New York’s Empire State Building, opened in 1931 at the height of the Great Depression, is seeking not only to reduce its energy use by nearly 40% and recoup its incremental costs within three years, but to demonstrate the business case for green retrofits of older buildings. The project team is providing its model and practical tools for other building owners to use and replicate.

Energy Renaissance

By Dana Schneider and Paul Rode
Retrofits typically reduce energy consumption by 10% to 20%; however, the team was able to project savings of 38% by taking an integrated approach.

A variety of energy conservation measures were studied prior to project implementation, including the process for refurbishing the Empire State Building’s 6,514 operable windows for energy efficiency. The team analyzed the cost and benefit of reusing the existing windows versus replacing them. It found that removing the sashes and the existing double-pane glass, adding a third pane with a low emissivity (low-E) film, and reinstalling the windows would reduce the upfront cost, double the energy savings and avoid material waste.

In the past, wireless systems were often viewed as unreliable and complicated. They performed poorly, had unacceptable battery life, required additional components and complex tools to install. Wireless connectivity was often limited in range and subject to interference. These systems only provided wireless connectivity between the sensor and controller, and networking still required the usual hard wiring. Needles to say, installations for building owners left much to be desired.

Today, Vicon’s wireless communicating solutions change all of that. Not only do our controllers function without batteries or special tools, but by integrating both our sensor and controller into one device, we have effectively eliminated the need for running additional costly sensor and network wiring.

Our ZigBee-based wireless control mesh technology provides a reliable and cost-effective solution, allowing you to capitalize and create exciting new retrofit opportunities. Today, our wireless communicating systems can be found in numerous locations including hotels, commercial buildings, portable classrooms, university dorm rooms, K-12 facilities and historical buildings.

Installers and building owners are no longer considering wireless installations as a last case scenario. Vicon’s wireless controls have become the solution of choice due to their simplified installation, integration and unmatched reliability.

Please contact us for more information on our complete line of wireless products and discover the freedom that Vicon’s wireless technology can provide.
The Empire State Building is struck by lightning about 100 times per year. It is designed to serve as a lightning rod for the surrounding area.

The air-handling units are another example of capitalizing on the pre-existing capital improvement plan. The team suggested that instead of replacing old units with the same models, the Empire State Building should replace them with variable speed fan units when they wear out. While the cost would be marginally higher, the energy efficiency that was achieved by regulating fan speed by temperature would be much greater, and the building would need only two units per floor instead of four.

**Recommendations**

The team collaborated from April to November 2009 and determined that at current energy costs, the Empire State Building could cost-effectively reduce energy use by 38% and save 105,000 metric tons of carbon dioxide over the next 15 years. Achieving an energy reduction greater than 38% appeared to be cost prohibitive under current economic conditions.

To achieve these results, the building needed to implement eight key projects or measures. The recommendations would reduce cooling load requirements by 33% (1,600 tons) and peak electrical demand by 3.5 MW, benefiting the building and utility.

**Reducing Loads**

**Building Windows.** The building’s approximately 6,500 insulated glass (IG) double-hung windows will be upgraded to include suspended coated film and gas fill. This “remanufacturing” of the IG units will take place within the building. IG units will be removed, delivered to a production area, and picked up for reinstallation. Different coated films will be used as the suspended film according to the orientation. A mix of krypton and argon gas will be used between the glass and suspended film. The upgrade will improve the thermal resistance of the glass from R-2 to R-6 and cut the solar heat gain by more than half, in addition to allowing for the reuse of all existing glass and frames.

**Radiative Barrier.** More than 6,000 insulated reflective barriers will be installed behind radiator units located on the perimeter of the building. In addition, the radiator will be cleaned and the thermostat will be repositioned to the front side of the radiator.

**Tenant Daylighting, Lighting, and Plugs.** Lighting power density and energy use in tenant spaces will be reduced by using ambient, direct/indirect and task lighting; installing dimmable ballasts and photo-sensors for perimeter spaces; and providing occupants with a plug load occupancy sensor for their personal workstations.

It is not likely that the Empire State Building will provide the capital to ensure the tenant measures are implemented; rather, building management will provide tenants with the examples (via prebuilts), the data (the team analysis), and the tools (the eQUEST model) to help them understand the cost-effectiveness of these measures over the term of their lease. The Empire State Building will benefit from tenant compliance with these recommendations as it will result in lower cooling demand and higher sustainability ratings for the building. Tenants will benefit from reduced utility costs and higher quality, more productive spaces.

**Efficient Technology**

**Chiller Plant Retrofit.** The cooling load reduction projects allow the team to reduce chiller capacity. This meant the team could recommend a far cheaper chiller retrofit project rather than bringing in new chillers. The chiller plant project will include the retrofit of four industrial electric chillers (one low-zone unit, two mid-zone units and one high-zone unit) in addition to upgrades to controls, variable speed drives and primary loop bypasses.
The team also considered several options for additional capacity, including cogeneration, gas-fired generation, fuel cells, renewable energy and purchasing capacity. The team recommended a 2 MW natural gas-fired generator to power variable chiller plant loads, increasing capacity to 11.6 MW. However, the ownership decided it was not necessary due to the substantial load reductions.

For all other chillers, the retrofit will involve the installation of new drivelines, new evaporator and condenser water tubes, new control panels, chiller water bypasses with two-way disk type valves, new piping in place of backwash reversing valves, new automatic isolation valves on the CHW supplies to each electric chiller, and temperature and pressure gages on all supply and return lines. In addition, existing R-500 refrigerant will be removed (per EPA guidelines) and replaced with R-134a refrigerant.

Controls

Tenant Demand Control

Ventilation. CO₂ sensors will be installed to control outdoor air to the chilled water air-handling and direct expansion (DX) air-handling units. One return air CO₂ sensor will be installed per unit in addition to removing the existing outdoor air damper and replacing it with a new control damper.

Direct Digital Controls.

The balance of the direct digital controls (DDC) project involves upgrading the existing control systems at the Empire State Building. The proposed project design and layout is based on Johnson Controls’ Metasys Extended Architecture BACnet controllers and includes Ethernet.

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In 1945 a B-25 bomber, lost in the fog, slammed into the 79th floor of the Empire State Building and killed 14 people. The accident caused $1 million in damages, but the structural integrity of the building was not affected.

LESSONS LEARNED

Developing solutions requires the coordination of key stakeholders. Planning energy efficiency retrofits in large commercial office buildings must address a dynamic environment, which includes changing tenant profiles, varying vacancy rates and planned building renovations. In the Empire State Building, the project team included engineers, property managers, energy modelers, energy-efficiency experts, architects and building management. Each of these stakeholders was needed to help build an energy model that addressed the building’s changing tenant profile and helped the team model the impacts of its energy-efficiency strategies. The team also coordinated with the tenants. Involving ten ants early in the process and considering their perspective is critical because more than half of the energy efficiency measures that will be implemented at the Empire State Building involve working both with ten ants and within their spaces.

Maximizing energy savings profitably requires planning and coordination. For an energy efficiency retrofit to be cost effective, the retrofit needs to align with the operation and management needs of multiple building systems and components. For instance, the Empire State Building had plans underway to replace its chillers, fix and reseal some of its windows, replace air-handling units, change corridor lighting and install new tenant lighting with each new tenant. Since these upgrades were already going to be carried out, the team redesigned, eliminated and created projects that cost more than the initial budget, but had significantly higher energy savings over a 15-year period. When these energy savings were accounted for along with the added upfront project costs, the net present value of the energy efficient retrofit projects was better than that of the initial retrofit projects. The total additional cost was $13.2 million with $4.4 million of annual savings, representing a three-year payback for the added cost. However, had energy efficiency projects not been coordinated with planned proj ects, the incremental cost would have been far greater than $13.2 million. Doing energy efficiency projects well before major systems and components are ready for replacement will likely be cost prohibitive, with a poor net present value.

A tension exists between business value and reducing CO2 emissions. In the Empire State Building, maximizing profitability from the energy efficiency retrofit leaves almost 50% of the CO2 reduction opportunity on the table. The building owner, while still selecting an optimal package of measures with a high net present value, sacrificed $30 million of projected profit to deliver more CO2 reductions and improve the light ing and tenant comfort within the building. Changes in energy prices and/or the cost of energy efficiency technologies may help to better align profit maximization and CO2 reduction. However, as things stand currently, a gap exists between the potential CO2 reduction and the financially beneficial amount of CO2 reduction from a building owner’s perspective.

A replicable streamlined process for a whole building retrofit is needed. Developing the energy efficiency strategies that will be implemented in the Empire State Building took over eight months of intensive building audits, brainstorming charrettes, energy modeling, documenta tion and financial analysis. Although the Empire State Building is a unique building with unusual challenges, the process that drove deep energy and carbon savings in the Empire State Building can be made much more accessible.

Having completed the recommendations for the Empire State Building, the project team recognizes that a number of opportuni ties for condensing the study period exist, including developing experienced teams, creating tools for rapidly diagnosing and categorizing a building (or a portfolio of buildings) as “top” or not, and quickly developing a “first-cut answer,” and developing and using tools such as financial and energy modeling to arrive at the optimal package of measures.

Carbon regulation does not significantly affect the Empire State Building recommendation. The financial decision-making tool helped to clarify that the recommended package of energy efficiency measures would not significantly change if carbon regulations led to slightly higher energy prices over time. Carbon regulation that changed energy prices by less than 2% per year had little effect on the financial performance of the modeled packages. However, if energy prices rise by more than 8% (associated with a carbon price of approximately $25/ metric ton of CO2), a package with all of the energy efficiency measures that were analyzed (as opposed to those that were recommended), rises to net present value (NPV) neutral instead of NPV negative.

Airtightness Testing - Not Just for Homes Anymore

Airtightness testing of homes has been around for more than 20 years. Various energy programs and fluctuating energy bills have provided homeowners an incentive to improve the airtightness of their homes. Energy tax credits can also be received by the homeowner but only if the house airtightness has been verified that it is less leaky after remodeling than before.

In England, airtightness testing of buildings over 10,000 square feet was the first regulation initiated to reduce energy consumption. Efforts to make commercial buildings more energy efficient in the U.S. has only recently been incorporated into various “green” initiatives. Tests of commercial building show that they tend to be more leaky than the average house, based on air leakage per square foot of surface area. That means that commercial buildings are less energy efficient than the average house.

To measure the actual airtightness of a large building means more air is needed to maintain a reasonable test pressure. The Energy Conservatory, a leader in airtightness testing, has kits available to directly measure more than 18,000 cubic feet per minute of air leakage. Multiple kits and fans can be used simultaneously to generate more air for accurate and reliable measurements of air leakage for testing before and after retrofitting.

For more information on multi-fan systems contact The Energy Conservatory at 612-827-1117 or visit our website at www.energycconservatory.com.
as sustainability tips and updates. Tenants will be able to compare their energy use to average high and low performers to understand how well they are performing.

**Retrofit Summary**

The greatest cost savings comes from the ability to retrofit the chiller plant rather than replace it. This was made possible by reducing the cooling load by 1,600 tons. The savings stem from the demand control ventilation project, which reduces total outdoor air introduction, and the window light retrofit, which reduces solar heat gain.

Under the proposed plan, peak electrical use would also be reduced by 3.5 MW, down from its current peak and capacity of 9.6 MW to just over 6 MW.

In addition to reducing energy and carbon dioxide emissions, the proposed sustainability program would deliver an enhanced environment for tenants, including improved air quality resulting from tenant demand controlled ventilation; better lighting conditions from coordinated ambient and task lighting; and improved thermal comfort resulting from better windows, the radiative barrier and better controls.

**Financial Analysis**

Johnson Controls (the performance contracting ESCO), the Empire State Building and tenants are each responsible for delivering some of the total savings. The base building projects will be financed out of the building’s cash flow. Work started in 2009 and will be complete by 2013 (55% of the savings will be in place by Dec. 31, 2010).

The ESCO agreed to deliver 61% of the total savings using a performance contract mechanism with a cost of $20 million and guaranteed savings of approximately 20%. The ESCO is implementing the short-term projects that can be done within 18 to 24 months, while the Empire State Building and tenants are implementing the longer-term projects that must be coordinated with tenant turnover.
Table 1 summarizes the cost and projected energy savings for each measure and the total project. When the on-site power generation project is included, the savings are approximately $4.4 million annually for an incremental capital cost of $13.2 million, representing a three-year payback. In addition to energy savings, several projects also qualify for utility rebates and provide operational savings.

**Conclusion**

A compelling need as well as an economic case exist for reducing greenhouse gas emissions in existing buildings. The Empire State Building provides an example of how this can be done. However, significant challenges remain that must be addressed to quickly and cost effectively capture the full greenhouse gas reduction opportunity for building retrofits on a widespread basis.

### Table 1: Costs and Projected Energy Savings

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Projected Capital Cost</th>
<th>Capital Budget 2008</th>
<th>Incremental Cost</th>
<th>Estimated Annual Energy Savings</th>
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<tbody>
<tr>
<td>Windows</td>
<td>$4.5m</td>
<td>$455k</td>
<td>$4m</td>
<td>$410k</td>
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<tr>
<td>Radiative Barrier</td>
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<td>$190k</td>
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<td>Direct Digital Controls</td>
<td>$7.6m</td>
<td>$2m</td>
<td>$5.6m</td>
<td>$741k</td>
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<td>$22.4m</td>
<td>~$17.3m</td>
<td>$675k</td>
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<td>Power Generation (optional)</td>
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<td>$320k</td>
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<tr>
<td>Total</td>
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<td>$93.7m</td>
<td>$13.2m</td>
<td>$4.4m</td>
</tr>
</tbody>
</table>

The first light to shine atop the Empire State Building (November 1932) was a searchlight beacon, which told people for 50 miles that Franklin D. Roosevelt had been elected president of the United States. Now hundreds of fluorescent lights can be changed with the flip of a switch. The changing lighting scheme recognizes holidays, sporting events such as the Super Bowl and occasions such as the homecoming of troops from Operation Desert Storm.

Building provides an example of how this can be done. However, significant challenges remain that must be addressed to quickly and cost effectively capture the full greenhouse gas reduction opportunity for building retrofits on a widespread basis.

### About the Authors

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