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Achieving Radically Energy Efficient Retrofits: The Empire State Building Example

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ABSTRACT

In order to avoid reaching unsustainable levels of atmospheric greenhouse gas (GHG) concentrations, we must reduce GHG emissions by 75% by 2050. "Deep" commercial building retrofits are an essential part of the solution. A "deep" retrofit is 1) a package of integrated, whole-building energy efficiency measures that 2) is coordinated with planned equipment replacement and that 3) optimizes cost and GHG reductions. Developing deep retrofits requires changes to the typical approach to building retrofits (which generally result in only ~15-30 percent energy savings). This paper highlights differentiators between the Empire State Building retrofit process and the typical approach to retrofits. These differentiators are likely not the precise or only changes needed to the typical retrofit process; however, they form a starting point for driving greater energy savings in building retrofits.

INTRODUCTION

It is necessary to reduce greenhouse gases by approximately 75% by 2050 and commercial building retrofits are a critical part of the solution (McKinsey Global Institute 2008). Retrofits have typically produced electricity reductions on the order of 15-30 percent of a building's energy consumption (Osborn et al. 2002); however, in order to meet aggressive greenhouse gas reduction targets, we need to develop new approaches that lead to far greater energy savings than are currently achieved. In this paper, the typical process employed in building retrofits completed by Energy Service Companies (ESCOs) is described. This process is compared to the process used in the Empire State Building (ESB) retrofit, and the elements differentiating the ESB process are explored.

TYPICAL APPROACH TO RETROFIT PROJECT DEVELOPMENT AND EXECUTION

Here, we describe the typical approach to retrofits as the typical Energy

Service Company (ESCO) approach as this process is most similar to the process used in the ESB project. The ESCO process for developing and executing a retrofit project can be described in four phases.

Phase 1: Target & Qualification (1-2 months). The first phase, the Target and Qualification phase, involves evaluating client eligibility for a retrofit. The ESCO investigates credit worthiness, capital constraints, energy cost savings potential, building lease structures, client goals, and other basic elements that determine the viability of a retrofit project. The Target and Qualification phase typically results in a Memorandum of Understanding between the ESCO and the client.

Phase II: Discovery (1-2 months). In the Discovery Phase, the ESCO collects data (from interviews, drawings and specs, past projects, utility bills, etc.) to develop a preliminary report that describes various bundles of energy efficiency measures (EEMs) or individual EEMs. The metrics provided on each measure or bundle (capital cost, energy savings, maintenance savings, simple payback, return on investment, net present value (NPV), internal rate of return (IRR), etc.) depend upon which metrics are requested by or are most appropriate for the specific client. In addition to providing the preliminary analysis report at the end of the second phase, the client is also presented with a project development agreement. This agreement places the cost of tasks completed during the third phase (Verification) on the client if the client does not proceed through to the Execution phase.

Phase III: Verification (10-14 months). The third phase, the Verification Phase, involves detailed engineering for each proposed EEM identified in the Discovery phase in order to determine detailed capital costs and energy and maintenance savings. This phase concludes with the presentation of a performance contract or proposal to the client detailing the project capital cost and guaranteed energy savings (if applicable). If the client signs the contract, the project proceeds to the Execution phase.

Phase IV: Execution (months to years). This final phase includes the implementation of EEMs described in the agreed upon contract as well as the on-going measurement and verification of energy savings. (Raathor 2010)

Clearly, there are many variables in this typical ESCO process that lead to varying levels of energy savings. A number of these variables can complicate an ESCO's ability to deliver aggressive energy savings.

Perhaps the most critical variable in determining energy savings revolves around the client. At the beginning of the project the client and the ESCO work to develop a common understanding of goals, financial metrics that will be used, and cash flows the client is comfortable including in the analysis. For most clients, the metric is simple payback period and the cash flows to be included in the analysis are capital expenditures, energy savings, and maintenance savings. Both using a restricted set of cash flows and relying on simple payback can serve to exclude or hide value that EEMs create, which leads to the rejection of value-enhancing projects. To adequately value savings, and potentially generate a larger performance contract, the ESCO could educate the client about the inclusion of additional cash flows such as changes in building value and the use of other project metrics, such as NPV or IRR that consider cash flows that accrue after the project is paid back. However, the ESCO must walk a fine line; pushing the client too hard could result in a lost job.

Second, during the Discovery phase, where most of the EEMs are identified, the ESCO is not under contract, thus is doing the most critical work (e.g. developing the EEMs) while working at risk. In this critical phase, the ESCO's incentive is to minimize the level of work needed to secure a contract, not to investigate all potential measures and understand the maximum potential energy savings for the building. It is not surprising then that many ESCO projects rely on experience and rule of thumb rather than more detailed and creative engineering and problem solving.

A third opportunity that is often thwarted by clients includes pursuing EEMs within tenant space that may cause tenant disruption. This removes a significant amount of potential savings from being considered.

Thus, while there are many opportunities to realize greater energy savings even within the current ESCO process, there are many challenges. The ESCO is often in a difficult position; one that leads to projects with energy savings far below what is cost-effective.

ESB APPROACH TO PROJECT DEVELOPMENT AND EXECUTION

The ESB process described here provides an example of how retrofits can achieve greater levels of savings and how several, but not all, of the challenges described above can be overcome. Over the course of an 8-month period, an energy efficiency retrofit project was developed for the ESB. Project development activities were divided into four phases roughly correlating to the phases in the typical ESCO process. These phases are:

- ESCO Phase 1: Target & Qualification = ESB Phase I
- ESCO Phase 2: Discovery = ESB Phase II, III, and IV
- ESCO Phase 3: Verification = ESB Performance Contract Development and Project Verification
- ESCO Phase 4: Execution & M&V = ESB Execution & M&V

Phases I - IV of the ESB process are described in this section. Differences between the typical process and the ESB process that cumulatively contributed to greater energy savings are summarized within each phase.

ESB Phase I: ESCO Selection and Inventory & Programming

In the initial weeks of the first phase, building ownership put together the project development team. Players included an Energy Service Company, the property management team directing the planned $550 million capital upgrade program at the ESB, and a third party non-profit design partner and peer reviewer charged with pushing the team to be more ambitious and creative in reaching deeper levels of cost-effective savings.

After the team was selected, the focus of Phase I was to define the "baseline capital projects" budget. This budget included projects from the planned $550 million capital upgrade program that 1) building ownership was planning to complete to maintain building functionality and that 2) may have some impact on energy use. The baseline capital projects budget of $93 million became the benchmark against which the cost of alternative or new projects could be compared to in later phases.

Phase I Differentiators: The key differentiators between the typical ESCO process and the ESB process in this first phase include the use of a collaborative team, the existence of a fully budgeted "baseline" program, and the advantage of a highly informed and motivated client.

In a typical retrofit project, the ESCO is usually the prime project manager and sole project developer for a retrofit project. With ESB, a collaborative team that included an ESCO, a large property management firm, and several non-profit organizations contributed. The use of third party representatives by the owner allowed the ESCO to be influenced to work beyond the typical process.

Secondly, it is rare for an ESCO to start an energy efficiency project when an alternative capital improvement program (that didn't consider energy efficiency) has already been fully detailed and budgeted. This was hugely advantageous for the ESB team because it elevated the powerful concept of incremental costs and savings for not just energy but also for capital expenditures.

Lastly, challenges occur in any project. When the project development team or ESCO starts to struggle, it is typical for the client to back away, re-evaluate options, and lower expectations. This was not the case with ESB. Goals were set, challenges occurred, and building ownership continually raised expectations, supported the team, and demanded aggressive results.

ESB Phase II: Design Development

The second project phase for ESB was aimed at documenting existing (e.g. pre-retrofit) building equipment as well as understanding building resource consumption trends. Existing infrastructure in the 2.8 million sq. ft. (260,120 sq. meters) building includes a large chilled water plant consisting of electric and steam chillers (total cooling capacity of 7,794 tons) and two cooling towers (5 cells each providing a total capacity of ~6,000 tons). Chilled water and condenser water pumps are on dedicated primary constant volume distribution loops that serve three separate zones. All heating for the building originates from a 125 psi (862 kPa) ConEdison steam header that serves four separate building systems: perimeter radiators (space heating), air handlers (space heating), domestic hot water, and steam chillers. The standard ventilation system for tenant spaces in the building is a 15-ton modular Air Handling Unit (ceiling-hung, constant volume). Common areas on typical floors are ventilated via infiltration and exfiltration from adjacent tenant spaces and central building shafts. Restrooms are ventilated via exhaust fans located on various floors throughout the building. Lighting systems vary dramatically amongst tenant spaces, corridors, restrooms, and lobbies. The most common lighting systems installed within the building include fluorescent fixtures with electronic ballasts and T8 lamps.

In terms of energy use, the ESB (office portion) has an annual energy cost of over $11 million, a peak electrical demand of 9.5 MW, and an annual energy use of 88kBtu/sq. ft./year (277 kWh/sq. meter/year). The total electricity consumption in 2007, excluding broadcasting, was 44,912,408 kWh and the total steam consumption was 95,210 MMBtu. The basic electricity rate was $0.13 per kWh, while the effective blended average electricity rate (including demand charges) was $0.19/kWh. The effective blended average rate for steam (including demand charges) was $29/MMBtu.

In addition to documenting building systems and understanding resource trends in

Phase II, the team generated over 70 energy efficiency ideas to estimate a “theoretical minimum” energy use of 68 percent. The term theoretical minimum was defined as the energy use if all measures that were technically possible using today’s technology (though maybe not economically feasible) were implemented (not including renewables or other generation technologies). If the team varied from the 68 percent savings potential, they wanted to understand why (e.g. measure was too expensive, was too invasive, etc). This goal setting exercise pushed the team to be more innovative and helped the client understand what was technically possible.

Phase II Differentiators: The key differentiators between the typical ESCO process and the ESB process in the second phase include the investigation of an extensive number of EEMs as well as the use of the theoretical minimum energy use as the primary reference target.

In a typical retrofit project, the ESCO is crunched for time in the Discovery phase to create the preliminary analysis report and to obtain a signed project development agreement, thus there is not time for an exhaustive investigation of potential measures. With ESB, it was expected and encouraged by ownership that the team examine all potential energy saving opportunities.

ESB Phase III: Design Documentation

Phase III of the ESB process focused on building a calibrated energy model as well as on creating strategies to minimize tenant energy use.

The energy modeling team created a custom weather file for the calibration year, input all data (geometry, zoning, envelope characteristics, internal gains, schedules, outside air requirements, HVAC systems and controls, and utility information) into the selected energy modeling simulation program, and calibrated the model. Once calibrated, the team set about translating each of the viable EEMs (reduced to approximately 20 measures based on redundancy, constructability, and cost) into appropriate energy model inputs.

The second main focus of Phase III was investigating strategies to reduce tenant energy use. Tenant energy savings, while less predictable and more challenging to achieve (as they are dependent upon program execution by ESB and incoming tenant profiles), are typically more visible to tenants, thus potentially have greater influence on tenant satisfaction, retention, and marketing efforts. The team focused on three strategies to address tenant energy use: 1) development of energy efficient pre-built space specifications, 2) creation of tenant design guidelines (for tenants who hire engineering/contractor teams to fit out their space), and 3) the use of energy management hardware and software to provide access to energy use data for all tenants.

Phase III Differentiators: The key differentiator between the typical ESCO process and the ESB process in the third phase includes the time spent evaluating opportunities in tenant spaces. Mostly due to owner direction, it is rare for an ESCO to design and evaluate alternatives for tenants in a multi-tenant building. As a result, many integrated design opportunities (e.g. reduced HVAC system size due to reduced cooling or heating loads) are lost, as the majority of the cooling and heating load cannot be affected.

ESB Phase IV: Final Documentation

The goal of the final ESB project development phase was to synthesize all of the energy audit data, brainstorming, team collaboration, and EEM development work completed during earlier phases and input this data into the energy and financial models to determine the recommended package of EEMs. To determine the relative financial impacts of implementing individual measures and packages of measures, the team developed a financial decision-making spreadsheet tool. The iterative energy and financial modeling process is described here:

Step 1. The team began by calculating the net present value (NPV) of individual measures.

Step 2. Based on these results, the team was able to begin to define points on an "NPV vs. CO_2" curve. By packaging the measures that had positive individual net present values, the team created the "NPV Max" package. Similarly, the team was able to create the "CO_2 Max" package by placing all measures into one package that maximized CO_2 savings.

Step 3. After creating the NPV Max and CO_2 Max packages, the team recognized that neither put forth the best solution for the client. This led to the creation of two more packages, the "NPV Neutral" package and the "NPV Mid" package, that provided more of a balance between economics and CO_2 savings. The iterative process of adding and deleting measures to each package was informed by the individual NPV and cumulative CO_2 savings calculations. The final four packages are shown in **Figure 1 below**.

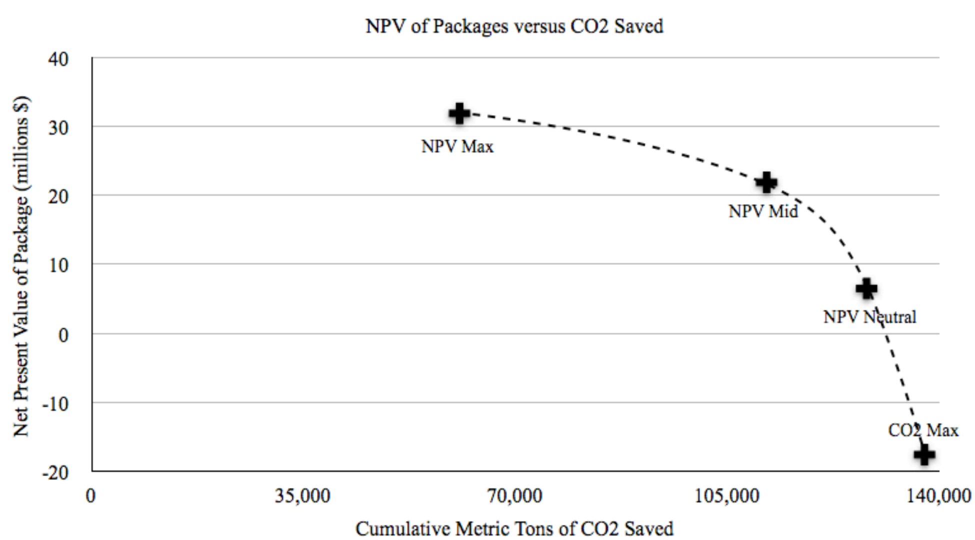

Figure 1 *Each of the modeled packages with their respective net present values and cumulative metric tons of CO2 are shown in the above diagram.*

Step 4. In finalizing the recommendations, the team conducted sensitivity analyses on the packages to test the effects of changes in capital costs, energy prices, energy savings, and rental premiums. Based on the building ownership's goal of implementing a retrofit program that was both commercially viable and achieves a high level of energy savings, the project development team recommended implementing the NPV Mid package. The NPV Mid package provides a 38% reduction in energy use, saves 105,000 metric tons of CO_2 over the next 15 years, and has an incremental net present value of approximately $22 million. The eight measures included in this package are described here:

1. Building Windows: Upgrade the existing insulated glass (IG) within the ESB's approximately 6,500 windows to include suspended coated film and gas fill.
2. Radiative Barrier: Install more than 6,000 insulated reflective barriers behind radiator units located on the perimeter of the building.
3. Tenant Daylighting, Lighting, and Plugs: Reduce tenant energy use by using ambient, direct/indirect, and task lighting, installing dimmable ballasts and photosensors for perimeter spaces, and providing occupants with a plug load occupancy sensor for their personal workstation.
4. Chiller Plant Retrofit: Retrofit four electric chillers (one low zone unit, two mid zone units, and one high zone unit) and upgrade controls, variable speed drives, and primary loop bypasses.
5. VAV Air Handling Units: Use a new air handling layout (two floor-mounted units per floor instead of four ceiling-hung units) and replace constant volume units with variable air volume units.
6. Demand Control Ventilation: Install CO_2 sensors for control of outside air to the Chilled Water Air Handling and DX Air Handling Units.
7. Balance of Direct Digital Controls (DDC): Upgrade the existing control systems to all digital controls for the following building systems: Refrigeration Plant Building Management System, Condenser Water System Upgrades, Chilled Water Air Handling Units, DX Air Handling Units, Exhaust Fans, Stand Alone Chiller Monitoring, Misc. Room Temperature Sensors, and Electrical Service Monitoring.
8. Tenant Energy Management: Collect 15-minute meter data and create a normalized database that can be used to support Time Series profiling, reporting to the ISO, and integration in the future with property management software for creating a bill based on current meter read.

Phase IV Differentiators: The key differentiator between the typical ESCO process and the ESB process in the last phase includes a focused effort to present a <u>sophisticated yet digestible business case</u> to compel the owner to push for deeper energy savings.

Just doing a detailed analysis is not enough to compel a client to select a more aggressive package of measures. The analysis must be presented in terms that resonate with the owner. The ESB team developed a compelling presentation that led the client through a series of charts, tables, and graphics that created a logical story and business case for the project. The detailed presentation of the business case was critical towards helping the client make their decision.

ESB Performance Contract Development, Project Verification, Execution & M&V

Following the conclusion of the fourth phase of the ESB Project Development, the project entered the equivalent of the typical ESCO “Verification” phase. First, performance contracts were signed for each project. Then the ESCO verified project details, construction costs and sub-contractors, schedules, and began executing.

CONCLUSIONS

Meeting aggressive carbon reductions in the U.S. and globally will require deep retrofits of commercial buildings. The Empire State Building retrofit provides an example of several unique elements that could improve the chances of retrofits achieving greater energy savings. First, building owners could benefit from primers regarding appropriate metrics, goals, inclusion of tenant scope, and team make-up (including third party oversight) for deep retrofits. Second, more time and analytical horsepower could be allocated to the phase of the retrofit that generates most of the EEMs (the Discovery Phase). This could require changes to typical contract structures so that ESCOs are incentivized to spend time to find the maximum energy savings. Lastly, more effort could be spent creating a compelling business case for deep retrofits.

For these differentiating elements described above, addressing several important questions could further legitimize their potential in helping to generate deeper energy savings in building retrofits:

- What level of additional savings can be gained from a more robust Discovery phase and at what point does a greater level of analysis hit diminishing returns? Are there other phases that can be sped up to enable more time for the Discovery phase?
- Is there a more effective energy-contracting model that incentivizes greater energy savings? (e.g. booster payments for 40%, 50%, etc. thresholds). Or a model that uses a third party player dedicated to develop projects that generate greater energy savings cost effectively?
- Is there a role for an independent third-party to develop a program to educate owners about the potential of deep retrofits and the factors that contribute to successful retrofits (e.g., potential of tenant-focused EEMs)?

The Empire State Building project demonstrates the potential for how some of these changes to the typical process may result in deeper energy savings. Greater investigation of these opportunities through both research and application will facilitate the much-needed implementation of deep, cost-effective commercial building retrofits.

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