Project Case Study: Empire State Building

Authors: Eric Harrington and Cara Carmichael, 2009

Overview Section

Location: New York City, NY
Building owner: Empire State Building Company, LLC, Malkin Holdings
Building type: Historic skyscraper
Incremental Capital Cost: $13.2 Million
Total Cost of Retrofit: $550 million for entire remodel, $106 million for energy related projects.
Building Size: 2,700,000 square feet
Completion Date: As of November 2010 the superwindow, radiant barrier, chiller rebuild, control systems and demand control ventilation projects were complete. The remaining energy efficiency measures are ongoing and dependant on tenant turnover/ refinishing schedules.
Annual Energy Use: 88 kBtu/sf pre-retrofit; 60 kBtu/square foot projected
Annual Energy Cost Savings: $4.4 Million

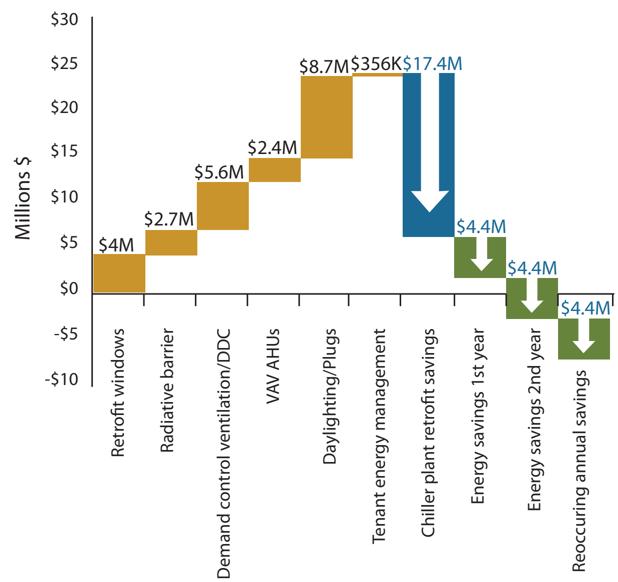
Retrofit Design Project Team

Owner: Empire State Building Company, LLC, Malkin Holdings
Program Manager: Jones Lang LaSalle
Energy Service Company: Johnson Controls, Inc.
Design Partner & Peer Reviewer: Rocky Mountain Institute
Facilitator: Clinton Climate Initiative

The retrofit of the iconic Empire State Building is now underway, with the most innovative undertaking—the remanufacturing of its 6,514 windows onsite into superwindows—completed in September 2010. Cutting winter heat loss by at least two-thirds and summer heat gain by half, the advanced glazing along with improved lighting and office equipment will cut the building's peak cooling load by one-third. The old chiller plant can then be renovated rather than replaced and expanded—saving more than $17 million of budgeted capital expenditure. That capital cost savings helps pay for other projects and cuts the overall incremental simple payback for the energy retrofit to three years. The expected 38 percent energy savings is several times the savings commonly achieved from a typical retrofit.

The energy efficiency retrofit of the Empire State Building is a great story—one that illustrates the results possible through leveraging the deep retrofit

Tunneling Through the Cost Barrier



Efficiency measures implemented on the Empire State Building (shown in red) and the subsequent capital cost reductions (shown in blue) and the annual energy savings (shown in green) demonstrate the concept of 'tunneling through the cost barrier'. For additional information, refer to the 10XE principles: rmi.org/rmi/10xE.

The annual utility costs before the retrofit were $11 million (~$4.00/sf/year). After the retrofit is fully implemented, the anticipated annual energy costs will be around $6.6 million (~$2.50/sf/year).

process. Anthony Malkin, the owner of the Empire State Building, spearheaded the project, along with the Clinton Climate Initiative, a non-profit that works with partners to help dramatically reduce global greenhouse gas emissions. The project also involved the property manager (Jones Lang Lasalle) and a large Energy Service Company (Johnson Controls Inc.) who is seeking to build greater market demand and associated service offerings for deep retrofits. Rocky Mountain Institute served as a design partner and peer reviewer, pushing the integrative design process to achieve deep energy reductions.

Financial

"All portfolio managers and real estate owners to some extent have been concerned with energy efficiency, and they've done small things. What this project is going to show is that it actually makes sense to make large and significant energy efficiency improvements, not the 5 to 10 percent type things, but the 20 to 30 percent and more type of improvements, and that there is a business case for doing so."

—Clay Nesler
VP of Global Energy and Sustainability
Johnson Controls

Several measures helped to ensure a sound financial decision making process and outcome for the project:

- The use of Life Cycle Cost Analysis (LCCA)
- Piggybacking energy upgrades on planned improvements
- Incorporating energy modeling into the design process to identify options of energy efficiency measures
- Using a hybrid of the ESCO model and owner investments to finance the upgrades
- Incorporating tenant energy reduction measures.

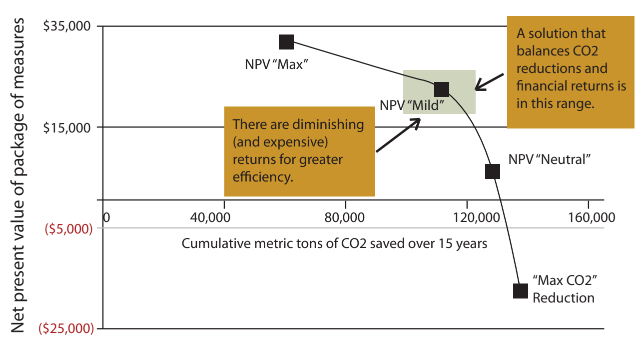
Taking advantage of an already planned retrofit enabled the building owners to make improving the energy performance of the building not only financially viable, but profitable. This project prompted cascading energy savings from several energy efficiency measures including: the reduced solar heat gain coefficient and increased r-value of the rebuilt windows; the radiative barriers on the perimeter heating units; and the daylighting/lighting controls.

The original budget for energy related projects (projects that may somehow affect energy use) was approximately $93 million. This energy budget included a project to replace the chiller plant to increase cooling capacity, which would have required tearing up Fifth Avenue to bring the new chillers into the building. However, by first implementing strategies that reduced the buildings cooling demand, it was possible to reduce the cooling capacity by 1,600 tons allowing the chillers to be retrofit rather than replaced for a capital savings of $17.3 million.

By packaging measures that had positive individual net present value, the team created the "NPV Max" package. Similarly, the team created the "Max CO_2" package by placing all the measures into one package that optimized CO2 savings. With these two packages, the team bounded the NPV extremes of the project. The team recognized that neither the "NPV Max" nor the "Max CO2" packages put forth the best solution for the client. This led to the creation of two more packages, the "NPV Neutral" and "NPV Mid" package, which provides a better balance between economics and CO2 savings. Building ownership selected the NPV "Mid" package of measures as a solution to meet CO2 saving goals balanced with finance constraints.

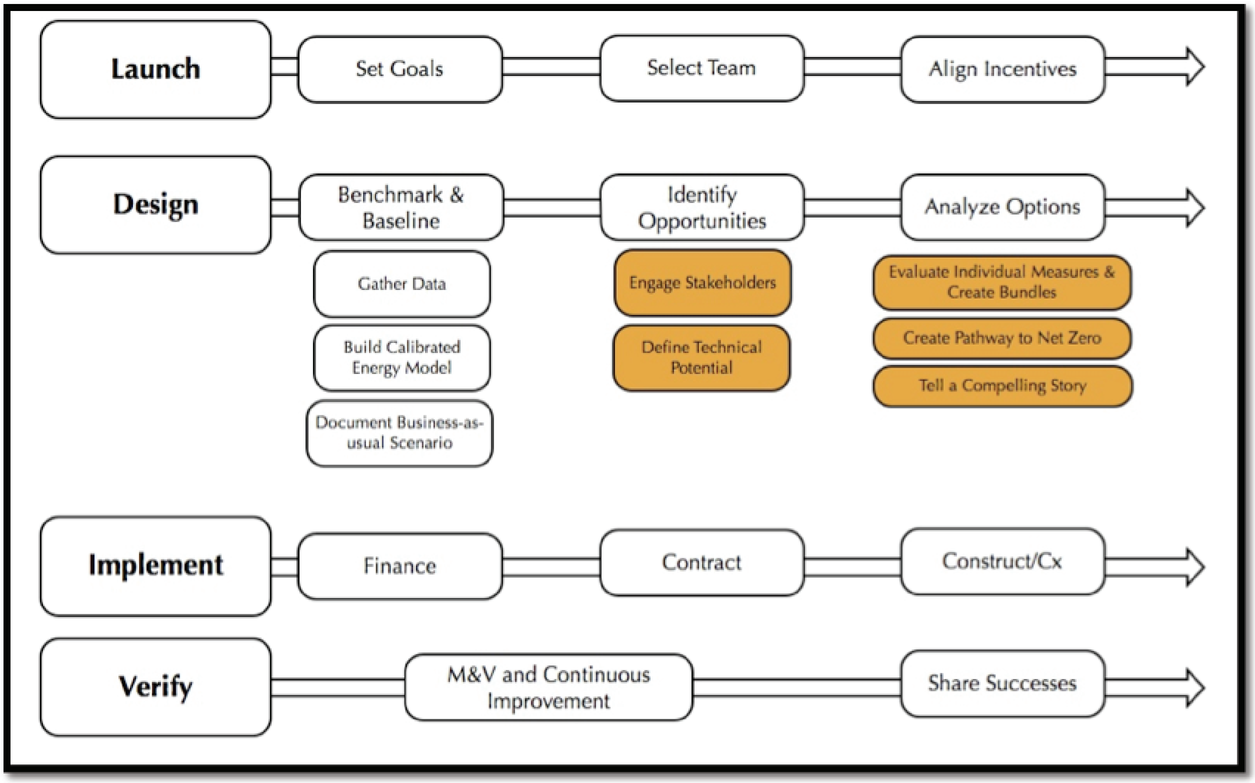
Retrofits not only affect the building owners' net operating income but they also have an impact on tenants. Proposed green pre-built spaces (office spaces that are finished out by the owner and ready for tenants to move in) will save $0.70–0.90 per square foot in operating costs annually. These spaces cost an additional $6 per square foot to

15-Year NPV of Package versus Cumulative CO_2 Savings



The 15-year Net Present Value of various bundles of energy efficiency measures. Individual energy efficiency measures (EEMs) were packaged together in bundles to determine their integrative effects on the overall energy use and carbon emissions.

Retrofit Process Diagram



The process followed in the Empire State Building retrofit. Orange boxes indicate steps that were particularly strong in this project and went above and beyond a typical retrofit process, which enabled significant energy savings.

finish, but we can anticipate that the investment will be recovered through reduced tenant turnover, reduced vacancy, and stable rents. The time spent designing the pre-built spaces evolved into guidelines for all tenants, even those who are finishing out their own spaces.

Project Development Process

Typically, improvements to buildings are made on an ad hoc basis determined by sudden equipment failure or tenant complaints. Not surprisingly, greater energy savings occur when building owners plan for investment and deliberately incorporate energy efficiency. At the Empire State Building, the project team developed a long-term plan coordinated with planned equipment turnover to maximize energy savings with minimal additional investment.

For further reading see: Achieving Radically Energy Efficient Retrofits: The Empire State Building Example: rmi.org/rmi/Library/2010-13_RadicallyEnergyEfficientRetrofits

Process Overview

The process for the Empire State Building retrofit roughly follows the main steps for a deep retrofit (shown in the diagram below). In this case study, we focus on two key steps— "Identify Opportunities" and "Analyze Options."

Identify Opportunities

Engage Stakeholders

A key part of "Identifying Opportunities" is to engage with building tenants. To this end, the team identified three key programs to reduce tenant energy use: the tenant pre-built program; tenant design guidelines; and a tenant energy management program. The proposed green pre-built design will save $0.70–0.90 per square foot in operating costs annually and the design reflects the tenant design guidelines. Nearly 40 percent of tenant space will turnover between now and 2015, so aggressive guidelines are needed immediately. For the tenant energy management program, each tenant space will be sub-metered and a feedback/reporting system will be put into place to inform tenants about their energy use. This program will also help tenants with their own carbon reporting efforts. The team designed a space on the 42nd floor (now complete) for the Empire State Building to use in marketing space to prospective tenants. Key tenant space design features include a highly responsive HVAC system, an indirect layered lighting system (to provide individual control over ambient, task and accent lighting), new high-performance glazing that provides better thermal comfort, and local, high-recycled content construction materials.

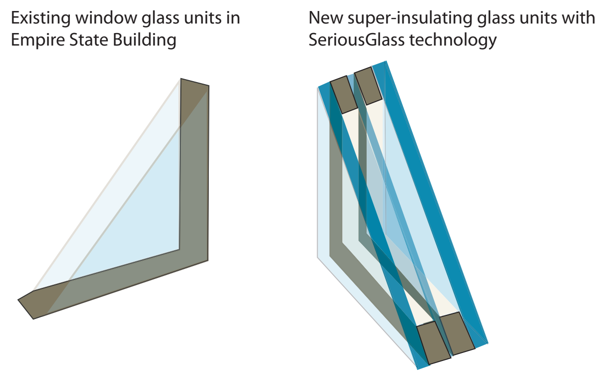
Define Technical Potential

To define the technical potential, the design team collected and brainstormed a long list of ideas for individual energy efficiency measures from in-house experts, outside consultants, and core design team members. This exercise was called a Technical Potential Workshop.

Out of this workshop, the team generated more than 70 energy efficiency ideas to estimate the theoretical minimum amount of energy the building could save, which in this case was 68 percent. This represents the maximum potential opportunity based on today's technology alone, not limited by cost, time, materials or other impediments.

A key approach the team used in identifying opportunities for the technical potential was to leverage the concept of the "right steps in the right order." This approach helps to ensure the team considers all options to reduce the need for lighting, heating, and cooling before considering efficient equipment to meet these needs. Ultimately, the energy efficiency measures for the Empire State Building retrofit aligned with three key pieces that ensured the right steps happened in the right order:

1. **Reduce Loads:** First, the team looked at design solutions that could reduce the thermal loads on the building, thus reducing the need for heating and cooling. The energy efficiency measures that contributed to heating and cooling load reduction strategies included the following:
   a. **Window Retrofit:** Windows were remanufactured on site to reduce the solar heat gain and conduction.
   b. **Radiant Barriers:** Radiant barriers were placed behind the perimeter heating units to direct more heat into the building rather than losing it through the wall to the outside.
   c. **Tenant Loads:** More efficient electric lighting was installed with controls that will help tenant spaces maximize daylight. Individual workstation energy use (plug loads) will be reduced through occupancy sensors and tenant education and feedback.
2. **Install Efficient Systems:** To meet the reduced loads of the new spaces, heating and cooling systems were upgraded with the most efficient systems available.
   a. **Chiller Retrofit:** The team reused the shells of the existing industrial electric



Super Insulated Windows by Serious Windows (Courtesy of Serious Materials)

The temporary window refurbishing production line at Empire State Building (Courtesy of Serious Materials) chillers and replaced the tubes, valves and motors with high efficiency equipment.

b. **Air Handling Units:** Variable air volume air handling units will replace less efficient constant volume air handlers. These provide greater control and occupant comfort while saving energy.

3. **Ongoing Controlling and Monitoring Energy Systems:**
   a. **Tenant Energy Management, Monitoring, and Submetering:** Tenants will receive real-time feedback regarding their energy use and will be able to benchmark their energy use against that of other tenants.
   b. **Demand Control Ventilation:** Measuring CO2 concentrations inside the building will determine appropriate levels of outside air to be brought to the building. This will improve air quality while also reducing energy use (by not conditioning unnecessary amounts of outside air).
   c. **Direct Digital Controls (DDC):** Controls help to optimize HVAC system operation as well as to provide more granular sub-metering of energy use.

Energy, carbon and financial analysis

After identifying an expansive list of opportunities, the design team significantly narrowed the list of over 70+ efficiency measures to ~20 by using decision-making tools such as energy modeling and life cycle cost analysis. Examples of efficiency measures that didn't get implemented included interior wall insulation and building wide LED lighting (though LED lighting was implemented in the observatory).

The team then created bundles of measures to understand the interactive effects of measures on one another and to compare the cumulative energy savings and carbon emissions of various bundles of measures. Ultimately, the team settled on four different bundles that represented a range of investment and savings options to present to building ownership.

The implemented projects include:

Windows: The 6,500 existing insulated glass units were remanufactured into superwindows onsite within a dedicated processing space at the Empire State Building. The double-hung windows have been dismantled and rebuilt to include a suspended coated film and gas fill. This more than triples the insulating value of each window. The total capital cost for this measure was $4.5 million and the annual energy savings is projected to be $410,000.

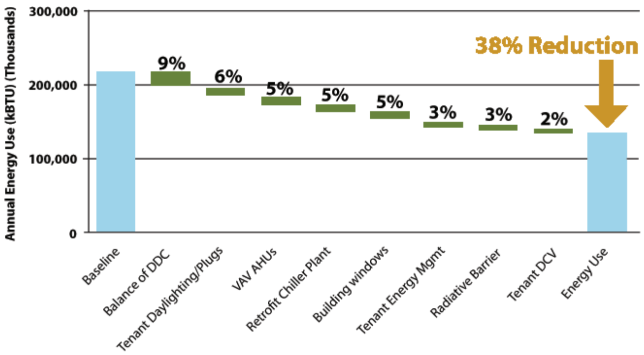
Benefits include:
- Increased occupant comfort through warmer-winter and cooler-summer glass surfaces
- Blocked winter heat loss three times better than the existing windows
- Greatly reduced heating and cooling HVAC loads
- 99+percent ultraviolet blockage to protect both furnishing and occupants
- Directional "tuning" to enhance north-window daylighting and south-elevation solar heat rejection
- Freedom from glass-surface condensation due to super insulation.

Radiative barrier: More than 6,000 insulated reflective barriers were installed behind radiator units located on the perimeter of the building. Currently approximately half of the heat radiates into the usable space, while the other half helps to heat New York City. This barrier will reflect most of the heat back into the occupied space where it was intended to go. Radiators will also be cleaned and thermostats will be repositioned to the front side of the radiator for easier control. The total capital cost for this measure was $2.7 million and the annual energy savings is projected to be $190,000.

Benefits include:
- Reduced heating costs
- Increased occupant comfort

Tenant daylighting/Lighting/Plug loads: 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. This will be implemented within the green pre-built spaces and will appear as recommendations within the tenant design guidelines. The total capital cost for this measure was $24.5 million and the annual energy savings is projected to be $941,000. Benefits of these measures include:
- Lower cooling demand due to less heat from electric lights and equipment
- Reduced utility costs for tenants
- Improved visual quality

Annual Energy Savings by Measure



Energy and CO_2 savings in the optimal package result from the 8 key projects.

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. The total capital cost for this measure was $5.1 million and the annual energy savings is projected to be $675,000.

VAV Air handling units: When tenant turnover occurs, existing constant volume units will be replaced with variable air volume units using a new air handling layout (two floor-mounted units per floor instead of four ceiling-hung units). VAV air handlers are more intelligent than constant volume units providing greater control. The total capital cost for this measure was $47.2 milion and the annual energy savings is projected to be $702,000. Benefits include:

- Greater occupant comfort and control
- Lower utility bills
- Reduced electricity demand

Direct digital controls upgrade: The measure involves upgrading the existing, piecemeal and primarily pneumatic control systems at the Empire State Building to comprehensive, consistent digital controls. The total capital cost for this measure was $7.6 million and the annual energy savings is projected to be $741,000. This measure involves control upgrades for the following building systems:

- Refrigeration Plant Building Management System
- Condenser Water System Upgrades
- Chiller Water Air Handling
- DX Air Handling Units
- Exhaust Fans
- Stand Alone Chiller Monitoring
- Misc. Room Temperature Sensors
- Electrical Service Monitoring

The benefits include:

- Providing greater flexibility
- More intelligence built into the systems
- Increased occupant comfort and control
- Lower utility bills

Demand control ventilation: This project involves the installation of CO2 sensors for control of outside air introduction to the air handling units. Capital costs for this measure was included in the cost for the direct digital controls and the annual energy savings is projected to be $117,000. Benefits include:

- Reduced cooling and heating demand
- Monitoring of indoor air quality
- Increased occupant comfort
- Reduced energy bills

Tenant energy management: This project will provide tenants with access to online energy and benchmarking information as well as sustainability tips and updates. Tenants will have access to a digital dashboard showing energy use in real time and comparing it to past use and other tenants. The total capital cost for this measure was $365,000 and the annual energy savings is projected to be $396,000. Benefits include:

- Live energy use feedback
- Comparison charts can encourage reduction of energy use

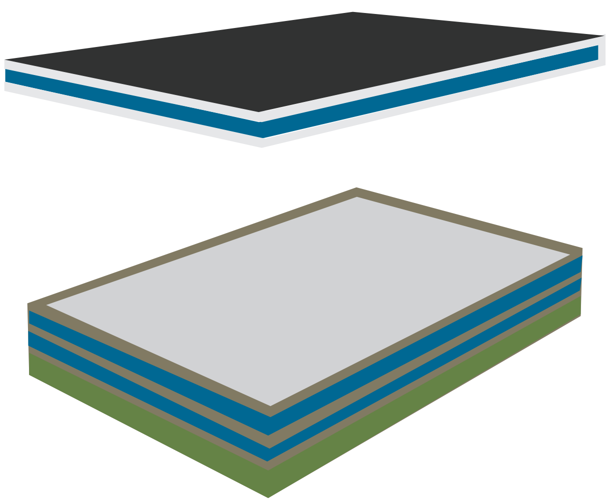
Tools

Extensive energy and financial modeling supported the financial case for the energy retrofit measures. The team ran energy analyses using DOE-2.2 (eQUEST interface), a building energy simulation tool that allows for the comparative analysis of building designs and technologies. After climatic, building geometry, material properties, equipment schedules, and system components information have been input, the program computes building loads and outputs annual building energy use and cost.

Once the team generated preliminary energy savings estimates for individual measures, the team turned to a large custom-built excel financial model to determine how to create packages of measures that maximized greenhouse gas savings while providing sound economic benefits. Iterations between the energy and financial models helped the design team make final recommendations to Empire State Building ownership regarding specific short-term and long-term projects and programs they could implement.

eQuest: www.doe2.com/equest
An hourly energy simulation tool that uses weather and building data to predict energy use with various efficiency strategies.

LCCA Tool
This tool simplifies the interface between architects, engineers, energy modelers and cost estimators



eQuest model of typical floorplate, as modeled.

Cover page of LCCA tool developed by RMI.

to make life cycle costing faster and more comprehensive so the right decisions can be made.

LEED: usgbc.org
An internationally recognized green building certification system provides third-party verification that a building or community was designed and built using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, CO2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts.

The Empire State Building is on track to receive LEED for Existing Buildings: Operations & Maintenance and some tenants are pursuing LEED for Commercial Interiors.

Energy Star: energystar.gov
An ENERGY STAR qualified facility meets strict energy performance standards set by EPA and uses less energy, is less expensive to operate, and causes fewer greenhouse gas emissions than its peers. Energy use in commercial buildings and manufacturing plants accounts for nearly half of all energy consumption in the U.S. at a cost of more than $200 billion per year, greater than any other sector of the economy. Commercial and industrial facilities are also responsible for nearly half of U.S. greenhouse gas emissions that contribute to global warming.

Empire State Building received an Energy Star score of 90 out of a possible 100. This places the pre-war building in the top 10 percent of all buildings for energy efficiency. It is possible the building will score higher once all of the retrofits have been completed in 2013.

Please visit the Tools & Resources section of RetroFit Depot.

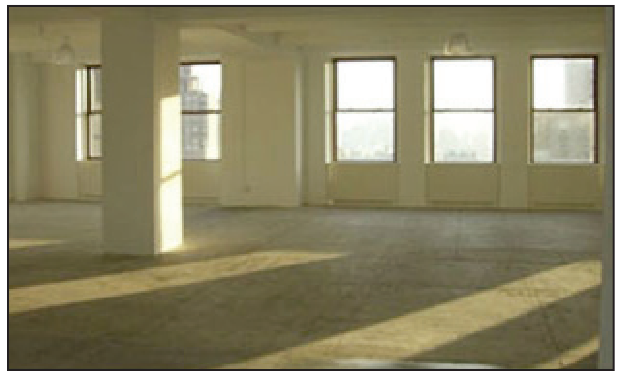
Energy Use Operating Data

The Empire State Building retrofit is expected to be fully completed by 2013. Modeled data indicates an expected 38 percent energy use reduction over the pre-retrofit building. As tenants turn over and their spaces are remodeled under the new tenant guidelines, the remodels will account for a ubstantial portion of the savings.

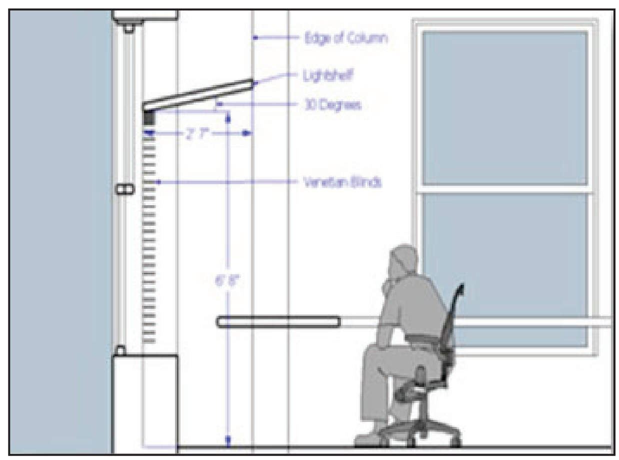
Opportunities for Improvement

Given that few cost-effective deep retrofits have been completed in the U.S., the team learned numerous lessons over the course of the project. Some opportunities for others to consider as they embark on this process include:

- **Navigating multiple stakeholders:** Key stakeholders included building ownership, Jones Lange LaSalle (property management/ tenant engagements), Clinton Climate Foundation (convening body), Johnson Controls (engineering and execution, some measures were implanted under performance contracts), and Rocky Mountain Institute (energy efficiency consultant). Keeping the team aligned throughout the project was a challenge. To overcome this common barrier, the design team purposefully worked very closely together communicating every day as well as via 'imbed' sessions where key team members would dedicate time to work together in the same room, wholly devoted to the project. This process enabled better team building and integration than typical 'distance-designed' projects. Also, multiple workshops conducted at key points (inception, at the conclusion of analysis, and prior to the final decision making point) included all five key stakeholders and allowed for robust discussion around key decisions. Documentation of the key decisions and outcomes was also helpful throughout the process, as it enabled all players to tell a consistent story.
- **Time:** The process took eight months from the inception, through goal setting, energy modeling, and presentation of recommendations to ownership. Beyond this work, the team spent additional time on detailed engineering and developing the performance contract documents. This process could have been shortened and streamlined if the team had more experience working together, had more dedicated staff and had a clearer vision of what outputs they were shooting for.
- **Tenant engagement:** As with any multi-tenant building, investments in energy efficiency measures can be confusing as the benefits often accrue to multiple parties. This challenge was overcome at ESB through the development of the pre-built spaces (where utilities are paid for by ESB) and through the tenant guidelines (where investments and savings are reaped by tenants).
- **Financing:** The financing of this retrofit was simplified due to coordination with already large planned capital investments. Had this project not been coordinated, financing certainly would have been a challenge.



Pre-built tenant space.

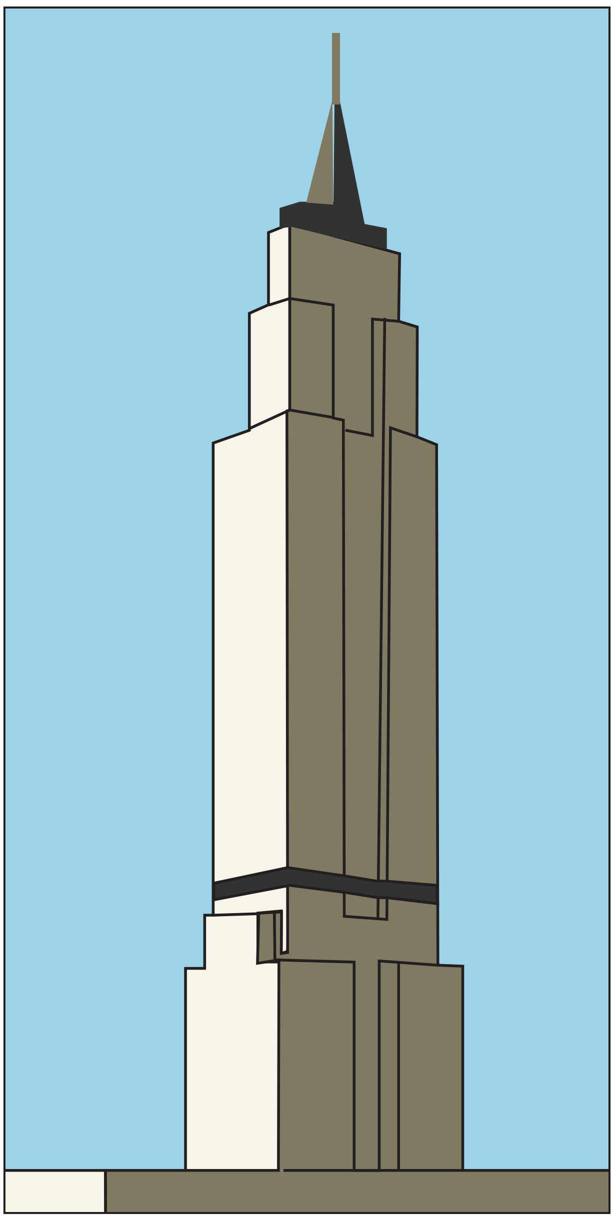


Recommended shading layout as included in the tenant design standards.

Other Benefits

The Empire State Building energy efficiency retrofit is just one component of a huge capital investment aimed at repositioning this iconic skyscraper as a Class A, state-of-the-art office building. The energy efficiency retrofit has created great public relations and is now serving as inspiration and a model for other multi-tenant, multi-story retrofits.

In addition to energy savings, the retrofit measures also improve indoor environmental quality for tenants by way of enhanced thermal comfort from better windows, radiative barriers and superior controls; they improve indoor air quality through tenant demand-controlled ventilation; and they create better lighting conditions that coordinate ambient and task lighting.



Sketch-up model of ESB.