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Negative life-cycle emissions growth rate through retrofit of existing institutional buildings: Energy Analysis and Life Cycle Assessment of a Case Study of University Dormitory Renovation

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Negative life-cycle emissions growth rate through retrofit of existing institutional buildings: Energy Analysis and Life Cycle Assessment of a Case Study of University Dormitory Renovation

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ABSTRACT: Buildings account for about one fifth of the world`s total delivered energy use, and thus methods for reducing energy consumption and carbon emission associated with buildings are crucial elements for climate change mitigation and sustainability. Voluntary challenges, mandates, and, particularly, public institutions have articulated these goals in terms of striving for “net-zero energy” buildings, and mandated measurable reductions in greenhouse gas emissions. Typically, the definition of net-zero and other energy consumption reduction goals only consider operational energy. By ignoring embodied energy during the entire life-cycle of the building (manufacture, use and demolition of materials and systems), such goals and mandates may drive suboptimal decisions in terms of cost-effective greenhouse gas emission reductions. Many new buildings will require decades of net-zero operational energy consumption to negate climate change and other environmental impacts during the construction process. Additionally, if a new building is part of a portfolio of institutional buildings, even with net-zero energy consumption, the most optimistic scenario is the eventual reduction of emission growth rate to zero. A more productive approach for reducing the life-cycle energy in a building and associated negative environmental impacts may be to focus on retrofitting existing buildings. However, since large investments in existing building stock can be difficult to justify and approve in an institutional context, fixed portions of life-cycle costs also highlight the importance of maximizing the operational energy impact associated with any renovation. This study uses life-cycle analysis to evaluate efficacy of energy retrofits for an existing institutional building located on the University of Massachusetts Amherst campus. Using data, energy models, and life-cycle analysis tools for an actual energy retrofit on an existing residential building, this study will show how poor controls and failing to address thermal bridges can affect our model expectations. By developing a process for life cycle based evaluating retrofit options this study will explore the implication of producing an institution-wide negative net-energy growth rate.

KEYWORDS: Net-zero, Life-cycle, Retrofit, Energy Analysis, Institutional, Emissions Growth Rate

INTRODUCTION

Buildings are responsible for about one fifth of total delivered energy of the world, which is required for their operation (U.S. Energy Information Administration 2010). Life-cycle energy of a building includes the construction, operation, and decommissioning phases of a building’s existence (Dixit and Fernandez-Solis 2010). Embodied energy (EE) in building materials has sequestered from the whole stages of production, construction, and demolition and disposal, while operating energy (OE) is consumed for maintaining interior environmental, including cooling, heating, operating appliances, and lighting (Ding 2004).

A leading tool for evaluating all sources and types of environmental impact is life-cycle assessment (LCA). This strategy has been determined by the International Organization of Standardization (ISO) 14040-14044 standards (Sodagar 2013). LCA aims to combine total energy inputs for a building into the whole life-cycle energy consumption, and analyzes the energy use of all stages from manufacture, use, and demolition (Sesana and Salvalai 2013). LCA study is a valuable method that should be completed on all projects to consider possible benefits of energy cost savings, carbon emission reductions and other environmental benefits (Buys, Bendewald, and Tupper 2011).

Most nations have instituted regulations to ensure reduced energy use in buildings. For example, all buildings built in the European Union should achieve nearly zero levels in energy use after 2020 under

Recast Directive of the energy performance in buildings (EPBD), published by European Union (EU) in 2002 (Sesana and Salvalai 2013). This guidance makes a commitment to a very high level of energy performance in all new buildings in less than one decade, and the energy will predominantly come from renewable energy sources (Sesana and Salvalai 2013).

While directives to achieve net zero energy can significantly reduce energy demands in new buildings, most regulations related to 'net-zero' only consider energy in operation and ignore the embodied energy (Hernandez and Kenny 2010). A summary of 73 buildings in 13 countries in the life-cycle energy analyses that includes office and residential buildings, concluded that 80-90% of energy use is for operation, while 10-20% is the embodied energy (Ramesha and Prakasha 2010). To account for the total energy impact of buildings, life-cycle aspects should be considered in global perspectives. The definition of life-cycle zero energy buildings (LC-ZEB) proposed by Hernandez and Kenny (2010) provides a useful framework for total building energy use, which includes embodied energy and shows attempt to develop regulations and policies on Life Cycle Zero Energy approaches. Typically, due to the relative energy inefficiency of new buildings, OE has been much larger than EE, even after just a few years of operation. However, as buildings are designed to consume less energy, the relative importance of EE is likely to increase.

Although there are several factors, such as cultural and economic values, that weigh into decision of whether to rehabilitate buildings or demolish and rebuild, environmental factors can be a compelling reason in favor of building conservation. Embodied energy saved in existing building structures is one of the main environmental benefits of building reuse, which aims to reduce greenhouse gas emissions (Preservation Green Lab, 2011). It will take decades for a new net zero energy building to overcome negative environmental impacts resulting from new construction including global warming potential, acidification, fossil fuel consumption and ozone depletion (Radermacher 2011). For most building types (excluding warehouses and multifamily residential buildings), it will take 10 to 80 years for a new construction, with 30%higher efficiency from average performance codes to negate, through efficient operations, the overall impacts of new construction (Preservation Green Lab, 2011). Therefore a potentially more efficacious approach for achieving energy efficiency that offers immediate climate-change reductions is to focus on retrofitting existing buildings (Radermacher 2011). To get the most significant emissions reductions, reuse and retrofitting for energy efficiency must work together. Construction materials selected during retrofit are also critical to minimize environmental impacts of reuse, since the type and quantity of materials selected during this process can reduce or negate the benefits of retrofit (Preservation Green Lab, 2011). Because most existing buildings were not constructed and designed for net-zero-energy performance, they present challenges to retrofits intended to bring operational energy to near zero (Radermacher 2011). Ardente et al. (2011) showed that the most significant environmental and energy benefits during retrofit come from improvement in thermal insulation envelope, such as replacing windows, improving insulation, and reducing infiltration. Additional major energy benefits come from renovating HVAC and lighting systems (Ardente et al. 2011).

Therefore, this research uses a case study building at the University of Massachusetts Amherst (UMass Amherst) to conduct a detailed analysis of building reuse and retrofit as part of a strategy to reduce overall campus energy consumption.

1. BACKGROUND AND OBJECTIVES

In August 2013, University of Massachusetts Amherst completed the second phase renovation of Grayson Hall Dormitory, which was started in March 2012 and was conducted in two summers while resident halls were closed. Grayson Hall, which was built in 1965, is one of the four similar buildings located in Orchard Hill Residential Area. The campus central combined heat and power (CHP) plant uses primarily natural gas to produce steam, which provides heat and hot water in this dormitory. The original Grayson envelope and exterior walls did not have thermal insulation and consisted of brick veneer, back up concrete masonry unit (CMU), and aluminum frame single glazed windows (Mostafavi 2013). UMass Amherst retrofit plan requires that all deteriorated brick facades are removed and single aluminum window panels are replaced with new double pane aluminum windows, which was done for the Grayson Hall. Also, 2 inches of polystyrene rigid insulation were added between the CMU walls and the new brick façade.

Despite this investment, a study of actual energy performance of the building in FY 2014 showed no difference in heating loads and steam consumption after renovation. Indeed, steam consumption actually increased, and Table 1 shows total and weather-normalized data (Table 1).

Table 1: Grayson Hall building actual steam consumption

Steam lb	Jul	Aug	Sep	Oct	Nov	Dec	Jan
FY10	56,796	-	272,350	492,042	527,979	760,727	716,825
FY11	138,606	166,010	208,215	372,627	512,418	681,235	817,953
FY12	190,229	189,655	195,902	393,423	401,939	573,850	650,362

FY14	182,108	188,301	186,022	300,388	495,793	578,354	622,728

Steam lb	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Total**	**Weather Normalized**
FY10	630,876	468,418	366,924	256,897	165,729	4,715,565	3,422,023
FY11	695,724	613,209	409,956	239,494	185,431	5,040,878	3,911,707
FY12	593,219	517,380	378,607	223,143	185,940	4,493,648	3,683,558
FY14	572,577	637,013	390,916	213,572	184,158	4,551,931	4,037,648

Building energy model, which was calibrated to pre-retrofit actual energy usage, predicted heating energy reduction of 26% (Mostafavi 2013). This project uses that calibrated model to explore an alternative retrofit path, so it is important to explain the divergence between the predicted and actual energy use.

2. ENERGY ANALYSIS

Based on simple degree-day analysis of building performance we hypothesized that divergence from model predictions were likely explained by changes in building operations and by inaccuracies in the model itself.

2.1. Building Operation

Like many buildings on campus, there are no room thermostats. Instead, the hydronic heating temperature is controlled using outdoor temperature reset. The building operator calculates a heat loss rate at two outdoor temperatures (often a design temperature and the balance point temperature), and determines the water temperature required to offset that heat loss. The line between these two points determines the outdoor reset curve. In the case of Grayson Hall, prior to retrofit work, hot water was set to 180°F at a design outside temperature of 0°F. After insulation was added to the walls and the windows were upgraded, the heat loss rate would have declined, however the outdoor reset curve was never adjusted to the new condition. In fact, interior temperatures recorded by the University's Energy Engineer show an average interior temperature increase of about 3°, which would be consistent with higher water temperatures and lower heat loss factor. The higher temperatures most likely led to overheating and occupants may have opened their windows more frequently to cool rooms down. The change in window opening behavior is not quantified, but as we can see in Figure 1, which was captured in 25°F outdoor conditions, most of the windows are open.

Table 2: Grayson Hall building average inside temperature.

Start Date	End Date	Average Temperature /Inside
12/1/2011	1/31/2012	69.4 °F
12/1/2013	1/31/2014	72.6 °F

Figure 1: Grayson Hall west façade open windows.

Figure 2: Thermal bridges with exposed concrete.

2.2. eQuest Model Inputs and Energy Runs

The baseline model was calibrated with average energy use from FY2010-2012. The model was modified (Mostafavi 2013) to account for the addition of R-6 Polystyrene insulation to the wall assembly and the thermally broken aluminum double pane windows with insulated lower panels. This resulted in predicted savings of 26% in the eQuest model. In reality, however, the building renovation only involved adding insulation to the in-fill panels of the brick façade between windows, leaving the concrete structure exposed and providing significant thermal bridging (Figure 2). This is indicative of a shortcoming in the capabilities of eQuest as a modeling interface, since only one wall assembly can be specified for each story. In this case, it was necessary to perform a simple two dimensional area-weighted parallel path heat loss calculation to find the "effective" whole wall R-value using standard R-values for the relevant materials (ASHRAE 2013). When concrete thermal bridges are accounted for, the effective R value of the renovated façade is just 0.6 ft2 °F hr/Btu higher than the pre-retrofit baseline R value of 2.0 (ft2 °F hr/Btu) (Table 3).

Table 3: Effective values for thermal performance of exterior walls.

Effective Values	U Factor (BTU/hr/ft2/°F)	R Value (ft2 °F hr/Btu)
Before Renovation	0.49	2.03
After Renovation	0.38	2.62

Using the effective R value of 2.6 ft2 °Fhr/Btu in the existing eQuest Model with the software calculation of balance point temperature and same internal loads resulted in a 9% reduction in thermal energy consumption and 18% reduction in heat loads. When the same model was run with a 3°F increase in temperature set points the result was energy consumption and heat loads nearly the same as the baseline model. This neatly recapitulates what occurred in reality, suggesting the validity of the above R-value calculation and the observation relating to outdoor temperature hydronic reset control settings.

Figure 3 shows the numbers and differences between Baseline Energy Consumption, Real Retrofit considering true R value, and the Actual Performance Run with 3°F increase set points in the eQuest model. We concluded that the difference in the set point temperatures and the effective heat transfer coefficient of the exterior walls are the reasons for discrepancy between the modeled and actual energy usage. Therefore not only the poor control was considerable in this case, also failing to address thermal bridges which was not reflected in the software menu made error in our energy level expectation of the building after renovation.

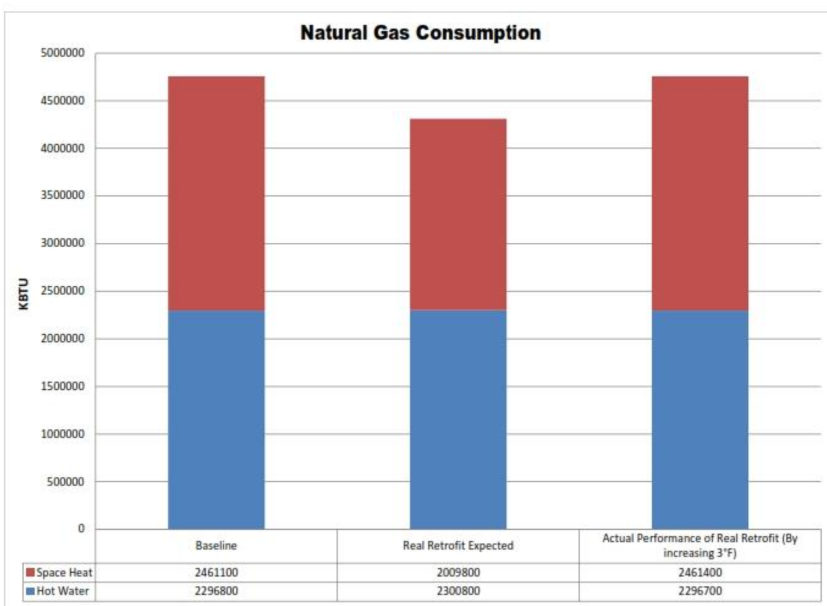


Figure 3: Current retrofit energy runs.

2.3. Alternative Renovation

Given the paltry performance of the actual retrofit, we propose an alternative, which covers the surface of the façade to eliminate thermal bridging\ and provides for a deliberately constructed continuous air barrier. The proposed method has been demonstrated on low-rise buildings and has proven to be buildable and effective wall insulation retrofit method, which can support the addition of 6 inch continuous insulation with R value of 30 ft^2-°F-hr/Btu (Lstiburek 2014). The method, described in Lstiburek (2014) provides for a continuous fluid-applied air and water barrier to coat the existing brick and concrete exterior. Dimensional 2x4 Wood or Metal studs are mechanically attached to the existing surface, spaced such that 1.5 inch rigid insulation can be placed between the studs, then rigid insulation is applied over the entire assembly with joints staggered and offset. We considered a total of 6 inches of rigid insulation. Vertical strapping provides an air gap and drainage plane behind the cladding as well as attachment surface for new cladding, which can be a light material like fibre cement-based composite panel. Figure 4 shows a section of this approach.

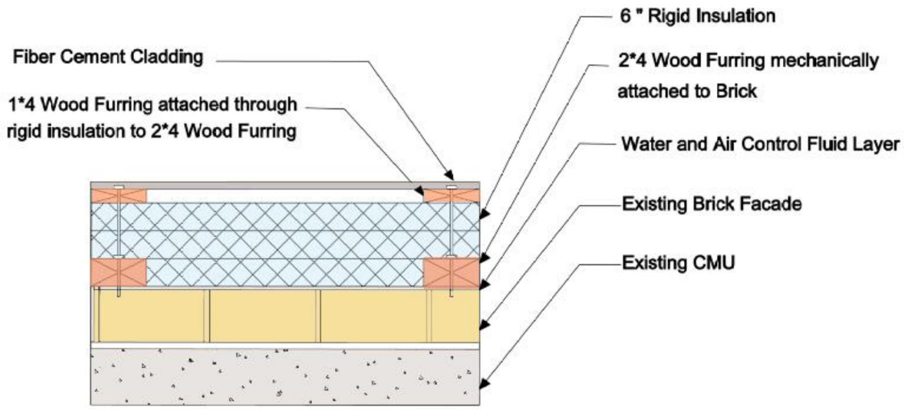


Figure 4: New recommendation for façade.

This total wall assembly with R value of 36 ft^2-°F-hr/Btu was specified in the eQuest model. The air leakage rate was modified to 0.038 CFM/sft ACH to reflect the deliberate air barrier fabrication approach. Figures 5 and 6 show the energy performance runs of this new alternative vs. real and baseline runs, and predicts 34% saving in total heating energy consumption compared to the baseline, and 64% savings over the heat loads of baseline before renovation. This new alternative shows considerable saving in energy performance of the building while we have not a very huge difference in cost.

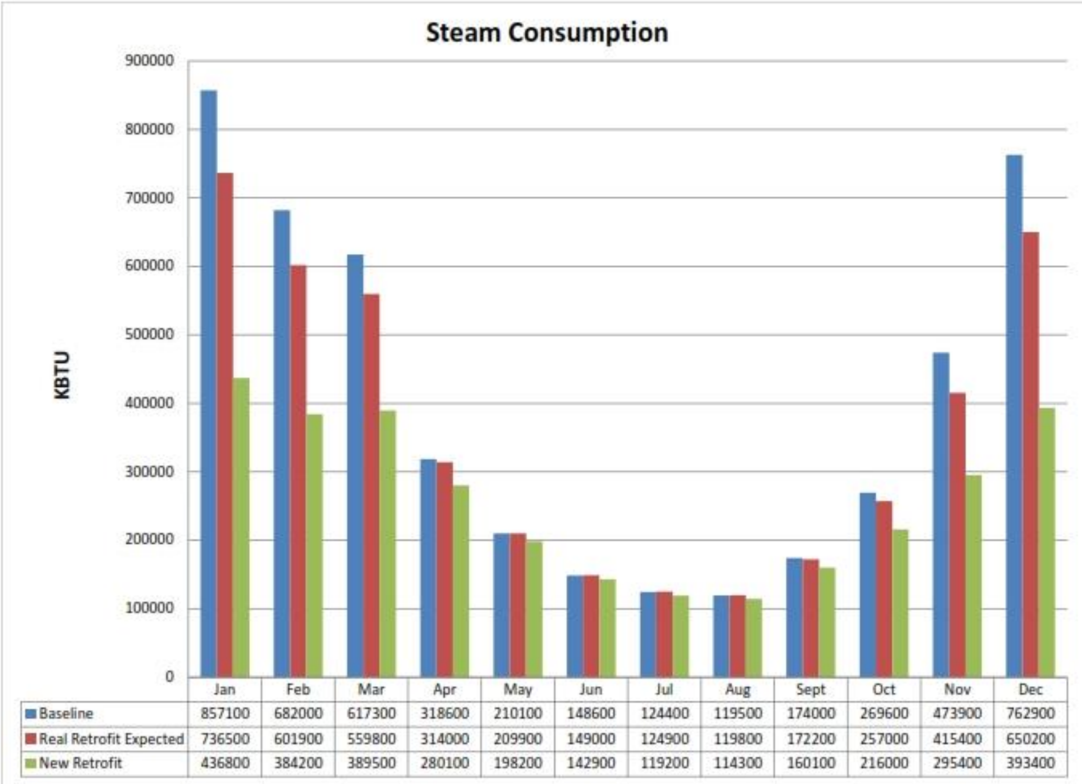


Figure 5: Monthly comparison graph between total heating energy consumption of real retrofit vs. new ideal alternative.

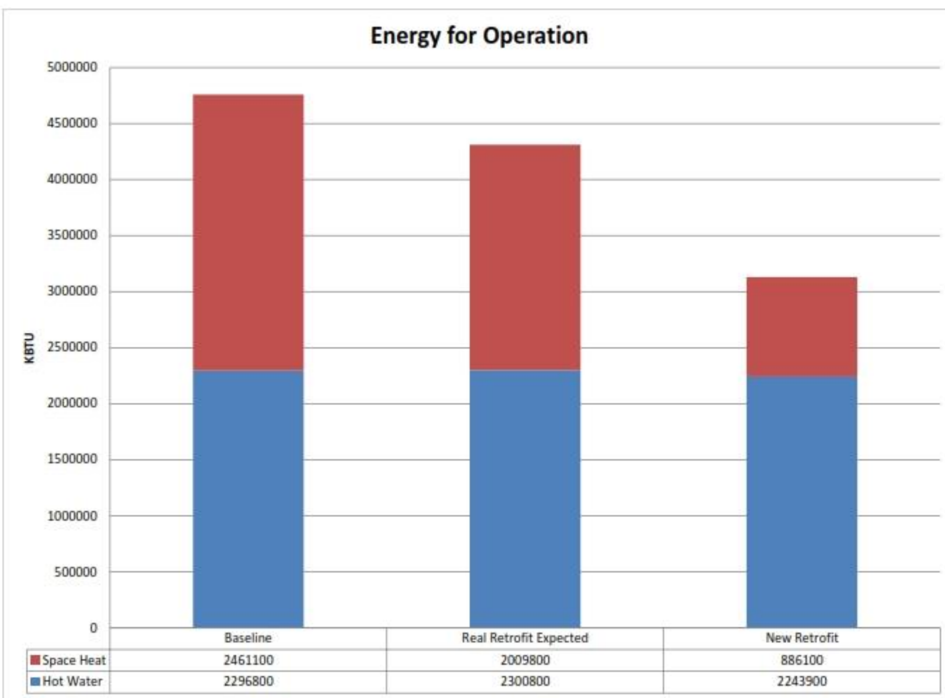


Figure 6: Total heating energy consumption comparison.

2. LCA ANALYSIS

2.1. LCA Analysis Method

This study was conducted using the ATHENA Impact Estimator, which is an environmental life-cycle assessment tool. This tool provides a cradle-to-grave assessment for buildings. The measurements are using US EPA analysis methods for assessment and reduction of environmental impacts. Also, this software uses the standard method for calculating life-cycle assessment, based on International Organization of Standardization (ISO) 21930/31. The outputs measure whole environmental impacts of buildings, including manufacturing, transportation, construction, energy use, building type and lifespan, maintenance, and demolition and disposal. The outputs can be divided into several categories: Global Warming Potential (CO_2 equivalent mass), Human Health Criteria (PM 2.5 equivalent mass), Acidification (Air) Potential (SO_2 equivalent mass), Smog (air) Potential (O_3 equivalent mass), Eutrophication (air & water) Potential (N equivalent mass), Fossil Fuel Consumption (GJ Total fossil fuel energy), and Ozone Depletion (air) Potential (CFC 11 equivalent), seen in Figure 7.

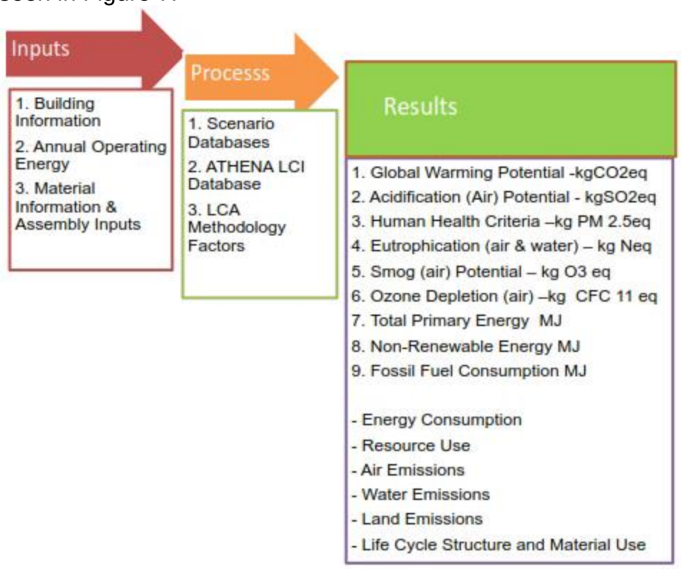


Figure 7: ATHENA Impact Estimator LCA conceptual model.

2.1. Grayson Hall Retrofit LCA

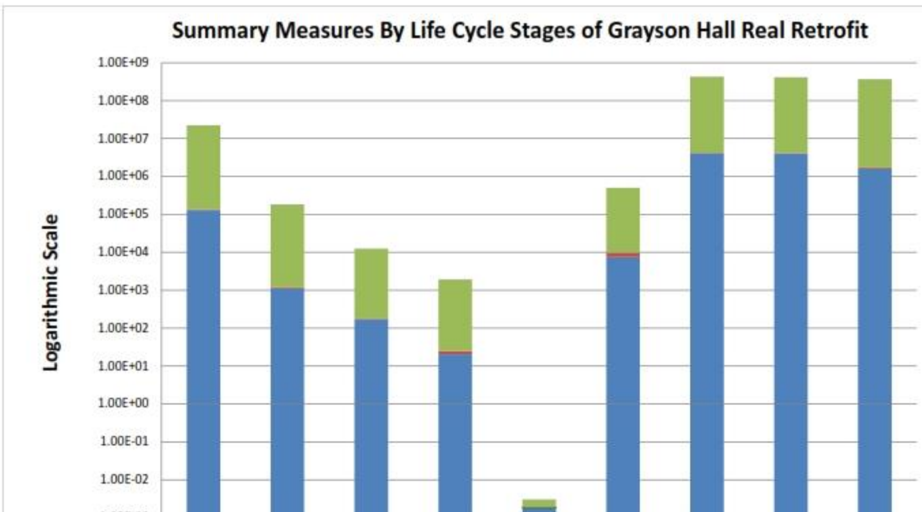
In this study, the LCA for real retrofit Grayson Hall Building was conducted to investigate emissions and impacts through the process of renovation over the life expectancy of 50 years. Since this retrofit was done after 50 years of building's life, we are expecting an average of 50 years for building's life performance before next decision. By importing the building information, annual operating energy and renovation materials to ATHENA and adding the impact of demolition materials from deteriorated existing brick façade and windows, the LCA of this renovation was conducted over the life span of 50 years. Table 4 shows building information, energy inputs, and the type and quantity of materials used in ATHENA. Operating energy was considered with 9% savings over the pre-retrofit baseline, as we assume the thermostat set points are adjusted and building is operating as low as model expectation.

Table 4: LCA inputs.

Inputs	Real Retrofit	Ideal Retrofit
Project Location	New York City	
Building Type	Multi Unit Residential- Rental	
Building Life Expectancy	50 Years	
Building Height	61.8 ft	
Gross Floor Area	78214 sqft	
Operating Description	370123.0 KWh	
	117067.7 m3 Natural Gas (4,310.6 MBtu)	84.317.8 m3 Natural Gas (3,104.7 MBtu)
Custom Wall	_	Wood Stud, Non loading, None Sheathing, 24 o.c., Stud 2*4, Kiln-dried
Windows	Number of Windows: 477 Frame Type: Aluminum Window Frame Double Pane Total Window Area: 13679.5 sf	

Doors	Glazing Type: Double Glazed Hard Coated Air Number of Doors: 17 Door Type: Aluminum Exterior Door, 80% glazing
Envelope	Polystyrene Extruded (6 inch) Air Barrier Brick- Modular (metric) Fiber Cement Siding
Extra Materials	Aluminum 1.2 (ton) Extruded Polystyrene 2,336 sf Concrete 3.9 yd3 -- Small Dimension Softwood Lumber
Demolition Materials From Existing Façade	Aluminum Window Frame: 15,274.99 lbs Glazing Panel: 20.67 ton(short) Metric Modular Brick: 9,691.428 sf

The final results and total impacts are shown in *Logarithmic Scale* graph, considering material and energy consumption impact of the whole life cycle of current renovation over next 50 years (Figure 8). In this chart the total energy consumption of the renovated building was taken into account to get the real impact of building over its life.



	Global Warming Potential (kg CO2 eq)	Acidification Potential (kg SO2 eq)	HH Particulate (kg PM2.5 eq)	Eutrophication Potential (kg N eq)	Ozone Depletion Potential (kg CFC-11 eq)	Smog Potential (kg O3 eq)	Total Primary Energy (MJ)	Non-Renewable Energy (MJ)	Fossil Fuel Consumption (MJ)
End of Life	2.28E+03	2.13E+01	1.23E+00	1.45E+00	8.31E-08	7.42E+02	2.84E+04	2.84E+04	2.83E+04
Use	2.22E+07	1.82E+05	1.21E+04	1.88E+03	1.16E-03	4.88E+05	4.19E+08	4.04E+08	3.64E+08
Construction Process	8.25E+03	8.07E+01	6.56E+00	4.74E+00	8.60E-06	2.43E+03	1.23E+05	1.23E+05	1.22E+05
Product	1.30E+05	1.12E+03	1.71E+02	2.05E+01	1.82E-03	7.42E+03	4.09E+06	4.02E+06	1.62E+06

Figure 8: Life-cycle impacts of the Grayson Hall renovation.

The renovation materials from ideal alternative, energy inputs, and demolition elements (Table 4) were also imported to ATHENA Impact Estimator to get the summary of Environmental Impacts. In this case, the wall assembly and extra materials were different, and energy for operation and demolition materials from existing façade was lower. The only element removed and demolished from existing façade was single pane aluminum windows. Table 5 shows the final reports comparing LCA impact of this ideal retrofit with total steam saving of 34% with Real Retrofit of %9 reductions in total heating loads.

Table 5: life cycle impact of real retrofit vs. ideal renovation.

		Real Renovation	Ideal Renovation
Global Warming Potential	kg CO2 eq	2.23E+07	1.83E+07
Acidification Potential	kg SO2 eq	1.83E+05	1.49E+05
HH Particulate	kg PM2.5 eq	1.23E+04	1.03E+04
Eutrophication Potential	kg N eq	1.91E+03	1.59E+03

Ozone Depletion Potential	kg CFC-11 eq	2.99E-03	2.99E-03
Smog Potential	kg O3 eq	4.98E+05	4.13E+05
Total Primary Energy	MJ	4.23E+08	3.55E+08
Non-Renewable Energy	MJ	4.08E+08	3.40E+08
Fossil Fuel Consumption	MJ	3.66E+08	2.97E+08

Also, another analysis was conducted to compare emissions produced by materials during renovation process and emission reductions related to the energy savings of real retrofit *ideally* when the set points have been adjusted. Figure 9 shows that the emission reductions would be higher than emission produced during the renovation process, indicating that renovation of existing buildings is indeed a preferable method for reducing carbon emissions associated with buildings.

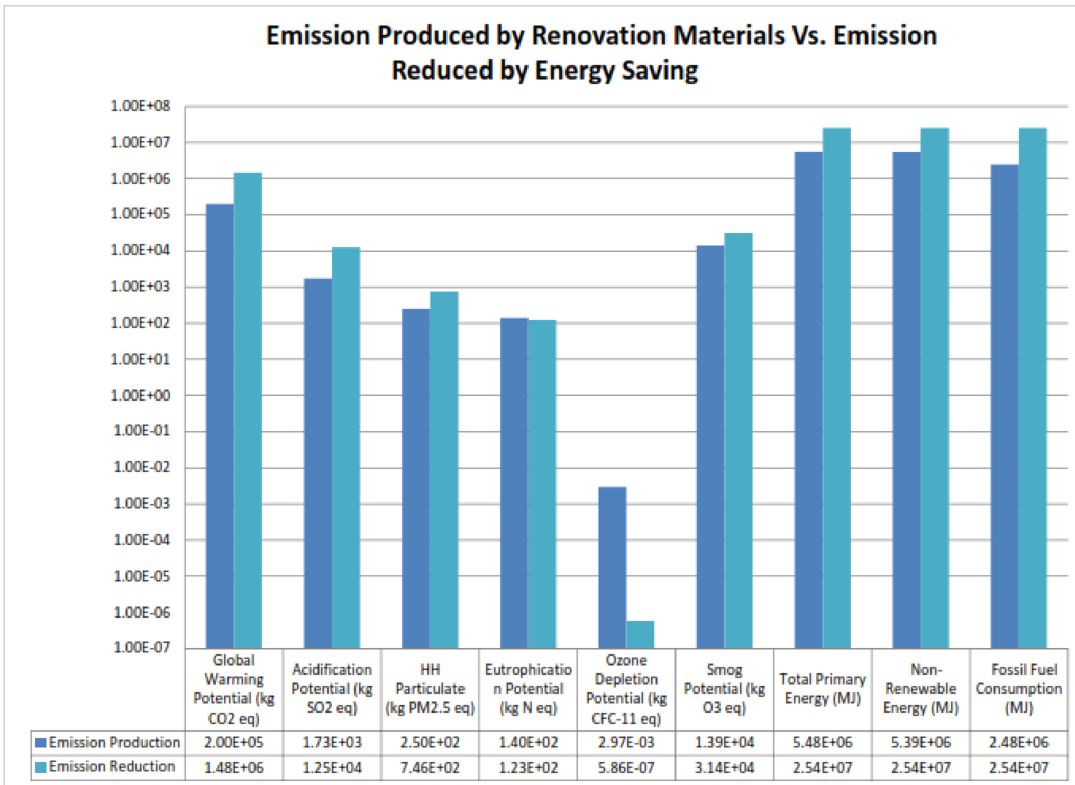


Figure 9: Comparison between produced and reduced emission through the process of Grayson Hall renovation.

CONCLUSION

This project has several outputs. First, it shows how thermal bridges have a significant effect on thermal performance of the building. In this case, thermal bridges in the exterior walls resulted in significant deviations from predicted energy use, while model expectations were based on just software menu and was not reflected this thermal exposure of façade elements. Therefore, we investigated a method for reducing thermal bridges and providing high thermal performance for façade by not a huge difference in cost. With improved building envelope, we showed that it is possible to achieve 34% reduction of gas consumption and 64% savings for heating loads. So this study will show clearly the importance of considering effective R value in thermal performance of the façade in a renovation process.

Next outcome from this study relates to the life-cycle impact of the renovation. We compared the total life-cycle energy of two retrofit approaches over life cycle of 50 years. Also, total environmental impact associated with renovation materials were compared by real reduced impact from energy savings. The results show that for almost all categories of environmental impacts this reduction in operational energy would be higher than emissions produced by renovation through the life-cycle of the building. Also in future study this result will be compared based on per square footage with a new LEED Dormitory of

Commonwealth Honors College to know whether reuse of a degraded building have lifetime carbon emissions and other environmental and financial impacts greater than or lower than a new construction. Life cycle cost of the project will be studied in future research.

The advantage of this study can be used in other three dormitories of Orchard Hill Residential Area which have the same geometry and renovation process as Grayson Hall Building. This process and results may also affect future retrofit policies at UMass Amherst and other higher education institutions, and provide clear understanding of environmental benefit for adaptive reuse and retrofit of existing buildings.

REFERENCES

Ardente, F., M. Beccali, M. Cellura, and M. Mistretta. 2011. *Energy and environmental benefits in public buildings as a result of retrofit actions.* Renewable and Sustainable Energy Reviews 15:460-470.

ATHENA Sustainable Materials Institute, 2013. *Life Cycle Assessment Software of Impact Estimator 2013*. < http://calculatelca.com/software/impact-estimator/>

Buys, A., M. Bendewald, and K. Tupper. 2011. *Life cycle cost analysis: Is it worth the effort?* Pages 541-548 in Life cycle cost analysis: Is it worth the effort? ASHRAE Winter Conference, January 29, 2011 - February 2. American Society of Heating, Refrigerating, and Air-Conditioning Eng. Inc.

Ding, G., 2004. *The development of a multi-criteria approach for the measurement of sustainable performance for built projects and facilities*, Ph.D. Thesis, University of technology, Sydney, Australia.

Dixit, M. K., J. Fernandez-Solis, S. Lavy, and C. H. Culp. 2010. *Identification of parameters for embodied energy measurement: A literature review*. Energy and Buildings 42:1238-1247.

Hernandez, P., and P. Kenny. 2010. *From net energy to zero energy buildings: Defining life cycle zero energy buildings (LC-ZEB)*. Energy and Buildings 42:815-821.

Hernandez, P., and P. Kenny. 2011. *Development of a methodology for life cycle building energy ratings.* Energy Policy 39:3779-3788.

Lstiburek, J.N. 2014, *Building Sciences: Deep-Dish Retrofits* ASHRAE Journal, vol. 56, no. 8: 38-45

Mostafavi, N., and Farzinmoghadam, M., and Hoque, S. 2013. *Envelope retrofit analysis using eQuest, IESVE Revit Plug-in and Green Building Studio: a university dormitory case study*. International Journal of Sustainable Energy

NIST Engineering Laboratory, 2013. *BEES Building Environmental and Economic Sustainability Online software 2010.* < http://www.nist.gov/el/economics/BEESSoftware.cfm>

Preservation Green Lab. 2011. *The Greenest Building: Quantifying the Environmental Value of Building Reuse*

Radermacher, R. 2011. *Net-zero-energy technology for building retrofit.* Hvac&R Research 17:1-1.

Ramesh, T., R. Prakash, and K. K. Shukla. 2010. *Life cycle energy analysis of buildings: An overview*. Energy and Buildings 42:1592-1600.

Sesana, M. M., and G. Salvalai. 2013. *Overview on life cycle methodologies and economic feasibility fornZEBs.* Building and Environment 67:211-216.

Sodagar, B. 2013. *Sustainability Potentials of Housing Refurbishment*. Buildings 3, no. 1: 278-299.

U.S. Energy information administration, 2010. *International Energy Outlook 2010*. http://large.stanford.edu/courses/2010/ph240/riley2/docs/EIA-0484-2010.pdf

US Environmental Protection Agency, 2013. *Climate Impacts on Energy.* <http://www.epa.gov/climatechange/impacts-adaptation/energy.html>