunities, modeling individual measures, and modeling packages of measures.

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Identify Opportunities → Model Individual Measures → Create Packages of Measures → Model Iteratively

Outcome:
Package of measures with best economic & environmental benefits

Source: Rocky Mountain Institute
Project Development Process

Significant time was spent 1) refining energy and financial model inputs to ensure outputs were accurate and 2) understanding the critical relationship between economics and CO$_2$ reductions.

**CO$_2$ Emissions for each Package**

**Incremental Cash Flow for each Package of Measures**

Source: Rocky Mountain Institute
Industry standard and newly developed design tools, decision-making tools, and rating tools helped to evaluate and benchmark existing and future performance.
Eight interactive measures deliver 38% energy use reduction

The Empire State Building can achieve a high level of energy and CO$_2$ reduction cost-effectively.

### 15-Year NPV of Package versus Cumulative CO$_2$ Savings

- NPV “Max”
- NPV “Mid”
- NPV “Neutral”

There are diminishing (and expensive) returns for greater efficiency.

A solution that balances CO$_2$ reductions and financial returns is in this range.

Cumulative metric tons of CO$_2$ saved over 15 years

Net Present Value of Package of Measures

Thousands

<table>
<thead>
<tr>
<th>NPV “Max CO$_2$” Reduction</th>
<th>NPV “Neutral”</th>
<th>NPV “Mid”</th>
<th>NPV “Max”</th>
</tr>
</thead>
<tbody>
<tr>
<td>15,000</td>
<td>$35,000</td>
<td>$15,000</td>
<td>$25,000</td>
</tr>
<tr>
<td>0</td>
<td>($5,000)</td>
<td>($5,000)</td>
<td>$0</td>
</tr>
<tr>
<td>40,000</td>
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<td>($5,000)</td>
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<tr>
<td>80,000</td>
<td>0</td>
<td>($5,000)</td>
<td>($5,000)</td>
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<tr>
<td>1,20,000</td>
<td>0</td>
<td>($5,000)</td>
<td>($5,000)</td>
</tr>
</tbody>
</table>

Source: Rocky Mountain Institute
Energy and CO\textsubscript{2} savings in the optimal package result from 8 key projects

Annual Energy Savings by Measure

<table>
<thead>
<tr>
<th>Measure</th>
<th>Energy Use (kBtu)</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>300,000</td>
<td>9%</td>
</tr>
<tr>
<td>Balance of DDC</td>
<td>200,000</td>
<td>6%</td>
</tr>
<tr>
<td>Tenant Daylighting/Plugs</td>
<td>150,000</td>
<td>5%</td>
</tr>
<tr>
<td>VAV AHU's</td>
<td>150,000</td>
<td>5%</td>
</tr>
<tr>
<td>Retrofit Chiller Plant</td>
<td>150,000</td>
<td>5%</td>
</tr>
<tr>
<td>Building windows</td>
<td>150,000</td>
<td>3%</td>
</tr>
<tr>
<td>Tenant Energy Mgmt</td>
<td>150,000</td>
<td>3%</td>
</tr>
<tr>
<td>Radiative barrier</td>
<td>150,000</td>
<td>2%</td>
</tr>
<tr>
<td>Tenant DCV</td>
<td>150,000</td>
<td></td>
</tr>
<tr>
<td>Energy Use</td>
<td>150,000</td>
<td>38% Reduction</td>
</tr>
</tbody>
</table>

Source: Rocky Mountain Institute
Taking the right steps in the right order ensures loads are minimized prior to investing in expensive new equipment or controls.

Reduce Loads

Use Efficient Technology

Provide Controls

Source: Rocky Mountain Institute
Eight interactive measures… ONE

WINDOWS: Remanufacture existing insulated glass units (IGU) within the Empire State Building’s approximately 6,500 double-hung windows to include suspended coated film and gas fill.
Eight interactive measures... TWO

RADIATIVE BARRIER: Install more than six-thousand insulated reflective barriers behind radiator units located on the perimeter of the building.

Source: Rocky Mountain Institute
Eight interactive measures... THREE

**TENANT DAYLIGHTING / LIGHTING / PLUGS:** This measure involves reducing lighting power density in tenant spaces, installing dimmable ballasts and photosensors for perimeter spaces, and providing occupants with a plug load occupancy sensor for their personal workstation.

*Source: Rocky Mountain Institute*
Eight interactive measures... FOUR

CHILLER PLANT RETROFIT: The chiller plant retrofit project includes the retrofit of four industrial electric chillers in addition to upgrades to controls, variable speed drives, and primary loop bypasses.

Source: Rocky Mountain Institute
Eight interactive measures... FIVE

VAV AIR HANDLING UNITS: Replace existing constant volume units with variable air volume units using a new air handling layout (two floor-mounted units per floor instead of four ceiling-hung units).
Eight interactive measures... SIX

**DDC CONTROLS:** The measure involves upgrading the existing control systems at the Empire State Building.

Source: Rocky Mountain Institute
Eight interactive measures... SEVEN

DEMAND CONTROL VENTILATION: This project involves the installation of CO$_2$ sensors for control of outside air introduction to chilled water and DX Air Handling Units.
Eight interactive measures… EIGHT

*TENANT ENERGY MANAGEMENT*: This project will provide tenants with access to online energy and benchmarking information as well as sustainability tips and updates.

*Source: Rocky Mountain Institute*
While investment decisions were made based on financials for packages, capital costs and savings were determined for each individual measure

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Projected Capital Cost</th>
<th>2008 Capital Budget</th>
<th>Incremental Cost</th>
<th>Estimated Annual Energy Savings*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows</td>
<td>$4.5m</td>
<td>$455k</td>
<td>$4m</td>
<td>$410k</td>
</tr>
<tr>
<td>Radiative Barrier</td>
<td>$2.7m</td>
<td>$0</td>
<td>$2.7m</td>
<td>$190k</td>
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<tr>
<td>DDC Controls</td>
<td>$7.6m</td>
<td>$2m</td>
<td>$5.6m</td>
<td>$741k</td>
</tr>
<tr>
<td>Demand Control Vent</td>
<td>Inc. above</td>
<td>$0</td>
<td>Inc. above</td>
<td>$117k</td>
</tr>
<tr>
<td>Chiller Plant Retrofit</td>
<td>$5.1m</td>
<td>$22.4m</td>
<td>-$17.3m</td>
<td>$675k</td>
</tr>
<tr>
<td>VAV AHUs</td>
<td>$47.2m</td>
<td>$44.8m</td>
<td>$2.4m</td>
<td>$702k</td>
</tr>
<tr>
<td>Tenant Day/Lighting/Plugs</td>
<td>$24.5m</td>
<td>$16.1m</td>
<td>$8.4m</td>
<td>$941k</td>
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<tr>
<td>Tenant Energy Mgmt.</td>
<td>$365k</td>
<td>$0</td>
<td>$365k</td>
<td>$396k</td>
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<tr>
<td><em>Power Generation (optional)</em></td>
<td>$15m</td>
<td>$7.8m</td>
<td>$7m</td>
<td>$320k</td>
</tr>
<tr>
<td>TOTAL (inc. Power Gen)</td>
<td>$106.9m</td>
<td>$93.7m</td>
<td>$13.2m</td>
<td>$4.4m</td>
</tr>
</tbody>
</table>

*Note that energy savings are also incremental to the original capital budget.
Three stakeholders, with different implementation mechanisms, will deliver the savings

Who implements each project?

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Implementer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows</td>
<td>ESCO</td>
</tr>
<tr>
<td>Radiative Barrier</td>
<td>ESCO</td>
</tr>
<tr>
<td>DDC Controls</td>
<td>ESCO</td>
</tr>
<tr>
<td>Demand Control Vent</td>
<td>ESCO</td>
</tr>
<tr>
<td>Chiller Plant Retrofit</td>
<td>ESCO</td>
</tr>
<tr>
<td>VAV AHUs</td>
<td>Owner</td>
</tr>
<tr>
<td>Tenant Day/Lighting/Plugs</td>
<td>Tenants &amp; Owner</td>
</tr>
<tr>
<td>Tenant Energy Management</td>
<td>All</td>
</tr>
</tbody>
</table>
The selected package of measures reduces peak cooling requirements by 33% (1600 TR) enabling immediate and future CapEx avoidance.

Cost of Cooling Efficiency

The 1600-ton load reduction allows for the chiller retrofit instead of replacement/adding capacity.
The optimal package of measures also reduces peak electrical demand by 3.5 MW, benefitting both the building and the utility.

**Office Building Electrical Capacity**

If on-site back-up generation is desired, options include:

- Cogeneration;
- Gas-fired/bio-fuel fired generation;
- Fuel cells;
- Renewables (PV/wind); and
- Purchasing new capacity from Con Edison.

Source: Rocky Mountain Institute
Is there a business case for whole-building energy efficiency retrofits?

**YES!** (But conditions apply…)
Lessons Learned: Teams must take a whole-systems, dynamic, life-cycle approach

Reduce Loads

Use Efficient Technology

Provide Controls

- Capital Cost
- Utility Savings
- Utility Rebates
- Tax Implications
- O&M Impacts
- Escalation Assumptions
- Discount Rate
- Future Cost of CO₂
- Tenant Utility Structure

Source: Rocky Mountain Institute
Lessons Learned: Projects are most cost-effective when coordinated with equipment replacement cycles

Source: Rocky Mountain Institute
Lessons Learned: More than half the savings exist within tenant spaces: don’t ignore them!

Source: Rocky Mountain Institute
Lessons Learned: Select the right buildings for whole-systems retrofits!

Retrofitting the right buildings in the right order can reduce the societal cost ($/metric ton) for carbon abatement.

Source: Rocky Mountain Institute
http://www.rmi.org/retrofit_depot
Thank you!