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# Whole-Building Retrofits: A Gateway to Climate Stabilization

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## ABSTRACT

*This paper discusses creative elements of deep whole building retrofits. It discusses process and technique, how to select suitable buildings, the key players that must be involved, project development tasks the design team must complete, and tools and skills that engineers will need to acquire to comprehensively and cost-effectively retrofit the existing commercial building stock.*

*For retrofits to achieve their potential in carbon emissions reductions, design teams must design deeper building retrofits that save more energy. Whole-building retrofits are more than lighting or chiller replacements. Engineers need to expand their skill sets to focus on load reduction measures that allow for efficiency improvements with avoided capital costs, or "tunnel through the cost barrier." Engineers advise owners on key decisions by estimating the carbon savings and life cycle cost of carefully designed packages of measures. This paper describes tools for wise decision-making that balance predicted operational cost savings with reduced carbon production. In this manner, design teams can achieve deep comprehensive building retrofits that provide significant carbon reduction.*

*Contributing to climate stabilization is one of the largest challenges facing the building industry. Engineers have an expanding opportunity and role to play in rising to this challenge through deep retrofits of existing buildings.*

## INTRODUCTION

As practitioners, we have strategic opportunities to influence dramatic energy savings in commercial building retrofits. The need is great. Commercial buildings consume roughly 37% of total energy in the United States, which includes 68% of our coal consumption and 55% of natural gas consumption (USEIA 2009). While the industry press has increasingly recognized sustainable design in recent years, there has been little measurable progress in increasing the efficiency of our commercial building stock. Despite new codes, design tools, technologies, media momentum, and early success stories, the U.S. commercial building stock is no more energy efficient today than it was 25 years ago (USDOE 2008).

As ASHRAE professionals embark on the mission proposed by Gordon V.R. Holness, P.E., ASHRAE President, to "Sustain our future by rebuilding our past," we will need to do just that. Rebuild. We need to rebuild with deep comprehensive retrofits that cost effectively reduce energy use by 50% or more. Comprehensive rebuilding requires

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more than efficient lighting and HVAC systems; the depth of rebuilding necessary to reach IPCC goals must include a whole-building, whole-systems analysis. More than simply upgrading systems, we can analyze and optimize the coordinated energy savings benefits deduced from the interactions between systems, such as daylighting systems, alternative mechanical layouts, envelope measures and other load reduction improvements. Additionally, we must reach a larger portion of the building stock than current penetration rates.

To date, design teams do not typically optimize building energy retrofits; we take simple savings while leaving copious opportunity untouched. There are several reasons for this (Lovins 1992):

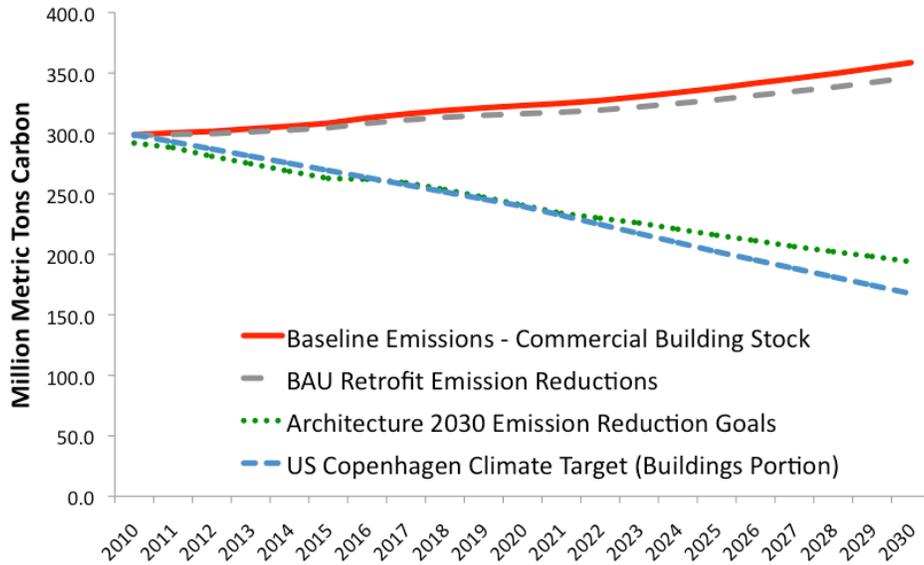
- a) The various systems (electrical, architectural, and mechanical) in buildings are fragmented and design teams often consider them as individual systems. Typical retrofits do not account for the interactions between systems; we need to encourage design teams to develop deep whole-building retrofits as coordinated packages.
- b) Design teams use first cost and simple payback more than Life Cycle Cost Analysis. This often favors bad investment decisions, as they do not coordinate cost analysis with energy analysis.
- c) Financing is not always available for comprehensive retrofits, and energy retrofits are not coordinated with other building system renovation;
- d) The industry lacks experience with the processes and knowledge required to perform deep retrofits; and,
- e) The landlord / tenant situation can create split incentives that building owners must address in order to realize cost savings as well as to achieve the deepest energy savings.

The following sections describe methods for design teams to overcome these barriers and achieve the deep, cost-effective retrofits required to meet IPCC carbon goals.

## **THE OPPORTUNITY FOR RETROFITS TO HAVE LARGE IMPACT**

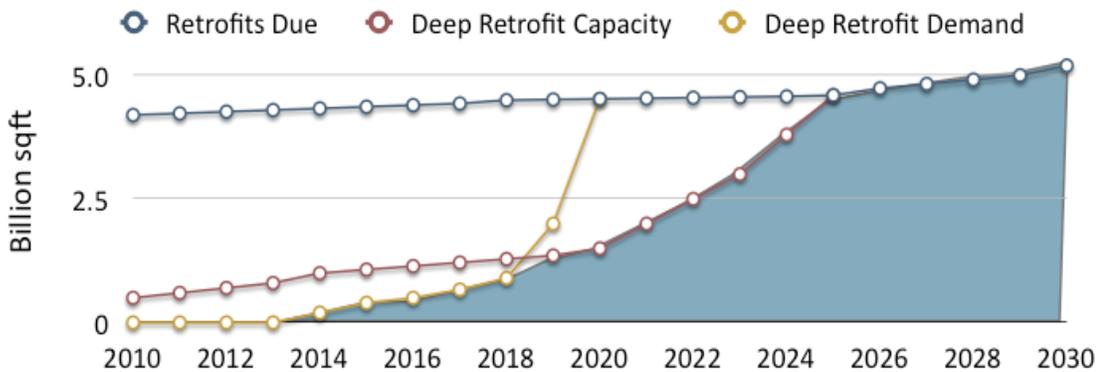
Existing commercial building stock is currently being retrofit at a rate of roughly 2.2%, or 2 billion square feet a year. Median savings from these retrofits is roughly 11% per building versus EIA Commercial Buildings Energy Consumption Survey (CBECS) average energy use intensity. At this rate, half of the existing building stock will be retrofit by 2030, with a cumulative carbon savings of 13.5 million metric tons (Mt). By contrast, the ASHRAE-supported 2030 Challenge goals require the existing U.S. building stock to reduce 179 Mt carbon emissions by 2030 through retrofits. There are two means to achieve the difference in carbon savings: Either we need to retrofit more square footage by 2030, or the space we retrofit must achieve drastically greater savings. A combination of both strategies will be key to achieving 2030 goals, as shown in (Figure 1).

## Commercial Building Carbon Emission Projections



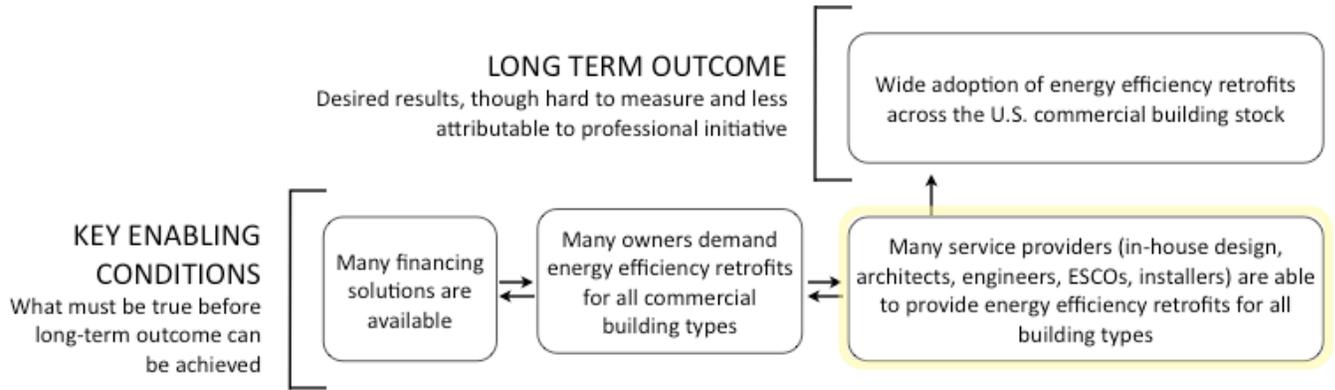
**Figure 1** Commercial Building Carbon Emission Projections - reductions possible by meeting the 2030 Challenge EUI targets in existing commercial building stock.

Figure 2 shows a path for increasing the number of buildings that will embark on a retrofit over the next 20 years. Two key limiting factors include 1) the number of buildings every year that are available for whole-systems solutions (based on equipment life cycles), and 2) professional capacity to design and execute whole-systems deep retrofits. By making a compelling business case, and ramping the quantity of whole-systems retrofits, we can encourage this retrofit adoption scenario. Equally critical is achieving drastically greater savings per building retrofit, which we can cost effectively achieve by using whole-systems thinking.



**Figure 2** Increasing Demand and Capacity to Retrofit 100% of Buildings Due

Methods to achieve a greater quantity of retrofits at a larger energy savings can be based on a theory of change with a long-term desired outcome at the top, and short-term outcomes that lead up to this (figure 3).



**Figure 3** Theory of change to reach intensified retrofit goals.

The long-term desired outcome is wide adoption of energy efficiency retrofits across the U.S. commercial building stock. Short-term outcomes to get there revolve around three major areas: 1) availability of financing solutions, 2) owners demanding highly effective efficiency retrofits, and 3) knowledgeable, effective service providers who can achieve the dramatic energy and cost effective savings. It is this third area (becoming effective service providers) where the professional architectural and engineering community can have a significant and direct impact. The two main ways professionals can ensure that deep retrofits are accomplished is by carefully selecting projects and by providing high performance project outcomes.

## SEEING THE BIG PICTURE: THE WHOLE SYSTEMS APPROACH

**Barrier:** The various systems (electrical, architectural, mechanical) in building are fragmented and design teams tend to consider them as individual systems. Retrofits traditionally do not account for the interactions between systems. **Solution:** Whole-systems thinking can produce a package of measures that optimizes the whole building for resource efficiency. This includes:

- Interactions between building systems, such as window upgrades resulting in lighting and HVAC downsizing
- Interdisciplinary approaches, such as integrating the economics of a variety of engineering solutions and comparing this to the carbon savings,
- Integrating energy and other retrofitting concerns; and,
- Designing to avoid capital costs.

Whole-systems thinking is a powerful way to maximize benefits available in a retrofit project. It is interdisciplinary, and requires more analysis earlier in the design process, but results in a comprehensive understanding of how the design can save the most energy in the most cost-effective manner. Without careful, comprehensive cost and energy analysis there is no way to account for the various

interactions of the variety of systems in play.

The whole-systems thinking process means following the right steps in the right order. It works to maximize potential efficiency through defining programmatic needs accurately first. By testing assumptions and clarifying needs, architectural and engineering professionals can define the actual services they will provide, rather than providing a solution that may be unnecessary to meet the requirements. Once needs are accurately defined, engineers can work with the rest of the design team to maximize efficiency by integrating the engineering upgrades with other architectural and program needs. **(See cost reduction method 1.)**

## **Making Retrofit Projects Cost Effective**

**Project Choice.** When we focus on meeting the strict demands of the 2030 challenge, project selection will play a much larger role than in the past. First, certain buildings are more available for whole-systems retrofits that can achieve drastic savings compared to the status quo. A cost-effective way to achieve savings upwards of 50 percent in existing buildings is to coordinate whole-systems retrofits with equipment replacement cycles. In this manner, the incremental increases in efficiency measures require less capital than when they are initiated outside of equipment replacement cycles, and become more economically enticing. **(See cost reduction method 2.)**

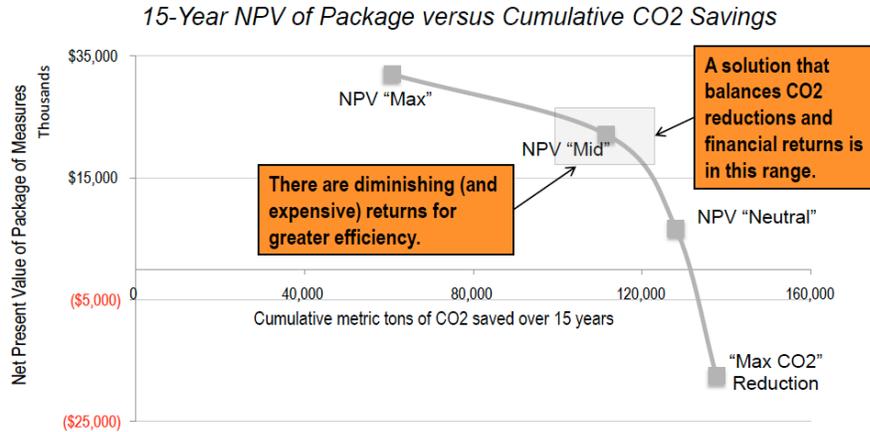
Project selection can also influence the amount of square footage we retrofit. A&E professionals as a group may consider opportunities to scale or amplify singular project strategies to a variety of similar project types, thereby cutting the time and financial investment required for whole-systems analysis. Strategies to do this might include applying retrofits to franchises or portfolios, or creating an industry-wide building assessment system where building managers or operators can input their building characteristics and receive information regarding whole-systems retrofits of similar building types.

**Comprehensive Analysis.** Barrier: Design teams consider first cost and simple payback more than life cycle cost analysis. This often favors bad investment decisions: Financial analysis is not coordinated with energy analysis. Solution: Comprehensively analyze cost and energy together; use deep efficiency savings to avoid capital costs.

When we pair a life cycle cost analysis with a variety of possible engineering options that meet the needs of the space, some surprisingly effective solutions may arise that we would not otherwise consider. Once the design team performs these first two steps with resolve, the ability to meet needs with passive design strategies greatly increases. Only after meeting as many needs as possible through passive solutions do we begin searching for ways to meet the remaining loads with efficient systems. Considering interactions between the systems allows us to use waste energy streams to further improve equipment efficiencies. Controls further this effort. The last steps can include adding clean power to meet the remaining needs of the facility, or purchasing carbon offsets if renewable energy on site or through a service provider is not feasible. Still, only a life cycle cost analysis taking into account coordinating benefits will show us what is possible.

Figure 5 shows how design teams can rank packages of energy efficiency measures

(in metric tons of carbon) by the net present value (NPV) of each package. This type of analysis can inform property owners of the financial and energy implications of decisions, and lead to higher levels of building retrofit performance.



**Figure 5** Ranking Net Present Value in terms of Carbon Savings

This coordinated, thoughtful analysis based on the interactions of each system is imperative to highly efficient retrofits because it is the only way to tunnel through the cost barrier. Often, we perceive energy efficiency measures to have a high capital cost, and we believe increasing energy efficient solutions will escalate the budget. When designers apply a whole-systems analysis, the cost savings from benefits become apparent, often resulting in larger energy savings at a reduced capital cost. This can happen in two ways.

**Cost reduction method 1: Multiple Benefits from Single Expenditures. We can achieve** multiple benefits from single expenditures. One common example is dimming ballasts. Dimming ballasts reduce light when it is not needed, allow for daylight to be the primary source of illumination for the space, save energy costs from reduced electricity use by the electric lights, as well as reduce heat that must be removed by the HVAC equipment. Since the HVAC no longer needs to remove that heat it can be sized smaller - which saves capital costs. Integrated engineering designs can achieve similar coordinating benefits by incorporating superwindows, daylighting devices, and alternative HVAC designs that regulate the temperature of the people as opposed to the spaces. Each of these items typically has multiple cost and system design benefits that we only have to pay for once.

**Cost reduction method 2: Capitalize Upon Planned Capital Expenditures.** A second means to tunnel through the cost barrier is to piggyback on already planned capital costs. The following table demonstrates an initial capital improvement budget of \$75,000. A life cycle cost analysis coordinated with efficiency measures resulted in an ideal solution totaling \$251,600 with a 5.8-year payback. This solution would result in an energy savings of \$43,200 per year. Because the energy efficient alternative saves \$19,400 in capital output for the HVAC system, and there were \$75,000 of capital costs allocated in the base budget, the resulting incremental

costs of efficiency measures becomes \$176,600 with a 4.1-year payback.

**Table 1. Cost Reduction Method #2:  
Piggybacking on Planned Capital Improvements**

<b>Measure</b>	<b>Full Cost</b>	<b>Budget</b>	<b>Incremental Cost</b>
Various efficiency	\$20,900	\$0	\$20,900
Daylighting	\$76,100	\$0	\$76,100
Electric lighting/controls	\$99,000	\$0	\$99,000
HVAC	\$55,900	\$75,000	-\$19,400
<b>Total</b>	<b>\$251,600</b>	<b>\$75,000</b>	<b>\$176,600</b>
Total Energy Savings		Negligible	\$43,200/yr
Payback		5.8 yr	4.1 yr

The extent of these benefits will vary by project, but are virtually always better than uncoordinated improvements, or only addressing superficial improvements. Efficiency measures for the Empire State Building retrofit resulted in a \$106.9 million incremental cost that allowed \$93.7 million in cost savings from planned measures for a total incremental cost of \$13.2 million at an estimated \$4.4 million/yr of savings and three-year payback.

### The Split Incentives Conundrum

*Barrier:* The Landlord / tenant pattern often contains divergent interests that result in disincentives the building owner must address in order to realize cost savings as well as achieve the deepest energy savings. *Solution:* Optimize benefits to both tenants and landlords.

When retrofits include energy efficiency improvements in tenant spaces as well as core building components, both tenants and landlords can achieve financial and ancillary benefits. High-performance buildings have been shown to reduce the tenants' occupancy cost, increase owners' net operating income and deliver owners an attractive return on investment (Fluhrer et al. 2008). Tenants and building owners are able to share savings achieved by the initial investment in these efficiency improvements. To achieve these win-win results, design teams consider tenant spaces in the analysis, and include tenants on financial discussions to make the investment and opportunities for return clear. Submetering of tenant spaces, along with green leases, which identify these benefits and assign incentives, make these energy savings achievable and dependable.

The recent Empire State Building Energy Efficiency retrofit found 58 percent of the savings available were under direct tenant control. The remaining 42 percent of annual energy savings available were attributed to base building systems. Tenant-associated measures include daylighting, electrical lighting, plug loads, air handling units, window strategies, radiative barriers, demand control ventilation, and overall tenant energy management. There are large opportunities here and ignoring them would mean leaving well over half the potential savings on the table.

Benefits to tenants may include the financial benefits of energy efficiency, and increased productivity of their workforce. Green marketing to tenants may also improve company reputation. Owner associated benefits include reduced operating cost and potentially a higher demand for the efficient space, which may facilitate a rent

premium. Energy efficiency and sustainability provide amenities such as lower energy costs, easier carbon reporting, and daylighting that can set the building apart from surrounding tenant space.

## CONCLUSION

Energy experts tout building energy efficiency solutions as the most cost effective way to achieve dramatic savings in U.S. carbon emissions (McKinsey 2007). Energy efficiency solutions have several added benefits, such as increased stability under volatile energy prices, and enhanced corporate image. While some climate and energy dependency solutions are still in developmental stages, this is not the case for building efficiency solutions. The building retrofit industry already has the technology to drastically and cost-effectively reduce energy use.

CBECS data shows our buildings now are no more efficient than 25 years ago (USDOE 2008). It is time to change this trend. Currently buildings are retrofit at an average of 2.2% of the building stock per year at an average of 11% savings. At this rate, we will achieve merely 8% of the IPCC goal, 18% of the potential savings McKinsey analysis has qualified as cost effective in the built environment - without accounting for whole systems benefits (McKinsey 2007). The United States is responsible for emitting 1,600 Million Metric Tons of carbon dioxide emissions per year, 16% of which are estimated to originate from commercial building demands (EIA 2006). Achieving 2030 challenge goals will require the A&E industry to increase the rate of buildings retrofit to 13% of existing building stock annually, at over 55% savings between now and 2030. This extent of influence is possible by using the strategies described in this paper. The world is looking for solutions, and A&E professionals are ideally situated to provide a large impact.

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