CONSORTIUM for BUILDING ENERGY INNOVATION

FINDINGS

The Consortium for Building Energy Innovation

CBEI is focused on generating impact in the small- and medium-sized commercial buildings (SMSCB) retrofit market. CBEI is comprised of 14 organizations including major research universities, global industrial firms, and national laboratories from across the United States who collaborate to develop and demonstrate solutions for 50% energy reduction in existing buildings by 2030. The CBEI FINDINGS series highlights important and actionable technical, application, operation and policy research results that will accelerate energy efficiency retrofits when applied by various market participants. CBEI views these FINDINGS as a portal for stakeholders to access resources and expertise to implement change.

Achieving Deep Energy Retrofits

CBEI defines deep energy retrofits as a whole-building analysis and construction process that achieves much larger energy cost savings (sometimes over 50% reduction) than those of conventional, simple retrofits and fundamentally enhances the building value.

The few owners who perform energy retrofits generally switch out the lighting and add new motors to the heating and cooling system. The decision making for this approach is driven by the capital cost and return on investment for each measure; hence big measures are typically not even considered because they are perceived as too risky.

The SMSCB market considers energy planning a luxury it cannot afford. To achieve results in this market that can yield acceptable return on investment (ROI) will require new approaches. The concept of building asset planning is not new, but incorporating energy asset planning is new.

Delivering low cost energy asset planning requires low cost whole building analytics (e.g. NREL simuwatt Energy Auditor), private/public economics that reduce planning cost/risk and trained energy companies to offer such services.

Research Finding: Building Asset Management

Implementing a deep energy retrofit, to achieve a 40 to 50% building level efficiency improvement, on a small to medium sized building is not financially viable as a single project. Therefore, creating an energy asset management plan that manages “deep energy retrofit triggers” over time is very important to consider.

In other words, to achieve deep energy retrofits in the SMSCB markets is achievable when energy audits are cost effective, reliable and lead to the development of an energy asset plan that identifies deep energy retrofit triggers and provides the economic rationale and optimal implementation. Stakeholders need to identify and deliver the following:

Deep Retrofit Triggers: Identifying the situations in a building’s life cycle that should trigger a deep energy retrofit.

Technical Potential: Finding the energy use that would result from implementing the most impactful efficiency measures possible.

Modeling: Economically and reliably determining energy and life cycle cost savings using advanced methods.

Right-Timing & Right-Sizing: Timing efficiency improvements with already planned capital improvements and breaks in occupancy; accurately sizing mechanical and electrical equipment.

Measurement & Verification: Ensuring achievement of savings while illuminating opportunities for continuous improvement.

Moving Toward Asset Management

Building 101 currently serves as a multi-tenant office building which is largely occupied and contains 69,246 ft^2 of conditioned area. The building was completely renovated in 1999 including a new HVAC system.

In 2010, PIDC[1] took ownership of the building and in 2011, CBEI occupied a portion of the building as its temporary headquarters. CBEI instrumented the building in 2012 to use as an energy model calibration tool and eventually to test component and system performance.

One result from this building performance data was the realization that the building automation system (BAS) was dysfunctional and needed to be replaced, especially since the system was no longer supported by the manufacturer. The BAS replacement and retuning effort is detailed on page 3.

In 2013 a refrigerant leakage was detected in one circuit of the condensing coil in CU2 (60 Tons). It was determined that the coil could not be repaired and given the age of the unit (14 years) repairing was not a viable option. This created a typical problem that would typically lead to a like-for-like replacement. CBEI was able to use its Energy Plus model of the building to perform energy analysis of retaining the three DX systems configuration, changing to a single air-cooled chiller, or an air-cooled chiller with heat recovery. This type of asset optimization should be a part of any energy asset plan and not made as a part of a failure recovery effort. Fortunately, CBEI had the data to help PIDC make the best decision – on the fly.

[1] PIDC is a non-profit partnership between the City of Philadelphia and the Greater Philadelphia Chamber of Commerce, which operates the Philadelphia Navy Yard complex.

Building 101 Baseline

Initially built in 1911 to serve as a U.S. Marine Corps barracks, Building 101 is a three story commercial building that underwent a major renovation in 1999 to accommodate a single tenant. This renovation included adding a forced air heating and cooling system to the formerly hydronically heated barracks. In 2010, the building ownership was sold back to the Philadelphia Industrial Development Corporation (PIDC).

Heating: The building's heating needs are met by a gas- fired, cast iron, sectional hydronic boiler rated at approximately 1,600 MBH output. Two (2) small pumps supply hot water from the boiler to the heating end devices. The building is heated primarily by air handling units and variable air volume (VAV) box hydronic reheat coils. The boiler is enabled and disabled by the BMS, based on outside air temperature.

Cooling: The building is cooled via direct expansion (DX) vapor compression refrigerant systems serving air handlers. Each of the three (3) main air handling units is cooled by its own DX evaporator coil and dedicated condensing unit. Two of the large DX units are rated at a nominal 60 tons of cooling; the third is rated at a nominal 40 tons of cooling.

Air Handling: There are a total of twenty-seven (27) variable air volume (VAV) terminal boxes. The VAV boxes use hot water coils for heating. The air handlers are equipped with variable frequency drives (VFDs) to control the speed of the supply fan motors.

Supply fan VFDs are modulated to maintain static pressure in the network of distribution ducts. As thermostat setpoints are met, VAV boxes close, duct static pressure increases and the supply fan VFD reduces speed to maintain a pressure set point. Conversely, when thermostats call for additional heating or cooling, VAV boxes open, pressure drops and the supply fan VFD speed increased.
Tenant space in the South basement area is served by a ground-mounted packaged air handling unit. Tenant space in the North basement area is served by an indoor packaged air handler.

Building 101 BAS Upgrade and Retuning

In December of 2012, the building owner, PIDC, based on the building performance data collected by the CBEI decided to implement a control system upgrade. The condition of the existing BAS system and the energy and economic potential of this energy efficiency measure (EEM) made the decision easy for the owner.

New VFDs were installed on the AHU supply fans to improve efficiency, harmonics and allow complete monitoring by the BAS systems. The new BAS system is built on the ability to measure and control temperature, humidity and CO_2 levels in each of the 27 HVAC zones. By adding this control feature, the BAS was equipped to operate using demand control ventilation with static pressure reset and supply air temperature control. In addition, enthalpy-based economizing control was also added, but this is somewhat limited by the physical size of the outside air intakes. The BAS controls the DX coils to maintain supply air temperature setpoints, which are set based on the load conditions. Zone temperatures are placed in setback during unoccupied periods by the BAS as well. Combining economizer operation, demand control ventilation, supply air temperature control and zone temperature setback provides optimal energy savings for this system while maintaining indoor air quality. The new BAS was designed and installed to provide the building's lighting and mechanical systems in an optimal performance setting. The exterior lighting is now controlled by photocells and the interior lighting remains largely schedule-based.

The Results

The average electricity cost from Jan-April, 2012 bills is about 14.7 cents/KWh. The gas cost used was $1.35/CCF. The annual electric savings was found to be $42,824 and annual gas savings were $12,559.

Table 1 Electrical energy use breakdown

End Use	Pre-Retrofit Consumption (KWh)	Annual Savings (KWh)	Annual Cost Savings
Exterior Lighting	16,316	3,600	$529
Interior Lighting	266,603	56,422	$8,294
Exhaust Fans	13,884	9,880	$1,452
AHU supply fans	184,697	112,756	$16,575
Cooling	250,001	108,660	$15,973
Total	731,501	291,318	$42,824

Table 2 Retrofit capital investment breakdown

Item	Capital Investment
Exterior Lighting	$2,700
Interior Lighting	$17,300
Building Automation System	$81,300
VFDs	$17,500
T, RH, CO_2 sensors	$9,500
Software Light Switches	$11,760
TAB	$16,300
Controls Retrofit	$146,860

The simple payback period for this retrofit is ($146,860)/($42,824+$12,559)=2.7 years.

Unplanned Condensing Unit (CU) Replacement

Using the CBEI energy model for Building 101 and the actual building load profile energy efficiency impact results for the three options were calculated. It was determined, in this case, that the energy efficiency of a DX replacement versus integrated building air-cooled chiller was negligible and heat recovery from the chiller system was not cost effective. The nature of the problem with CU2 needing to be replaced for tenant comfort reasons and to be able to remove several rental air conditioning units (DX2 system is operating at less than 50% capacity), replacing CU2 is considered an emergency replacement which can be directly negotiated by the operating agent. Replacing the HVAC system requires a public bidding process which would be worthwhile if significant gain could be achieved, which is not the case. Nevertheless, preplanning this deep energy retrofit trigger would provide a more certain outcome.

Lessons Learned

Deep energy retrofits are expensive and generally cannot be amortized using incremental energy savings alone. CBEI experience working with its customer base confirms that, to achieve deep energy retrofits, building/equipment triggers that are critical. Building an asset management plan incorporating energy triggers like the following:

End of useful life: Planned envelop upgrades (roof, window and siding) provides opportunity for improvement in efficiency and daylighting at an incremental cost that also reduces heating/cooling loads and lighting requirements. Major equipment replacements provide opportunities to address other building systems as part of a deep retrofit. After reducing thermal and electrical loads, the marginal cost of replacement is lower.

Tenant changes and building adaptation: Building redevelopment requires significant capital expense. Deep energy retrofit costs become incremental and small in comparison and can offset other expenses especially when upgrading a building's class level.

Code compliance: Regulatory upgrades can lead to disruption and cost. Life safety upgrades can provide opportunity to incrementally increate the project costs, while substantially improving energy efficiency. Again, using the trigger can provide an incremental step toward a deep energy retrofit.

Ownership change: New acquisition or refinancing at today's low interest rates establishes a means to finance building energy upgrades as part of the transaction.

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CBEI is a research and demonstration center that works in close partnership with DOE's Building Technologies Office.

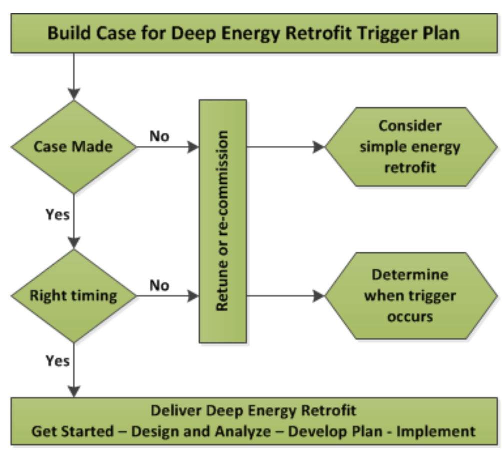
Moving Forward

Working through the BAS system and retuning effort resulted in about a 40% reduction in Building 101 lighting and HVAC system electric consumption. This is a major accomplishment, but one that is seldom performed in buildings of this size where split incentives exist.

In the case of Building 101, the eight tenants in the building are not separately metered, therefore, their energy payment are prorated by square footage, so there is some interest by the owner to reduce energy as it is transparent to any prospective tenant and becomes a factor in decision-making. Furthermore, Philadelphia is a benchmarking and disclosure jurisdiction and this building is subject to energy disclosure.

EPA, DOE, ASHRAE and other entities are developing building labeling programs, some of which are being codified. These efforts will certainly become drivers in the future.

Moving forward from this case study, there is a clear path forward to engage stakeholders particularly with portfolios of medium and small sized buildings and develop energy asset plans that will yield deep energy retrofits and leverage asset management planning across the nation.



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