CASE STUDY

Energy Performance of Chicago Properties Retrofit With Fiber Glass Insulation

ENERGY EFFICIENCY FOR ALL

AUGUST 2019

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REPORT PARTNERS

Elevate Energy is a nonprofit organization that designs and implements programs that reduce costs, protect people and the environment, and ensure the benefits of clean and efficient energy use reach those who need them most. Since launching its multifamily energy efficiency programs in 2008, Elevate Energy has upgraded 48,000 units in low-income communities.

Natural Resources Defense Council (NRDC) is an international nonprofit environmental organization with more than 2.4 million members and online activists. Since 1970, its lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment.

Three^3, Inc. (ThreeCubed) is a research and educational organization that conducts innovative and interdisciplinary social science research, and offers educational programming, to promote the integrated achievement of the three pillars of sustainability—equity, environment, and economics—in combination.

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INTRODUCTION

As the body of research on healthier building materials expands and contractors and others who specify which materials to use incorporate these materials into energy-efficiency upgrades, the question of how energy performance is affected is often raised. This case study presents an analysis of the energy savings achieved in 13 multifamily properties in the Chicago metropolitan area that were retrofitted between 2014 and 2016. In each of these properties, the roof cavity or attic floor was air-sealed and then insulated with a blown-in fiber glass insulation, Knauf Insulation Jet Stream® ULTRA Glass Mineral Wool Blowing Insulation. Fiber glass insulation is in the recommended category of insulations examined in Energy Efficiency for All's (EEFA) report, *Making Affordable Multifamily Housing More Energy Efficient: A Guide to Healthier Upgrade Materials*. And, this Knauf fiber glass insulation, in particular, holds the following third-party, material-related designations:

- UL Environment GREENGUARD Gold
- Verified formaldehyde free by UL Environment
- Living Building Challenge compliant
- Free of content on Red List
- Declare participant[1]

This case study is intended to illustrate that energy savings were achieved in a set of Chicago metro area multifamily properties upgraded with a fiber glass insulation. The energy savings analysis is based on pre- and post-retrofit weather normalized energy usage data gathered from utility bills. The energy performance of these properties is compared with the findings from a larger national study conducted by Three[3] on the post-retrofit energy savings of multifamily units weatherized as part of the U.S. Department of Energy's Weatherization Assistance Program (WAP) in program years 2010 and 2011.[2]

In addition to the EEFA study, *Making Affordable Multifamily Housing More Energy Efficient: A Guide to Healthier Upgrade Materials*, this Chicago case study builds on the following healthy building materials research, guidance, and policy recommendations published by EEFA and its partners, Natural Resources Defense Council, Healthy Building Network, International Living Future Institute, Three[3], and Vermont Energy Investment Corporation:

- Guidance for Specifying Healthier Insulation and Air-Sealing Materials
- Policy Matters: Making Energy Upgrades Healthier for Residents, Workers, and Neighbors
- Drivers, Adoptability, and Performance of Healthier Energy-Efficiency Retrofit Materials in Affordable Multifamily Housing

This is a case study of 13 Chicago metropolitan-area multifamily properties in which retrofits included air sealing and then insulating the roof cavities or attic floors using a blown-in fiber glass insulation. Fiber glass insulation is in the recommended category of insulations examined in Energy Efficiency for All's report, *Making Affordable Multifamily Housing More Energy Efficient: A Guide to Healthier Upgrade Materials.* For the 13 properties, the average gas energy savings was 18%. Gas energy savings ranged from 2% to 41%; the median was 17%. The subset of properties in which only the roof cavity or attic was air sealed and insulated realized an average gas energy savings of 17%. By comparison, a national study found that attic insulation and air sealing represented an average post-retrofit gas energy savings of 8% and 7%, respectively. The national comparison further supports the observation that fiber glass insulation, specifically an insulation that contains lower levels of toxic materials as verified by third party designations, achieves effective levels of energy performance.

BACKGROUND ON PROPERTIES

Most of the 13 properties selected for this analysis were built between 1920 and 1930. Eleven of the 13 properties are located in Chicago and the remaining two are located in Evanston, Illinois, a suburb just north of Chicago. Most have masonry exteriors with three heated floors. They range in size from 8,200 square feet (6 units) to 32,500 square feet (65 units) and have 1.5 to 2.5 occupants per unit. As is typical in Chicago, the building owners pay for the space heat and domestic hot water in the common areas and tenant units. The tenants are often (though not in all buildings) responsible for paying in-unit cooking gas and electric usage. In properties of this vintage, heating systems are predominantly gas-fired steam or hot water boilers and provide heat for the entire building. Cooling, if used, is provided by window air-conditioner units, often installed by tenants. Building energy conservation codes require that there be approximately 17 inches of insulation blown into the roof cavity of all the properties to meet the R-49 insulation standard. The average square footage of installed insulation was 6,212. The smallest roof cavity insulated was 2,840 square feet; the largest was 13,880 square feet. Additional details of the 13 properties' characteristics are provided in Appendix A.

SUMMARY OF ENERGY PERFORMANCE ANALYSIS

TABLE 1. GAS SAVINGS POST-RETROFIT AND PRE- AND POST-RETROFIT GAS ENERGY USE INTENSITY (EUI)

	Gas Savings Post-Retrofit (%)	Pre-Retrofit Gas EUI (kBtus/sq ft)	Post-Retrofit Gas EUI (kBtus/sq ft)	Difference in Pre- and Post-Retrofit Gas EUI (kBtus/sq ft)
Mean	18	111.8	91.1	-20.6
Minimum	2	101.5	99.1	-2.4
Maximum	41	133.2	79.0	-54.2

TABLE 2. GAS SAVINGS POST-RETROFIT BY PROJECT SCOPE

Project Scope	Number of Properties	Average Gas Savings Post-Retrofit (%)
Roof Cavity Air Sealing and Insulation Only	3	17
Roof Cavity Air Sealing and Insulation + Window Replacement	2	21
Roof Cavity Air Sealing and Insulation + Heating or DHW Upgrades	8	18
All Projects	**13**	**18**

Note: Because of the size of gaps and accessibility issues, all projects used a one-component polyurethane foam sealant to air seal the roof cavity. This type of air-sealing product is not in the recommended category of air sealants examined in EEFA's *Making Affordable Multifamily Housing More Energy Efficient: A Guide to Healthier Upgrade Materials*. As healthier air sealants come into use, additional case studies will be needed to analyze their performance.

Given the climate zone of northern Illinois (International Energy Conservation Code Zone 5), the vast majority of energy savings from air sealing and insulating roof cavities or attics is seen in a reduction of the energy used to heat a building. Therefore, owner-paid gas utility account data was collected pre- and post-retrofit for this analysis. In addition, for ease and accuracy of comparison from year to year, i.e., pre-retrofit and post-retrofit, the gas energy use intensity–the ratio of gas usage in thousands of British thermal units (kBtus) to building square footage–was weather-normalized to remove the annual fluctuations in temperature.

Across the 13 properties, the average pre-retrofit gas energy use intensity (EUI) was 111.8 kBtus/sq ft. The average post-retrofit gas EUI was 91.1 kBtus/sq ft, resulting in an average savings of 18 percent. The range of energy savings achieved varied from 2 percent to 41 percent. The median was 17 percent. Table 1 shows the percentage of minimum, mean, and maximum energy savings for the sample set of properties and the associated pre- and post-retrofit gas EUI for those properties.

It is important to note that 8 of the 13 properties installed additional gas saving measures, such as new boilers, boiler controls, domestic hot water equipment, or heating pipe insulation. These additional measures were often installed four to nine months before or after the air sealing and insulation retrofits were done. (It is commonly the case that energy-efficiency upgrades are not done all at once.) The sequencing of these upgrades can affect the pre- or post-retrofit gas energy usage since pre-retrofit gas energy usage was calculated based on 12 months of utility bills pre-retrofit while post-retrofit usage was based on 12 months of utility bills post-retrofit. Therefore, the energy savings cannot be solely attributed to roof cavity air sealing and insulation. Furthermore, gas savings in properties with central heating or domestic hot water systems, or both, such as gas-fired boilers, are very dependent on the equipment and system knowledge and operational skill of the maintenance staff. As a result, post-retrofit energy savings often vary widely even though the high efficiency equipment and building envelope upgrades are known to be effective. For example, the property that experienced the largest savings (41 percent) received

TABLE 3. ENERGY SAVINGS BY MEASURE FOR MULTIFAMILY HOUSING UNITS WITH NATURAL GAS AND FUEL OIL FOR MAIN HEAT IN THE WEATHERIZATION ASSISTANCE PROGRAM, PROGRAM YEARS 2010 AND 2011

Measure	Units Receiving the Measure (%)	Unit Level Energy Savings per Installation (therms/year)
Air Sealing	62	48
Attic Insulation	36	56
Heater Replacement	32	48
Water Heating Replacement	13	27
Window Replacement	30	33

roof cavity air sealing and insulation in April 2015 and a boiler replacement, boiler controls, heating pipe insulation, and a main-line vents upgrade in September 2015. Meanwhile, the property with the lowest energy savings (2 percent) received a boiler replacement, boiler controls, and main-line vents upgrade in November 2015 and roof cavity air sealing and insulation in February 2016. The differences in savings are most likely due to building operations.

Of the remaining five properties, three received only the roof cavity air sealing and insulation upgrade. Their average post-retrofit gas energy savings was 17 percent. This suggests effective performance was achieved in these upgrades that used a blown-in fiber glass insulation with lower levels of key avoidable toxins. The remaining two properties received window upgrades in addition to roof cavity air sealing and insulation. These properties realized average gas energy savings of 21 percent, a figure that, as expected, is not much greater than that for the just mentioned three properties because most of the savings are due to the air sealing and insulation retrofit. Table 2 summarizes the gas energy savings by project scope.

Providing a national comparison, an energy savings analysis of multifamily units that were retrofit through the WAP in program year 2010 and 2011 found that installing attic insulation and air sealing produced average post-retrofit gas energy savings of 8 percent and 7 percent, respectively. The study was based on the weatherization of 1,205 multifamily units primarily heated with natural gas or fuel oil located across the United States.[3] It found that the 36 percent of multifamily units that installed attic insulation saved an average of 56 therms/year.[4] Similarly, the 62 percent of multifamily units that were air sealed saved an average of 48 therms/year.[5] Table 3 illustrates that these two measures were most common and resulted in the highest savings relative to other measures.

The average pre-WAP gas energy use for participants in this study was 700 therms/year.[6] Based on that finding, the gas energy savings achieved from installing attic insulation (56 therms/year) and air sealing (48 therms/year) represent an average post-retrofit savings of 8 percent and 7 percent, respectively.

Although the exact materials used in these weatherization projects were not specified in the study, the study provides useful comparative data. A comparison of the savings achieved in the subset of case study properties that only installed insulation and were air sealed (17 percent) with the national study's results (15 percent collectively; 8 percent and 7 percent separately) supports the observation that the fiber glass insulation material used in the case study properties saves energy.

CONCLUSION

Even though this was not a scientific study but rather an analysis of 13 properties (289 units) and their pre- and post-retrofit gas energy usage, the findings suggest energy savings can be achieved by using Knauf Insulation Jet Stream® ULTRA Glass Mineral Wool Blowing Insulation, which is less toxic than the more commonly specified insulation materials for multifamily building roof cavities or attics. In the sample of 13 properties, the average gas energy savings was 18 percent. Additional analysis was conducted to examine the energy savings of properties that only received roof cavity air sealing and insulation upgrades relative to those with broader project scopes. The results show the air sealing and insulation projects produced an average of 17 percent post-retrofit gas energy savings, only one percentage point lower than the average of all projects. This is an indicator of the level of impact that air sealing and insulation can have and the level of performance that this fiber glass insulation, carrying several significant material-related designations, achieves.

As a point of comparison, a national study found that attic insulation and air sealing represented an average post-retrofit savings of 8 percent and 7 percent, respectively. Comparing the performance of the 13 properties in this case study with a national data set further supports the observation that fiber glass insulation, particularly an insulation that contains lower levels of toxic materials than those found in more commonly specified insulation materials as confirmed by third-party designations, results in energy savings on levels comparable to commonly used insulation.

APPENDIX A — PROPERTY CHARACTERISTICS

Building ID	City	State	Zip Code	Year of Con-struction	Total Conditioned Space* (sq ft)	Number of Residential Units	Number of Occupants	Payor of Living Unit Space Heat Bills	Payor of Hot Water Bills	Payor of Cooking Gas Bills	Payor of Electricity Bills
A	Chicago	IL	60626	1926	13,324	12	30	Owner	Owner	Tenant	Tenant
B	Chicago	IL	60639	1930	24,528	32	100	Owner	Owner	Tenant	Tenant
C	Chicago	IL	60626	1925	10,125	6	9	Owner	Owner	Tenant	Tenant
D	Chicago	IL	60628	1920	14,132	16	23	Owner	Owner	Tenant	Tenant
E	Chicago	IL	60645	Unknown	30,960	37	80	Owner	Owner	Tenant	Tenant
F	Evanston	IL	60201	1925	29,157	31	90	Owner	Owner	Tenant	Tenant
G	Chicago	IL	60660	1920	30,859	65	90	Owner	Owner	Not Available	Owner
H	Chicago	IL	60659	Unknown	32,508	32	70	Owner	Owner	Tenant	Tenant
I	Evanston	IL	60202	Unknown	12,474	15	30	Owner	Owner	Tenant	Tenant
J	Chicago	IL	60647	1920	10,827	13	20	Owner	Owner	Tenant	Owner
K	Chicago	IL	60649	1931	8,219	6	18	Owner	Owner	Tenant	Owner
L	Chicago	IL	60649	Unknown	10,147	12	Not Available	Not Available	Not Available	Not Available	Not Available
M	Chicago	IL	60643	Unknown	8,909	12	Not Available	Owner	Owner	Not Available	Tenant

*Space that is heated and/or cooled.

APPENDIX B — RETROFIT SCOPE AND ENERGY PERFORMANCE OF PROPERTIES

Building ID	Other Retrofits Within 12 Months	Building: Pre-Retrofit Gas EUI (kBtu/sq ft)	Building: Post-Retrofit Gas EUI (kBtu/sq ft)	Difference in Pre- and Post-Retrofit Gas EUI (kBtu/sq ft)	Gas Savings Post-Retrofit (%)
A	Air Sealing and Insulation–Roof Cavity	104.40	92.59	-11.81	11
B	Air Sealing–Roof Cavity or Attic; Boiler Replacement; Insulation–Heating Pipes	110.38	104.06	-6.32	6
C	Air Sealing and Insulation–Roof Cavity; Air Sealing–General	93.33	79.39	-13.94	15
D	Air Sealing and Insulation–Roof Cavity; Boiler Controls; Main-Line Air Vents; Insulation–Heating Pipes	112.27	97.32	-14.95	13
E	Air Sealing–General; Air Sealing–Roof Cavity or Attic; Boiler Controls; Boiler Replacement; Window Replacement	110.38	82.82	-27.56	25
F	Air Sealing–General; Air Sealing–Roof Cavity or Attic; Boiler Controls; Boiler Replacement; DHW Heater Replacement	97.29	94.32	-2.97	3
G	Air Sealing–Roof Cavity or Attic; Boiler Controls; Boiler Replacement	137.69	102.48	-35.21	26
H	Air Sealing–General; Air Sealing–Roof Cavity or Attic; Window Replacement	93.91	75.70	-18.21	19
I	Air Sealing–General; Air Sealing–Roof Cavity or Attic; Window Replacement	116.44	89.80	-26.64	23
J	Air Sealing and Insulation–Roof Cavity; Boiler Replacement; Boiler Controls; Main-Line Air Vents; Insulation–Heating Pipes	133.23	79.00	-54.23	41
K	Air Sealing and Insulation–Roof Cavity; Air Sealing–General; Boiler Controls; Boiler Repair and Tune-up; Main-Line Air Vents; Radiator Vents; Leak Fixing; Insulation–Heating Pipes	129.28	92.40	-36.88	29
L	Air Sealing and Insulation–Roof Cavity	132.79	98.90	-33.89	26
M	Air Sealing and Insulation–Roof Cavity; Boiler Replacement; Main-Line Air Vents	101.50	99.10	-2.40	2

APPENDIX C — RETROFIT PROJECT MATERIALS

Building ID	Insulation				Air Sealing			
	Specific Material or Type of Material	Application	Area and Thickness of Material Installed	Minimum Required R-Value	Specific Material or Type of Material	Application	Total Volume of Product Used (cu ft)	Size Range of Gaps Sealed (in)
A	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	4,800 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	37.44	0.5– 1.5
B	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	8,200 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	49.92	0.5–1.5
C	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	3,626 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	28.08	0.5–1.5
D	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	5,701 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	43.68	0.5– 1.5
E	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	8,446 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	65.52	0.5–1.5
F	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	13,880 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	109.20	0.5–1.5
G	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	5,296 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	40.56	0.5–1.5
H	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	9,030 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	70.20	0.5–1.5
I	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	5,535 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	42.12	0.5– 1.5
J	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	4,018 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	31.20	0.5– 1.5
K	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	2,840 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	42.12	0.5–1.5
L	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	3,690 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	29.64	0.5–1.5
M	Knauf Jet Steam ULTRA Glass Mineral Wool Blowing	Roof cavity	5,689 sq ft 17 in	R-49	Soudal SoudaFoam Gap & Block (one-part polyurethane foam)	All gaps and penetrations in attic	37.44	0.5–1.5

Endnotes

1 Declare is a voluntary, building material ingredient self-disclosure program. For more information, see: https://living-future.org/declare/declare-about/.

2 Three[3] research staff managed the national WAP evaluation under the auspices of Oak Ridge National Laboratory.

3 Bruce Tonn et al., *The Impacts of Weatherizing Low-Income Multifamily Buildings: A Summary Report of the Evaluations of the U.S. Department of Energy's Weatherization Assistance Program*, JPB Foundation (2017)

4 Ibid.

5 Ibid.

6 Ibid.

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