Energy study for improving building enclosure performance

Chris Norris, PE

ABSTRACT HEADING

Buildings in the United States contribute to an average of 41% of the national energy use and 38% of all CO2 emissions. Building enclosure retrofit of existing building stock represents a significant opportunity to improve sustainability. Sustainability rests on three key pillars: economic responsibility, environmental responsibility, and social responsibility. Building enclosure retrofits can contribute to all three pillars of sustainability by providing significant energy savings and increased occupancy rates (economic), aesthetic and occupant comfort improvements (social), and reduced carbon footprint (environmental).

Understanding which types of buildings are the best retrofit candidates, and which types of retrofit options can provide the best return on investment are key to developing optimized retrofit solutions. This paper presents an engineering study on the impact of EIFS over-cladding of existing wall assemblies as an energy retrofit option. The impact of EIFS over-cladding is studied for prototype pre-1980's vintage office and hotel buildings in three different US cities (Atlanta, Baltimore and Chicago), representing three climate zones (Zone 3A, Zone 4A, and Zone 5A). The use of EIFS over-cladding wall retrofit is studied in combination and in comparison with window and roof retrofit options to understand the relative benefits of various retrofit options as both stand-aline options or in combination.

INTRODUCTION

U.S. Energy Information Administration reported about 40% of U.S. energy consumption was consumed by buildings in 2015 [1]. Building enclosure retrofit of existing buildings represents a significant opportunity to reduce energy consumption by building operations to improve sustainability. To quantify the potential energy saving by building enclosure retrofit, an energy study was performed for three building prototypes and in three different climate zones.

OBJECTIVES

The objectives of the study were to utlize energy modeling to develop a relative comparison of energy savings available by the exterior enclosure retrofit options for different building and occupancy types in different climate zones; and to use the developed energy savings data combined with probably retrofit construction costs to evaluate the return on investment of various retrofit options.

Chris Norris is the Building Enclosure Practice Area Leader for Walter P. Moore.

METHODOLOGY

Multiple energy models were constructed utilizing eQUEST to evaluate the effectiveness of retrofitting existing buildings using EIFS over-cladding in combination and in comparison with window and roof retrofits to understand the relative benefits of various retrofit options. The study was performed for different building types in different climate zones. Baseline energy models for prototype pre-1980's vintage office and hotel buildings were developed for three different climate zones: Atlanta (Zone 3A), Baltimore (Zone 4A), and Chicago (Zone 5A). Three different building types were modeled for each climate zone: a pre-1980 medium office building, a pre-1980 large office building, and a pre-1980 large hotel building. The baseline models were constructed based on data provided in a report prepared by National Renewable Energy Laboratory (NREL) [2]. Table 1 shows the building information input for baseline building models for medium and large office buildings and large hotel. The annual energy cost of typical pre-1980 constructions was calculated based on average energy prices reported by U.S. Department of Labor [3,4,5]. The average energy prices in 2016 were used for the purpose of simulation and are presented in Table 2. Actual costs may vary with the condition of a building, the occupant schedule, the micro-climate around the building and other factors. The calculated annual costs are intended for comparative purposes of building and occupancy types, and do not represent the actual energy cost of any specific building(s).

Table 1. Baseline building information

		Building Locations (Climate Zone)		
		Atlanta (3A)	**Baltimore (4A)**	**Chicago (5A)**
Window-to-Wall Ratio	**Medium Office - 3 floors (163.8'x109.2' - 53,600 sf)**	33%	33%	33%
	Large Office - 12 floors (240' x 160' - 460,800 sf)	40%	40%	40%
	Large Hotel - 12 floors (240' x 160' - 460,800 sf)	40%	40%	40%
Air Infiltration Rate (cfm/sf)		1.5	1.5	1.5
Wall Insulation (R-value)		4.4	5.6	6.4
Roof Insulation (R-value)		10	11.6	13.8
Window (U-value)		1.22	1.22	0.62
Window SHGC		0.54	0.54	0.41
Equipment (Average Efficiency)		0.8	0.8	0.8

Table 2 Average energy cost used for energy simulation

City	Electric cost ($/kwh)	Gas cost ($/therm)
Atlanta	0.122	1.436
Baltimore	0.136	1.048
Chicago	0.152	0.779

Parametric study

To assess how much energy can be saved by EIFS over-cladding wall retrofit, increasing the R-value of building enclosure, retrofitting windows and reducing air infiltration rate, a matrix was developed for a parametric study (Table 3).

Overall building geometry and the window to wall ration were fixed parameters in the study. The study was divided into two parts. In the first part, alternative retrofit options were modeled at an air infiltration rate of 1.5 cfm/sf @ 1.57 PSF. In the second part, the simulated the retrofit options were modeled at an air infiltration rate of 0.4 cfm/sf @ 1.57 PSF. Figure 1 shows the process flow for how the energy simulation was performed.

Three wall retrofit options with low R-value, medium R-value, and high R-value were evaluated. Three roof retrofit options with low R-value, medium R-value, and high R-value were evaluated. One window retrofit option with lower U-value and smaller Solar Heat Gain Coefficient (SHGC) was evaluated. In addition, three combination retrofits were assessed: combination of low R-value wall with roof retrofit and window retrofit, combination of medium R-value wall retrofit with roof retrofit and window retrofit, combination of high R-value wall retrofit with roof and window retrofits. For prototype buildings in the three different climate zones, the baseline R-values for wall assemblies and roof assemblies are different. Therefore, in each subgroup for low R-value, medium R-value, and high R-value, the R-values for wall assemblies and roof assemblies are different.

Table 3 Matrix for building retrofit options

<table>
<tr><th colspan="2">Building locations / Climate zone</th><th>Atlanta (3A)</th><th>Baltimore (4A)</th><th>Chicago (5A)</th></tr>
<tr><td colspan="2">Window to Wall Ratio</td><td>Fixed per baseline model</td><td>Fixed per baseline model</td><td>Fixed per baseline model</td></tr>
<tr><td colspan="2">Air Infiltration Rate</td><td>1.5 cfm/sf,
0.4 cfm/sf</td><td>1.5 cfm/sf,
0.4 cfm/sf</td><td>1.5 cfm/sf,
0.4 cfm/sf</td></tr>
<tr><td colspan="2">Roof Insulation</td><td>Baseline (10), R24, R35</td><td>Baseline (11.6),
R28.8, R41.6</td><td>Baseline (13.8),
R35, R45</td></tr>
<tr><td colspan="2">Wall Insulation
EIFS panel retrofit</td><td>baseline (R-4.4),
+ R7.7, +R15.4,
+R30.8</td><td>baseline (R-5.6),
+ R7.7, +R15.4, +R23.1</td><td>baseline (R-6.4),
+ R7.7, +R15.4, +R23.1</td></tr>
<tr><td>Window</td><td>Window Assembly U-Value</td><td>baseline, 0.5</td><td>baseline, 0.42</td><td>baseline, 0.42</td></tr>
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	Window SHGC	baseline, 0.25	baseline, 0.4	baseline, 0.4

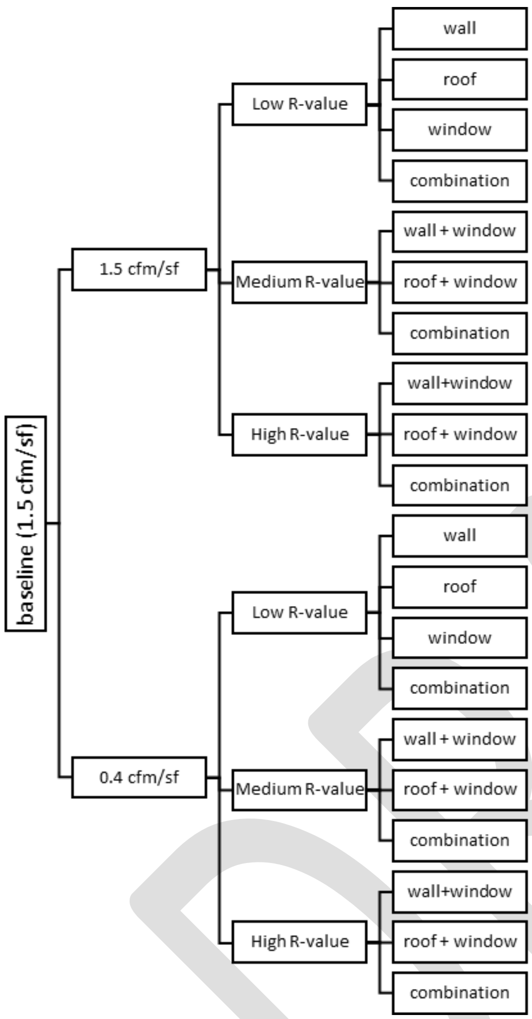

Figure 1 Energy simulation process chart

RESULTS

General

The simulation results are presented in the form of annual electric cost saving, annual gas cost saving, and total annual energy cost saving. The relative saving is compared among studied retrofit options and summarized in graphs. The graphs allow readers to visually understand the saving potential for each retrofit options.

Energy consumptions and annual savings vary between different climate zones and between different building types. Increasing insulation can significantly reduce the heat loss through the wall during heating seasons and therefore has larger impact on the energy saving for heating than the energy saving for cooling.

Medium Office

For the medium office in Atlanta, the annual energy cost for baseline model is $79,877. Heating contributes 52% towards the total energy cost, while cooling and ventilation contributes 48%. Among the alternative retrofit options, the average percentage cost saving is 14%. The maximum percentage cost saving is 34%, by reducing air leakage, increasing roofing insulation to R45, and increasing exterior wall insulation to R34.

For medium office in Baltimore, the annual energy cost for baseline model is $69,671. Heating contributes 48% towards the total energy cost, while cooling and ventilation contributes 52%. Among the alternative retrofit options, the average percentage cost saving is 11%. The maximum percentage cost saving is 27.5%, by reducing air leakage, increasing roofing insulation to R52, and increasing exterior wall insulation to R29.

For medium office in Chicago, the annual energy cost for baseline model is $56,687. Heating contributes 42% towards the total energy cost, while cooling and ventilation contributes 58%. Among the alternative retrofit options, the average percentage cost saving is 7%. The maximum percentage cost saving is 17%, by reducing air leakage,, increasing roofing insulation to R55, and increasing exterior wall insulation to R31.

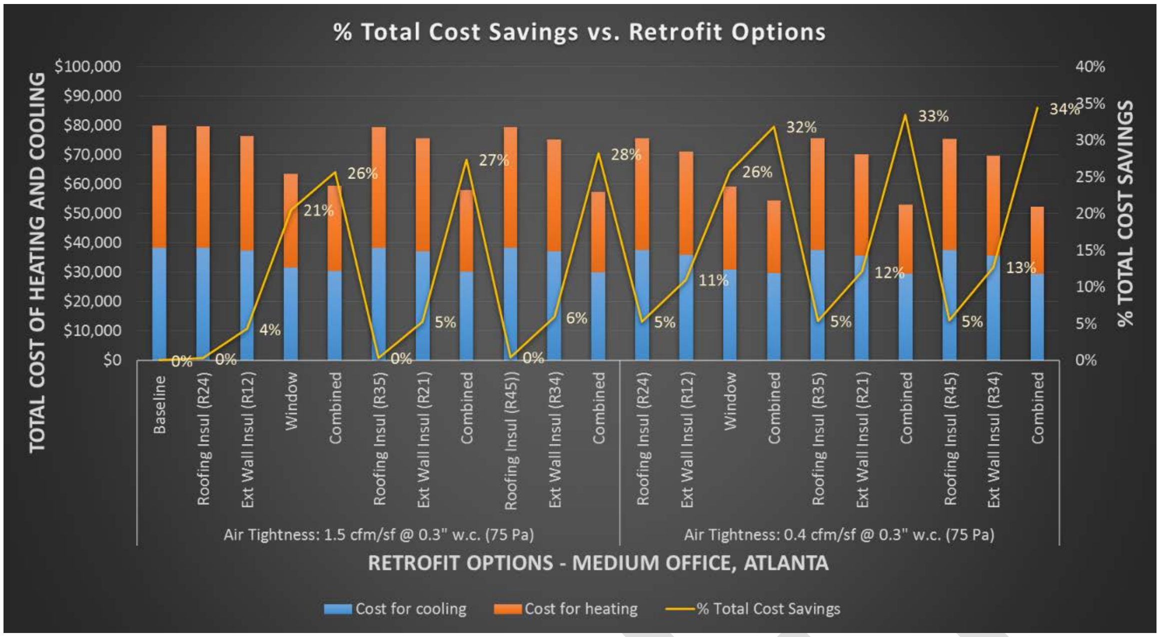

Figure 2 Percentage cost saving vs. Retrofit options – Medium office, Atlanta

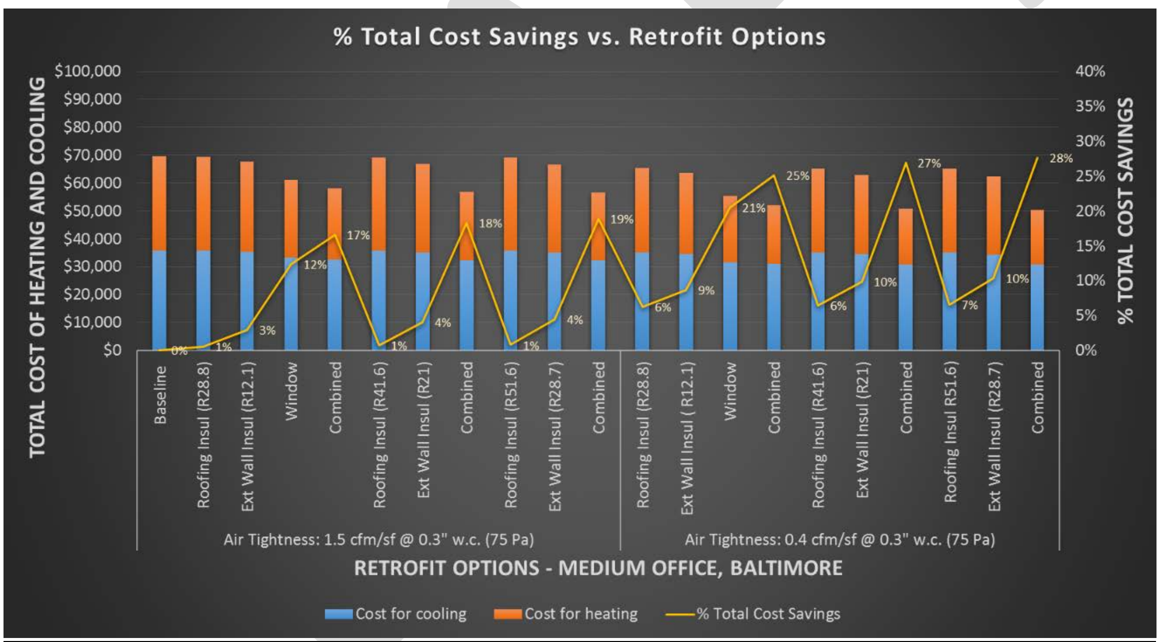

Figure 3 Percentage cost saving vs. Retrofit options – Medium office, Baltimore

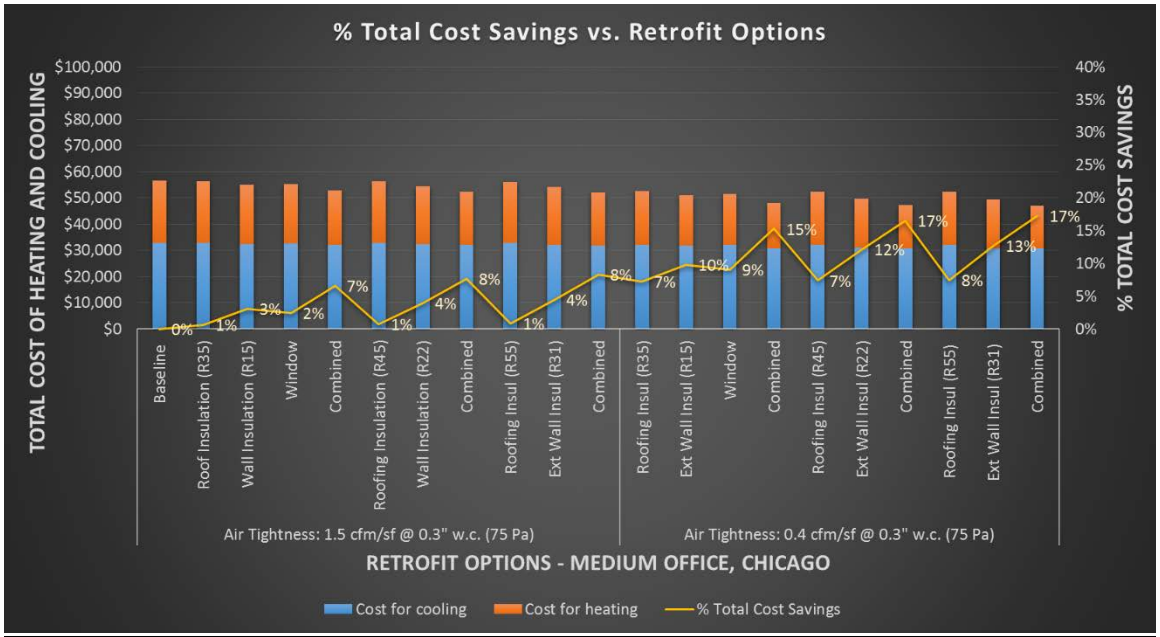

Figure 4 Percentage cost saving vs. Retrofit options – Medium office, Chicago

Large Office

For large office in Atlanta, the annual energy cost for baseline model is $160,322. Heating contributes 20.5% towards the total energy cost, while cooling and ventilation contributes 79.5%. Among the alternative retrofit options, the average percentage cost saving is 10%. The maximum percentage cost saving is 23%, by reducing air leakage, increasing roofing insulation to R45, and increasing exterior wall insulation to R34.

For large office in Baltimore, the annual energy cost for baseline model is $171,257. Heating contributes 27% towards the total energy cost, while cooling and ventilation contributes 73%. Among the alternative retrofit options, the average percentage cost saving is 12%. The maximum percentage cost saving is 26%, by reducing air leakage, increasing roofing insulation to R52, and increasing exterior wall insulation to R29.

For large office in Chicago, the annual energy cost for baseline model is $156,691. Heating contributes 25% towards the total energy cost, while cooling and ventilation contributes 75%. Among the alternative retrofit options, the average percentage cost saving is 8%. The maximum percentage cost saving is 14%, by reducing air leakage, increasing roofing insulation to R55, and increasing exterior wall insulation to R31.

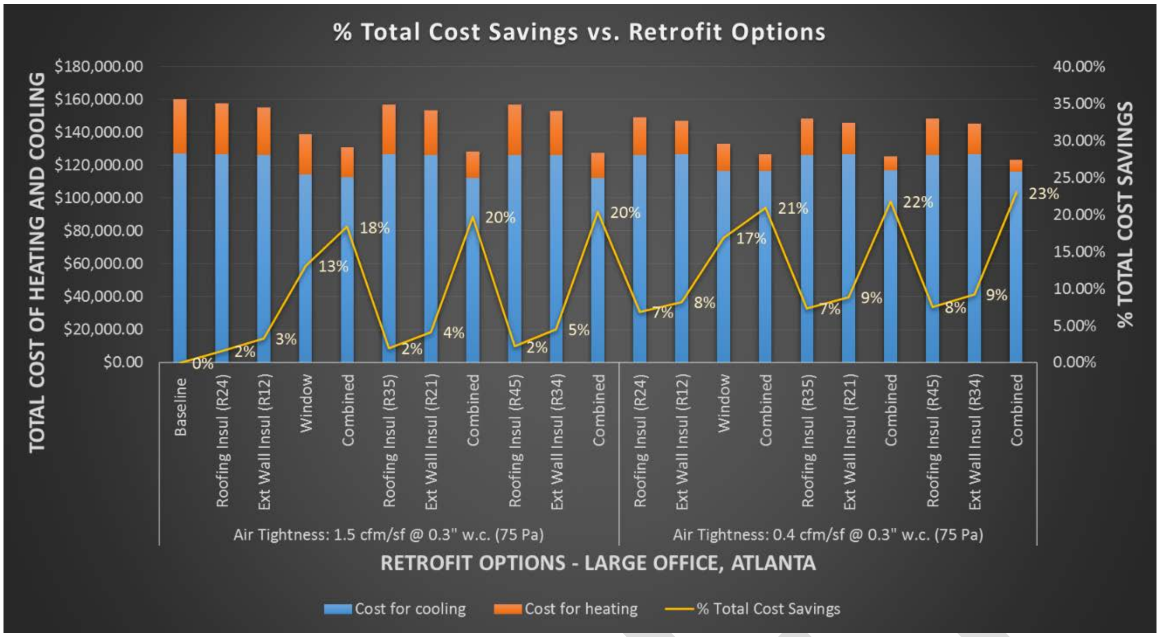

Figure 5 Percentage cost saving vs. Retrofit options – Large office, Atlanta

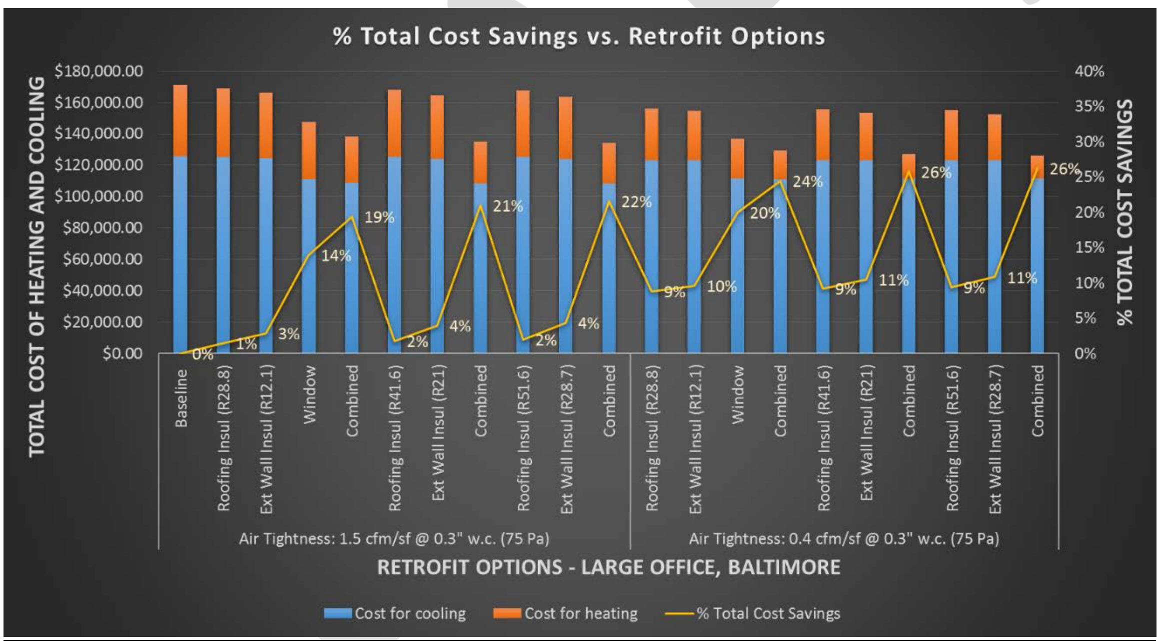

Figure 6 Percentage cost saving vs. Retrofit options – Large office, Baltimore

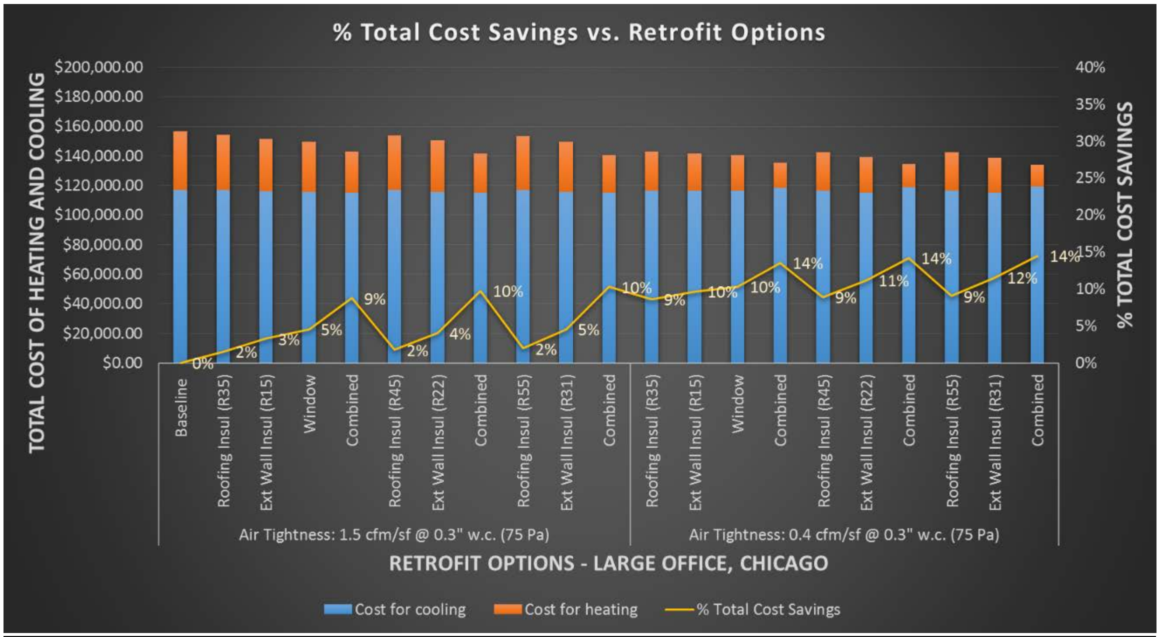

Figure 7 Percentage cost saving vs. Retrofit options – Large office, Chicago

Large Hotels

For large hotel in Atlanta, the annual energy cost for baseline model is $385,006. Heating contributes 32% towards the total energy cost, while cooling and ventilation contributes 68%. Among the alternative retrofit options, the average percentage cost saving is 13.5%. The maximum percentage cost saving is 31%, by reducing air leakage, increasing roofing insulation to R45, and increasing exterior wall insulation to R34.

For large hotel in Baltimore, the annual energy cost for baseline model is $416,492. Heating contributes 37% towards the total energy cost, while cooling and ventilation contributes 63%. Among the alternative retrofit options, the average percentage cost saving is 10%. The maximum percentage cost saving is 24%, by reducing air leakage, increasing roofing insulation to R52, and increasing exterior wall insulation to R29.

For large office in Chicago, the annual energy cost for baseline model is $366,526. Heating contributes 38% towards the total energy cost, while cooling and ventilation contributes 62%. Among the alternative retrofit options, the average percentage cost saving is 5%. The maximum percentage cost saving is 11%, by reducing air leakage, increasing roofing insulation to R55, and increasing exterior wall insulation to R31.

Figure 8 Percentage cost saving vs. Retrofit options – Large hotel, Atlanta

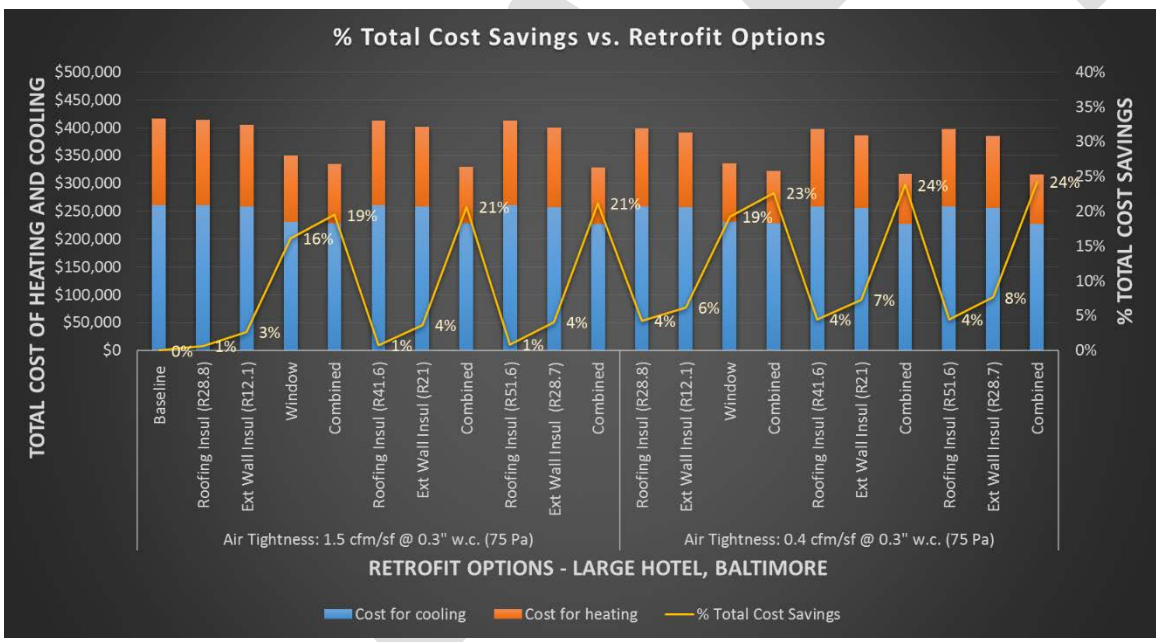

Figure 9 Percentage cost saving vs. Retrofit options – Large hotel, Baltimore

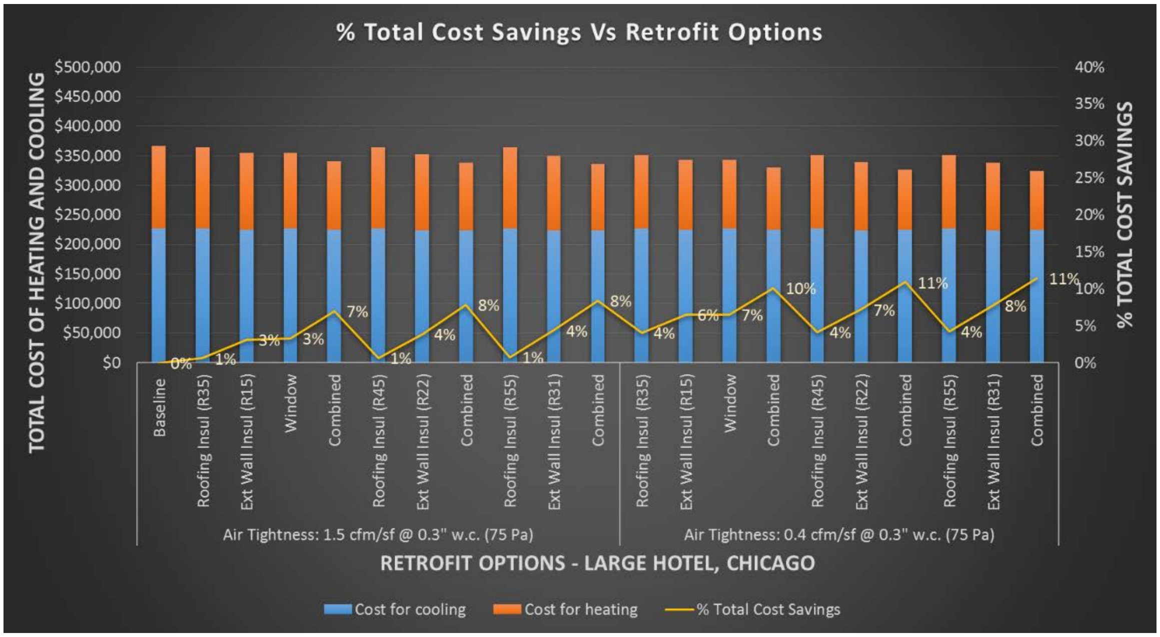

Figure 10 Percentage cost saving vs. Retrofit options – Large hotel, Chicago

DISCUSSION

A significant improvement in energy savings was seen for all retrofit options when combined with a reduction in air leakage rate for the building. From a practical stand point exterior retrofit of walls when combined with appropriate interface detailng can provide an excellent opportunity to reduce air leakage as a continuous air barrier can be installed from the exterior and integrated with the windows and the roof.

In general retrofit of windows was found to be more impactful for the Atlanta and Baltimore climates. This is believed to be a result of the fact that the original baseline windows lower peforming than for Chicago, which is typical of this vintage of construction. Significant improvements can be achieved in the Solar Heat Gain Co-efficient and to the U-value by retrofitting pre-1980's vintage windows in Atlanta and Baltimore.

In general, adding wall insulation has more impact on energy use reduction as a stand-aline measusre as compared to adding roof insulation. Increasing both wall and roof insulation has better energy improvement. This demonstrates the benefit of providing continuous insulation for the building envelope.

Large office and large hotel were modeled with the same building envelope system and HVAC systems in each climate with the only exception being the occupancy schedule. By comparing the simulation results, it is found that building enclosure retrofits provide a higher cost savings for large hotel than large office. Based on this finding, it is expected that building enclosure retrofits can have more energy cost saving for buildings with large occupancy load and longer operation hours.

LIMITATION

This study is conducted using prototype buildings in simulation tools. The result does not necessarily reflect actual percentage energy cost saving for any specific existing building.

REFERENCE

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