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/or expertise to implement change.

Moving from Standard to Deep Retrofits

The largest source of energy demand in the United States has been for the operation of buildings. In 2011, 43% of all energy consumed in the U.S. was for heating, cooling, and powering buildings, which is greater than the demand for both industry and transportation. In fact, the demand for electricity in building operations accounts for more than 75% of all electric use. Forty percent (40%) of all U.S. carbon emissions emanate from the existing building stock.[1]

Energy efficiency in existing buildings is most often addressed by upgrading outdated lighting equipment and adding efficient equipment to the heating and cooling systems. This “standard” retrofit approach saves energy and addresses some of the large energy inefficiencies. However, the limited scope of this standard practice generally prevents the realization of much greater energy savings. Such interventions are typically not considered because of high up-front cost and perceived higher risk.

Improving building envelopes (walls and windows) is a key to achieving deep energy retrofits, as the envelope controls flow of heat to and from the ambient across the structure. More energy is lost through walls than any other building envelope component.

(con’t on page 2)

Research Finding: Standardized Wall Retrofit System

Energy efficiency in existing buildings is most often addressed by upgrading outdated lighting equipment and adding efficient equipment to the heating and cooling systems because of low risk and short financial payback.

Building wall energy retrofits are rarely undertaken because of high up-front cost (lengthy payback periods) and perceived higher risk.

Thermal heat gain, through commercial building walls, and building infiltration account for significant primary energy use (2.77 quads).

The building envelope and energy systems complement each other. Wall sealing and insulation significantly reduce thermal load on a building, reducing HVAC system size requirements and operating costs.

A 15 year or less payback for wall sealing and insulation is deemed a good financial target for scalability when coupled with HVAC equipment right sizing.

A cost-effective retrofit wall insulation and sealing solution is in the process of being identified that will provide a potentially scalable performance and payback period.

After field testing the selected solution(s) and assessing the results, a retrofit best practices guide will be created and disseminated throughout the industry.

Moving from Standard to Deep Retrofits (con't)

In order to have the greatest impact on energy savings, next-generation building envelope insulation materials must be applicable to walls to increase the energy savings impact at a component level.

Uncontrolled heat, air, and moisture have a significant impact on energy usage. A comprehensive strategy for concurrently regulating these factors will be revolutionary and have a major impact on reducing overall building energy consumption. The table below shows that, in 2010, infiltration was responsible for 1.29 quads of space heating energy lost in the commercial sector and 1.48 quads lost by conduction through the walls.

Primary Energy Consumption in Quads (Fenestration and Building Envelope Components) in 2010[2]

Building Component	Heating	Cooling
Roofs	0.88	0.05
Walls	1.48	-0.03
Foundation	0.79	-0.21
Infiltration	1.29	-0.15
Windows (Conduction)	1.6	-0.3
Windows (Solar Heat Gain)	-0.97	1.38

Scaling envelope efficiency retrofits requires reducing retrofit cost and ultimately reducing risk to a point where market actors will commit funds. CBEI has narrowed its focus on selecting materials and methods that can achieve installed cost reduction, standardization and reasonable paybacks where market uptake is possible.

Quick and easy building envelope retrofit solutions – Energy-efficiency retrofits of commercial buildings must be performed quickly. Commercial sector building occupants cannot afford to shut their business down and lose business for days or weeks. This effectively increases payback time for energy-efficiency measures.

High-quality standardized construction subcomponents – (e.g., plug-and-play panels) may help reduce installation time and costs, as would the increased use of non-intrusive and non-destructive retrofit installation approaches. Furthermore, if materials and products can be developed with a high tolerance for error in installation, installation requirements can be less stringent and costly.

The objective of the work is to develop an integrated package of wall retrofit solutions that exceed ASHRAE 90.1-2010 requirements, with payback of 10-15 years. A list of retrofit scenarios, vetted through industry experts, were evaluated against 6 critical parameters to down-select 3 top-performing scenarios. These scenarios were constructed as mock-up walls for lab tests. Down-selected scenarios based on lab test performance will be demonstrated on the Flexible Research Platform at ORNL to collect actual field data.

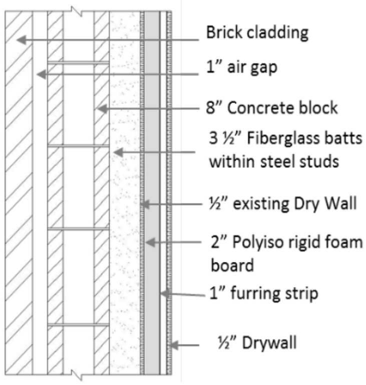
The retrofit scenarios constructed as mock-up walls for laboratory testing were:
1. Retain existing insulation; install 2” polyisocyanurate (PIR) rigid board with taped seams on existing wall[3].
2. Demolish existing insulation; install 2.5” PIR rigid board with a separate air barrier layer[4].
3. Demolish existing insulation; install 3.5” closed-cell spray polyurethane foam (SPF) with 1.5” continuous insulation.[5]

CBEI Wall Retrofit Scenario Costing and Laboratory Testing

Laboratory tests were performed on the mock-up walls at ORNL to determine:

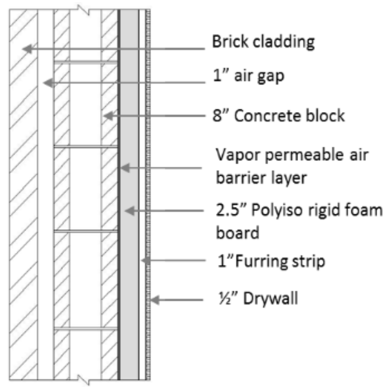
- Thermal Performance in accordance with ASTM C1363 (hot box test)
- Air Leakage analysis for the assembly in accordance with ASTM E2357

A. Retain existing wall

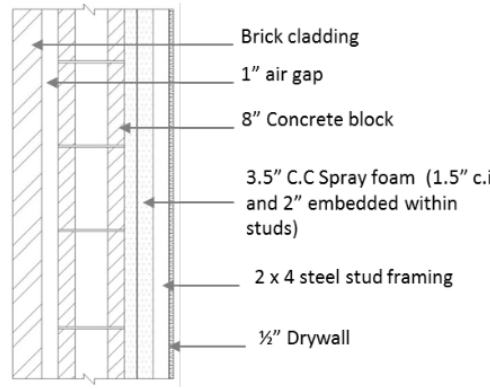


Scenario 1

B. Remove existing wall completely



Scenario 2



Scenario 3

	R-Value	**U-Value**	Payback Period Years	
			Baseline with existing insulation (R-13)	Baseline with no existing insulation
Scenario 1	20.7	0.048	14	NA
Scenario 2	17.6	0,056	29*	17
Scenario 3	21.6	0.046	25*	16

Scenario 1 (above) exhibits a high R-Value and a 14 year payback versus a baseline with existing insulation and 8L/s.m^2 air leakage indicating good prospects for implementation. *These paybacks decrease considerably where baseline has no existing insulation

	Commercial	**Institutional**	**Total**
Economic/Financial Impact			
Energy Savings (Trillion Btu)	848	293	1,141
Total Investment ($ Billion)	72	25	97
Social Impact			
Cumulative Job Years Created (# FTEs over course of investment program)	857,000	296,000	1,153,000
Environmental Impact			
Greenhouse Gas Emission Reduction (metric tons of CO_2 per year)	175,000,000	59,000,000	234,000,000

Summary of impact by market size, climate and employment categories[8]

Oak Ridge National Laboratory Hot Box Testing of Wall Retrofit Scenarios

Scaling Deep Energy Retrofits

Improving building envelopes (walls and windows) are a critical element in achieving deep energy retrofits. Scaling building deep energy efficiency retrofits in the U.S., shown in the Table to left, offers a $97 billion investment opportunity. The energy savings over 10 years could total more than $300 billion[6]. Scaling building retrofits could mitigate more than 234 million metric tons of CO_2 per year (~4% of U.S. emissions in 2010)[7]. Increased building retrofits could create more than 1.1 million new direct and indirect cumulative job years (excluding induced) in the United States economy.

[6] Converting 1,141 TBtu to dollars at 10¢/kWh

[7] Source: http://epa.gov/climatechange/emissions/usinventoryreport.html

[8] Rockefeller Foundation, 2012. McKinsey, Unlocking Energy Efficiency in the U.S. Economy (2009); Center for American Progress, The Economic Benefits of Investing in Clean Energy (2009); Energy Information Administration Commercial Building Energy Consumption Survey 2003, Residential Energy Consumption Survey 200. Note: Analysis is based on an assumption of 30% energy savings in buildings built before 1980. Category impact information represents an aggregation of the values calculated for the segments associated with that category. TBtu = Trillion Btu.

Lessons Learned

Scenario 1 is a cost-effective solution which retains the existing fiberglass insulation and proposes a retrofit solution over the existing assembly. This scenario provides the fastest payback. In the case of a baseline which has no existing insulation, this scenario is not applicable.

The top two retrofit scenarios (1 and 3 on Page 3) identified based on the thermal test results, air leakage test results, energy savings and payback analysis are:

1. Scenario 1: Most cost-effective - Retain existing insulation; install 2” polyisocyanurate rigid board with taped seams.[9]
2. Scenario 3: Most energy-efficient - Demolish existing insulation; install 3.5 closed-cell spray polyurethane foam with 1.5” continuous insulation.

Although scenario 3 does not satisfy the payback ranging from 10-15 years, the payback calculated for this scenario against the baseline assembly with no existing insulation borders on the 10-15 year payback range, and should be investigated further.

Building energy efficiency (BEE) is invisible, and there is widespread skepticism among customers and lenders that estimated BEE savings will actually materialize; this skepticism hampers access to low-cost financing and market scalability. The fundamental problem is lack of physical validation of models. This logically requires a new level of field testing.

[9] This scenario is cost-effective, offers lower payback and good energy savings. However, before implementing this scenario it is essential to ensure that the existing wall is in effective condition and is not susceptible to any moisture issues.

Consortium for Building Energy Innovation

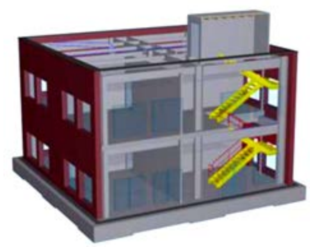
4960 South 12th Street
The Navy Yard
Philadelphia, PA 19112
p: 215-218-7590
e: info@cbei.psu.edu

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

Moving Forward

Laboratory test data is important in selecting path(s) forward, but field testing is essential to convince early adopters to spend money for wall retrofits.

ORNL has constructed a two-story flexible research platform (FRP) having a footprint of 40x40 ft to field test complete roofing and wall systems. The permanent FRP consists of a building frame, slab and the necessary utility and IT infrastructure to support a variety of test building configurations that might be applied.



Schematic Design FRP

FRP Structural Frame

Specifications for the two top-performing retrofit scenarios have been generated to receive bids from contractors for demonstrating the two scenarios as retrofit strategies on the Flexible Research Platform (FRP).

The data collection of the demonstrated retrofit strategies on the FRP will begin as soon as possible. The actual field data collected for the retrofit scenarios will be utilized to validate the findings obtained for the project through initial evaluation, energy modeling and laboratory test results. This validated data will then be used to build an effective use case for the identified best practice recommendation.

Acknowledgment:
"This material is based upon work supported by the Consortium for Building Energy Innovation (CBEI) sponsored by the U.S. Department of Energy under Award Number DE-EE0004261."