A Comparison of Two Weatherization Techniques:

N.U. Seal-up vs. The Air-Sealing Specialist

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EXECUTIVE SUMMARY

Northeast Utilities (NU) assists its residential customers in saving energy through several programs, including **Operation Wrap-up/ Seal-up** (WUSU). The Seal-up portion of this program is designed to saving heating and cooling costs by reducing a home's rate of air infiltration.

An alternative method of weatherizing homes uses a "blower door" to depressurize the home, and special leak-detecting tools to locate air leakage sites.

This study compared these two weatherization methods, with the goal of determining which has the best return for the customer's and for the company's investments. One hundred homes were weatherized: fifty using Seal-up methods, and fifty using the Air-Sealing Specialist's techniques.

Concurrently with the weatherization tests, each home was tested for three common indoor air pollutants, to evaluate whether tightening the home might cause its pollutant levels to increase.

Conclusions

The busy reader is urged to review the Conclusions section of this report for more detailed discussion. In brief, the study found that the Air-Sealing Specialist reduced infiltration by about 7 to 8 times as much as was done by Seal-up. The total cost (to the customer + NU) for the two approaches, per kilowatt-hour saved, was nearly the same, since the Specialist's work is estimated to cost about 7 to 8 times as much as the average total Seal-up job would cost.

Noteworthy differences emerged between the two programs:

* The Air-Sealing Specialist could assure the customer a higher level of infiltration reduction, and therefore energy savings, because measuring tools were used.

* Seal-up usually achieved small but measurable infiltration reductions, but sometimes also achieved no measurable reductions. In other words, some customers received no value in return for their modest investment.

Air quality measurements indicated that the natural, random variations in indoor air pollutant levels are of the same magnitude as any measured weatherization-induced increases in pollutant. Weatherizing a home does not cause a measurable decrease in its indoor air quality.

The data from this study indicate that NU and its electric heating customers would benefit from the Air-Sealing Specialist's approach to weatherization, through savings in space conditioning energy and concurrent demand reduction.

IX. CONCLUSIONS

Infiltration accounts for roughly a third of a typical home's heating energy requirement. Reducing infiltration is a readily available way to reduce heating cost and electric peak demand. NU currently offers its Wrap-up/Seal-up program; an alternative approach is to examine and treat the house using the Air-Sealing Specialist's tools. This study examines the potential for heating energy and electric demand reduction through the use of weatherization. It also examines the potential of weatherizing to adversely effecting the indoor air quality in the house.

The Test Method

One hundred sites were tested; they were divided into three Groups. Three methods of infiltration reduction were tested:

Group 1 - Standard Wrap-up/Seal-up (WUSU): 25 sites
Group 2 - Maximum WUSU; every possible WUSU measure was installed: 25 sites
Group 3 - Air-Sealing Specialist approach; eliminating air leaks where they are found: 50 sites

Characteristics of the average tested home

The infiltration rate in the average house in this test was 0.7 to 0.9 air changes per hour (ACH). They ranged widely, from 0.3 to 1.6 ACH. Since 0.3 ACH is an acceptable ventilation rate in most homes, there is room for improvement in almost all houses.

Differences between gas-heated and electrically heated homes

The tested homes with electric heating systems were found to have a 38 % lower leakage rate than those with gas heating. (A part, though not all, of the difference is likely due to the presence of a flue.) Houses with ductwork had 15 % more leakage than those without.

Which houses could benefit the most

Infiltration rates were found to be higher in older houses, especially Victorians. In general, infiltration increases by about 0.05 ACH for every 10 years of a house's age. (This probably reflects changes in construction techniques and architectural styles, and possibly aging

and drying of components.) The Air-Sealing Specialist did, in fact, reduce infiltration in the three Victorians tested by about 20 to 30 %.

Group 1's infiltration reduction

The average WUSU participant in this test requested $25 worth of measures; the average WUSU customer (not in this test) requests $33 worth of measures. Effectiveness of the installed measures varied considerably; some were effective and others did not show a measurable infiltration reduction. Attic ladder covers were found to be ineffective at reducing infiltration (though they appear effective as insulation, and could certainly be made effective as infiltration reducers, with design changes). Sill seal was found not to be effective in the three homes where it was tested.

Standard WUSU (neglecting the above-mentioned ineffective measures) reduced infiltration by 3 to 4 %.

Group 2's infiltration reduction

Installing all possible WUSU measures in a house had a greater effect on infiltration, as expected. Infiltration was reduced by 10 to 12 %. If the homeowner had paid for these measures, he would have paid, on average, $230. Total installation costs ranged from $53 to $408 per site. Spending nine-times as much yielded a 3-times increase in leakage reduction. Doing intensive WUSU appears to have a diminishing return.

Group 3's infiltration reduction

The Air-Sealing Specialist's work was, as expected, the most effective method for reducing infiltration. Infiltration was reduced by 24 to 31 %. While significant differences were found in the degree of reduction that could be achieved in gas heated vs. electrically heated houses (the electric sites were tightened more) the electrically heated houses in Group 3 all had central electric boilers, rather than the more common baseboard heat. They were also older than the average tested house. It would therefore be risky to predict that Air-Sealing can tighten the typical electrically heated house more than it could the gas heated house. For all Group 3 sites, the Specialist's tools and measurement techniques enabled him to locate many previously-unknown leaks in the houses. A great variety of infiltration points were located and sealed, most of which could not be treated using the tools available to WUSU crews.

Relative value of Air-Sealing

The cost of the Specialist's work in a full-scale program is ill-defined, as it is dependent on program costs and specifications that have not yet been established. If one assumes that the Specialist's work were to cost about $300 to $400 per site, it would be 12 to 16 times as expensive to the customer as the WUSU work done in this test. For that price, it reduces infiltration by 7 to 8 times as much as was done at the WUSU test sites. If one includes the NU program cost as part of the Group 1 WUSU work, the Group 3 work is about 7 times as expensive as the Group 1 work, and has the same payback rate.

The Air-Sealing work done in this test was performed by crews trained in WUSU methods; much of their work was done within the living space, less was done in attics and basements. Other firms (primarily the Princeton Energy Partners group) claim that 90 % of their tightening work is done in attics and basements. It is felt that further training (and possibly training with other tools such as the infrared camera) could increase the Air-Sealing crews' effectiveness, yielding perhaps a 30 to 40 % infiltration reduction, as a practical upper limit.

Average annual savings

Average annual savings for the three test groups was calculated to be as follows:

Heating Season Average Annual Savings

	Gas Heat	Electric heat	
Group 1	$10	$ 22	265 kWh/yr
Group 2	37	81	972
Group 3	70	154	1,852

Air-conditioning savings was not calculated, although 15 test sites have central air conditioning and another 52 have one or more room air conditioners. There would certainly be some measurable cooling savings.

Simple Payback

Simple Payback is simply the installed cost divided by the annual savings. It shows the number of years required to recover the investment, assuming constant energy costs and no foregone interest. Paybacks were calculated based on estimated savings vs. customer costs and total (customer + NU) costs. NU currently spends $28.50 per

site in support of seal-up work in the WUSU program. Median payback were as follows:

	Paybacks (in years) to: Customer	(NU + customer)
Group 1	1.1	2.7
Group 2	3.2	3.7
Group 3	2.8*	2.8*

*at $400 total cost, regardless of wh pays -- customer, NU or NU+customer

While the savings achieved by WUSU work (Group 1) are low (averagin $22/site), the payback to the customer is quite rapid. Neither th Company nor the customer fares as well when "maximum WUSU" work i done; doing a lot of Seal-up work insures that some of it will b ineffective.

Payback to the customer for Air-Sealing work is (surprisingly) longe than that for WUSU work; nevertheless 2.1 years is a very acceptabl payback to the residential customer. **On the basis of total cost of th work to NU and the customer, Air-Sealing has the fastest payback of th three tested methods of weatherizing.** The work done on Group 3 coul cost nearly $400 per site and still have the same payback as the WUS work done for Group 1.

Assuming a maximum allowable payback of three years, we could spen $420 per site on weatherizing.

Cost of Conserved Energy (another measure of value)

The "Cost of Conserved Energy" (CCE) is the amount one would pay t save one kWh of electric energy. It takes into account the lifetime o the conservation measure and the cost of money. When the CCE is sig nificantly less than the current cost of a kWh (presently 8.3 ¢/kWh) it is worthwhile for the customer to pay for the conservation measur instead of paying for the kilowatt-hour.

If the lifetime of the weatherization work is more than ten years, al approaches tested here were shown to be worthwhile; they all had CCE of less than 3 ¢/kWh. Even if they only lasted 5 years, the WUSU an the Air-Sealing work (at $300/site) both had CCEs under 4 ¢/kWh. I the Specialist's work cost $400/site and lasted only 5 years, it stil has a reasonable CCE of 5 ¢/kWh.

Demand reductions

Peak demand reductions were estimated. The Group 1 WUSU achieved, on average, a 0.13 kW reduction. The Air-Sealing done for Group 3 achieved seven times as much demand reduction - 0.92 kW per site. NU could therefore spend seven times as much in program support cost -- $200/site -- to achieve the same level of demand reduction that it presently gets from WUSU. Demand reduction costs $216 per kW for the present Group 1 WUSU work.

Indoor Air Quality Issues

It was of interest to determine whether weatherizing a home might cause its air quality to be adversely affected.

Three pollutants were measured in each home before and after weatherizing: Radon, formaldehyde (HCHO) and nitrogen dioxide (NO_2). In all three test Groups and for all three pollutants, nearly as many sites showed a decrease in pollutant concentration as showed an increase, after weatherization.

A statistical analysis was done on each pollutant's change in concentration after treatment. In each pollutant test, least-squares curve fits showed that, based on this study, there was no meaningful correlation between a realistically-achievable decrease in infiltration and an increase in the pollutant.

Indoor air quality was not shown to be adversely affected by weatherization.

Limitations of the study

As with all studies involving real customers and their homes, field measurements, and energy calculations, there were limitations to this study.

* The average Group 1 participant requested less WUSU work than the average non-participating WUSU customer ($25-worth vs. $33-worth of infiltration-control measures).

* The basic blower door measurement system has a ±5% basic accuracy, assuming very careful instrument readings. All subsequent savings calculations are based on these instruments' readings.

* The Air-Sealing Specialists in this study were the same crews who normally do WUSU work. They are, of course, most familiar with

WUSU methods and procedures. They have not had training in the use of the infrared camera, and they concentrated on measures in the living space. Had they done further attic and basement work, and had they been trained in tracking air flows through partition walls with the camera, they might have been able to achieve on average 40%, rather than 30%, infiltration reductions.

* Savings calculations were based on a very simple algorithm whose accuracy appears reasonable, but has not been tested against more complex models such as DOE-2.1 or against instrumented homes.

* The best estimates of actual savings (aside from heavily instrumenting several homes) would be based on bill analyses. This method would require surveying each home's appliance complement and resident population for the year before and the year after the test. Many more participants would be required for reasonable statistical accuracy. Ideally, recording watt-hour meters would be installed on each participant's electric heat circuits. These steps are beyond the intended scope of this study.

* Homes were being lived-in and weather conditions varied, as air quality tests were done, so there was necessarily some added "noise" to the chemical tests. The tests would have had greater precision if they had been made over longer periods (to reduce the weather-induced variations in infiltration) and in unoccupied houses (to eliminate the possibility of occupant-caused changes in source strength and infiltration rate).