Re-Side Tight, Ventilate Right

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ABSTRACT

Re-Side Tight, Ventilate Right explored the opportunity for improving energy efficiency while re-siding a home. Infiltration is recognized as one of the biggest energy wasters in single-family homes; the EPA states that in a typical American house infiltration accounts for 25 to 40 percent of the heating and cooling loads (EPA 2012). Considering that every year 1.1 million homes are re-sided (Harvard Joint Center for Housing Studies 2013) for maintenance and aesthetic reasons, the opportunity to improve energy efficiency through exterior air sealing while re-siding is promising.

Because much of the focus for air sealing a home has centered on the attic and basement, this study seeks to assess the impact air sealing the walls can have on the overall air leakage of a home in New Jersey. The hypothesis was that a re-siding job could incorporate a reduction in infiltration at a relatively low incremental cost, once contractors are made familiar with detailing a water resistant barrier (WRB) to function as an air barrier, and provide comparable results to attic and basement air sealing jobs. The goal of a 20% reduction in infiltration through re-siding a home was found to be readily attained at an incremental cost of about $1500 while contractors were learning the installation techniques and could conceivably drop to the material and testing costs only, about $500, as crews become more accustomed to air barrier detailing. Achieving effective air sealing at a low incremental cost aligns with a study by the National Renewable Energy Laboratories, which concluded that moderate air sealing in the area of a 20% reduction is much more cost effective than aggressive air sealing in the 50% reduction range (Casey & Booten, 2011).

The average reduction in infiltration among the study homes was 18.64%[1] with the largest drop being 37.8%. For all the study homes the only air sealing executed was the detailing of the WRB as an air barrier. No additional air sealing was done for the study results[2]. None of the study homes required the installation of mechanical ventilation as none of the homes were tightened to or beyond their Building Tightness Limit. The average annual projected heating and cooling savings was $105 and ranged from an increase of $6 to a savings of $252. The average savings to investment ratio for the re-side tight homes was 1.2 and ranged from -.10 to 3.4. Ultimately, the study found that when the WRB was installed to act as an air barrier, the result is a cost-effective infiltration reduction strategy in climate zones 4 and 5. Further research is needed to determine potential air leakage reduction of re-siding on homes that have already received air sealing to the ceiling and floor planes.

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[1] This average does not include House 2 where the team could not get a reading from the post-siding blower door test. The team tried to test the home several times on two separate site visits but

[2] Two homes had additional air sealing done in the attic after the completion of the study.

Introduction

Air sealing existing homes is commonly considered a cost-effective first step toward improved energy efficiency. Air sealing is an energy efficiency measure used in the two largest national existing home energy efficiency programs, the Weatherization Assistance Program, (WAP) and Home Performance with Energy Star (HPwES). In the WAP, 26 states out of 50 use a priority list for weatherization work rather than completing an audit. A priority list itemizes weatherization measures that computer analysis has shown to be cost-effective for typical housing stock. On most of these priority lists, air sealing is shown at the top of the measures ranked highest in priority (Kelso, 2012). This is also the typical finding from WAP energy audits. In HPwES, sealing air leaks is cited as among the most common home improvements executed in the program (EPA, 2012).

While it is understood that air sealing is an appropriate measure for existing homes, both the WAP and HPwES primarily air seal homes from the inside, as that is the most accessible area for the work. The WAP air sealing procedure focuses on basements, crawl spaces and attics. HPwES air sealing is also targeted at the “low holes” in basements and crawlspaces and “high holes” at the attic or roof. The Re-Side Tight approach focuses its air sealing on the exterior walls, beneath the siding.

Re-Side Tight Study Design and Execution

The Re-Side tight study was designed to test the change in infiltration rates of fifteen homes[3] after a water resistant barrier (WRB) was installed as an air barrier as part of a re-siding job. This required selecting appropriate WRBs to install, devising a strategy for mechanical ventilation when and if needed, finding reputable siding contractors with planned siding jobs to participate in the study, and establishing a testing protocol.

Water Resistant Barrier Materials

The Re-Side Tight team wanted to include commonly used residential WRBs as well as one liquid applied WRB. The WRB acts as a second line of defense to water penetration when water gets behind cladding. The re-side tight project limited itself to houses clad with siding and did not include any stucco or brick veneer homes[4]. Wood, fiber cement, and vinyl siding all use a WRB beneath them, installed over the home’s sheathing or existing siding if it is to be left in place. The WRBs had to be code approved air barriers and vapor permeable for use in the study.

The Re-Side Tight study did not intend to compare among different WRBs that are code-approved air barriers. It did intend to use WRBs that are commonly used in the marketplace and show contractors how to detail WRBs to function as air barriers.

The study used four WRBs: three house wraps, Tyvek, Rain Drop and GreenGuard Max; one rigid insulation underlayment, GreenGuard XP38; and one liquid applied air barrier, Sto Gold. These are all code approved air barriers. Tyvek, Rain Drop and GreenGuard are commonly used in the residential market. Sto Gold is less common in the residential market and more common for commercial applications. The team was eager to include a liquid applied WRB like Sto Gold as liquid applied WRB’s perform well in the commercial market.

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[3] The study ultimately included 17 homes.
[4] Three of the homes did have small masonry veneer areas.

Code Approved Air Barriers

WRBs that are code approved air barriers have been tested in accordance with the ASTM E2178 Standard Test Method for Air Permeance of Building Materials or through an evaluation report stating that the material is code compliant as an air barrier. This ensures that these materials have a sufficiently low air permeance and can be part of an effective air barrier system. Not all WRBs are code approved air barriers. Perforated home wraps are not air barriers, precisely because of their perforation, nor is 15# felt, commonly used under siding.

Vapor Permeability

The team wanted vapor permeable WRBs to ensure that wall drying could occur to the outside when conditions allowed. For new construction, the relative importance of a WRB's vapor permeability has been questioned, since most common wall sheathings currently used, such as plywood and oriented strand board, are only semi-permeable. However, for the re-side tight homes, the existing sheathing was unknown. Therefore staying with a vapor permeable WRB was considered a preferable strategy.[5]

WRB Industry Partners

After considering these criteria, the principal investigator contacted DuPont® (Tyvek), Pactiv (Rain Drop, GreenGuard Max and Green Guard XP38) and Sto® (Sto Gold) regarding study participation and support. All three companies committed to the project from the outset and all agreed to provide technical support and discounted or entirely donated materials. Technical support consisted of printed material appropriate for use in the field and direct on-site guidance.

Table 1. Re-Side Tight WRBs

WRB	Code approved air barrier?	Vapor permeability
GreenGuard Max	Yes	16 perms
GreenGuard XP38	Yes	1 perm
Rain Drop	Yes	8 perms
Sto Gold	Yes	5 perms
Tyvek	Yes	58 perms

Mechanical Ventilation

If homes in the study were tightened beyond their building tightness limit (BTL), the team would have to install mechanical ventilation. The BTL is a threshold of air exchange below which the maintenance of acceptable indoor air quality is potentially compromised (WAPTAC, 2014). The study required a mechanical ventilation solution that was relatively easy to install in

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[5] Despite this original intent, one re-side house did use a vapor semi-permeable WRB, Green Guard XP38. To ensure that its use would not cause potential moisture issues, the study team ran a hygrothermal analysis on the wall assembly of this house. The modeling confirmed that use of the Green Guard XP38 would not increase the chance of condensation in the wall assembly.

existing homes, provided balanced ventilation, and was energy efficient. Panasonic's WhisperComfort spot energy recovery ventilator (ERV) met the criteria. Energy Recovery Ventilators exhaust stale air and replace it with outdoor air. Conditioned indoor air passes by the incoming outdoor air and tempers it. As an ERV, it also transfers some of the moisture from the more humid air stream. This is done with very little mixing of the two air streams. The project lead met with Panasonic and they agreed to provide technical support and WhisperComfort spot ERVs for the re-side tight homes as needed. Ultimately none of the homes in the study needed additional mechanical ventilation. According to the manufacturer, in the New Jersey market, the mechanical ventilation described here would cost about $300 in equipment and $600 in labor.

Recruiting Siding Contractor Participants

The Re-Side Tight team looked to several sources for potential contractor participants including:

- NJ Chapter members of the National Association of the Remodeling Industry (NARI)
- Vinyl Siding Institute (VSI) certified installers,
- NJ Home Performance with Energy Star (NJHPwES) contractors
- Contractor contacts from the industry partners, DuPont (Tyvek), Pactiv (RainDrop, GreenGuard) and Sto (Sto Gold).

The team generated an informational flyer for potential contractor and distributed it to the above mentioned groups. Originally, the intent was that five or more contractors would participate in the study, each having a maximum of three jobs. As the study progressed, the team saw the benefits of contractors having several projects, allowing them to increase their understanding of the air barrier installation. They became more adept with each home by refining their field techniques for the desired result. Ultimately, four contractors completed the 17 homes in the study.

Infiltration Testing

A Minneapolis Blower Door and was used for the before and after infiltration testing of the re-side tight homes. Two sets of equipment were used, but each individual home was tested with the same blower door for the pre- and post-measurements. The team performed blower door testing using the Energy Conservatory Tectite 4.0 Building Airtightness Test Analysis Program, and depressurized each home to -50 Pascals (Pa)[6] using a calibrated blower door fan installed in the home's front door. All exterior doors and windows are closed for this test as well as fireplace dampers (where present). As the fan pulls air out of the home to depressurize it to negative 50Pa, air is forced through all the cracks and leaks in the building envelope. The blower door measures the airflow through the fan and the airtightness of the building envelope in CFM50 (cubic feet per minute at -50 Pascals). Tighter houses require less air flow to get to -50Pa and so have lower CFM50 readings.

[6] A Pascal is a unit of pressure. Fifty Pascals is equivalent to .2inches of water column and approximates a 20 mph wind (Community Housing Partners 2012)

The Re-Side Tight homes' envelope leakage in CFM50 range from 1848CFM50 to 7026CFM50 with an average of 4117CFM50 overall, and 3671CFM50 when excluding House 2.[7] If we refer to common air sealing guidelines which recommend air sealing for CFM50 readings of about 2000 or greater (Krigger & Dorsi, 2009), air sealing would be recommended for all the homes in the study. Figure 1 below shows the pre-siding CFM50 measurements for the 17 homes in the study.

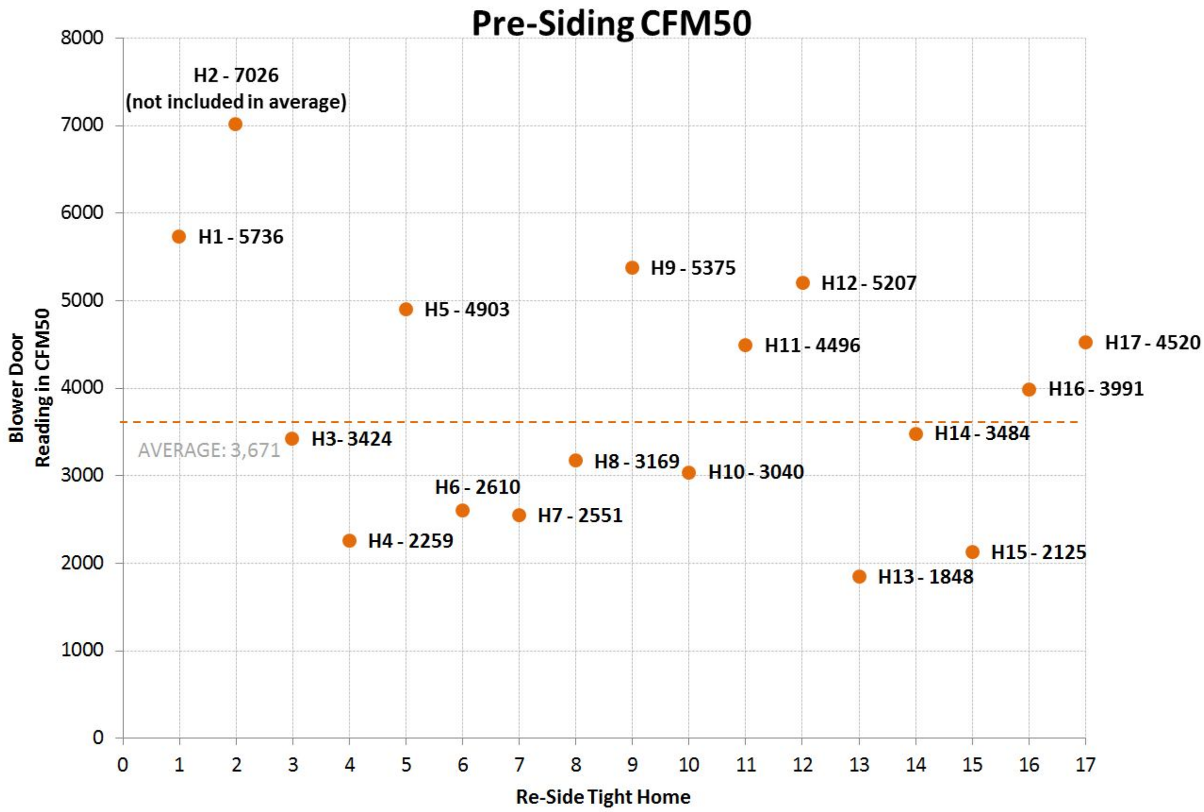

Figure 1. Pre-siding CFM50.

Air changes per hour at 50 Pascals (ACH50) is another measure of house leakage that can be more useful than CFM50, as it accounts for a home's volume. Air Changes per Hour at 50 Pascals is the number of complete air changes per hour the house will have when 50 Pascals of pressure are applied. The calculation to convert the CFM50 blower door number to ACH50 is:

ACH50 = (CFM50x60)/house volume.

[7] There was no post-siding test data for House 2. The team was not able to conduct the test using Tectite's "cruise control" mode, where the software controls the fan speed. The team then ran the test manually, but kept getting manometer error messages. After contacting technical support and not being able to resolve the issue, the team scheduled another test date. The team returned for re-testing one week later. The second day of testing also resulted in manometer error messages. The equipment had been used successfully on another home between the first and second day of testing at House 2, so the team concluded that the blower door was not the problem. The team planned to return to the house for a third testing attempt, and to perform supplemental air sealing between the attic and the living space. Unfortunately, the homeowner did not agree to the supplemental air sealing and as such, the air sealing and testing was not performed.

The re-side tight houses ACH50 numbers are shown in Table 2 and range from 8.34 to 29.09 ACH50.

Table 2. Study home existing infiltration rates

Existing Infiltration Rates		
House	Exist CFM50	ACH50
1	5736	17.42
2	7026	29.09
3	3424	13.56
4	2259	10.52
5	4903	11.49
6	2610	9.34
7	2551	14.32
8	3169	16.12
9	5375	15.15
10	3040	17.21
11	4496	16.86
12	5207	29.04
13	1848	11.04
14	3484	14.33
15	2125	8.34
16	3991	18.97
17	4520	17.09
Average	3671	15.1

WRB Installations

After completion of the pre-siding blower door tests, the WRB installations began. The installations occurred from August 2011 through July 2012. Ten homes had Rain Drop house wrap installed, two homes used Tyvek house wrap, one used GreenGuard XP38 siding underlayment, one used GreenGuard MAX home wrap and three homes had the Sto Gold liquid applied WRB installed. The contractors had varying degrees of difficulty installing the different WRBs as air barriers. On-site support was typically provided for a few hours at each home, until the crews felt comfortable getting the details right. The images below show an example Re-Side Tight home once its existing siding was stripped, the WRB was installed and the completion of the new siding.

Figure 2. Example WRB Installation. Photos, Liaukus, C.

Post Siding Infiltration Rates

Table 3 provides a summary of the pre and post siding infiltration rates and the percentage reductions for each house.

Table 3. Pre and post-siding change in infiltration

House	Pre-Siding ACH50	Pre-Siding CFM50	Post-Siding ACH50	Post-Siding CFM50	% Change	Annual Savings	SIR
House 1	17.4	5736	13.9	4587	-20.03%	$109	1.4
House 2	29.1	7026	NA	NA	NA	NA	NA
House 3	13.6	3424	8.1	3385[8]	-40.27%	$34	.47
House 4	10.5	2259	8.6	1838	-18.64%	$82	1.0
House 5	11.5	4903	11.6	4955	1.06%	-$6	-.10
House 6	9.3	2610	9.3	2600	-0.38%	$1	.01
House 7	14.3	2551	11.9	2115	-17.09%	$38	.54
House 8	16.1	3169	15.7	3090	-2.49%	$17	.22
House 9	15.2	5375	13.6	4814	-10.44%	$51	.66
House 10	17.2	3040	10.7	1891	-37.80%	$220	2.7
House 11	16.9	4496	12.0	3194	-28.96%	$252	3.1
House 12	29.0	5207	22.3	4007	-23.05%	$242	3.2
House 13	11.0	1848	10.9	1821	-1.46%	$3	.03
House 14	14.3	3484	11.8	2876	-17.45%	$122	1.5
House 15	8.3	2125	5.6	1426	-32.89%	$136	1.7
House 16	19.0	3991	14.4	3035	-23.95%	$85	1.1
House 17	17.1	4520	12.9	3417	-24.40%	$98	1.3
AVG	15.1	3671	12.1	2982	-18.64%	$105	1.2

The infiltration reduction among the Re-Side Tight homes ranged from an increase of 1% to a decrease of 40.27% with an average of 18.64%. Figure 3 shows the data in a graphic form.

[8] CFM50 results for house 3 calculated from the change in ACH50 would be 2051CFM50. This house had an addition constructed along with the re-siding work.

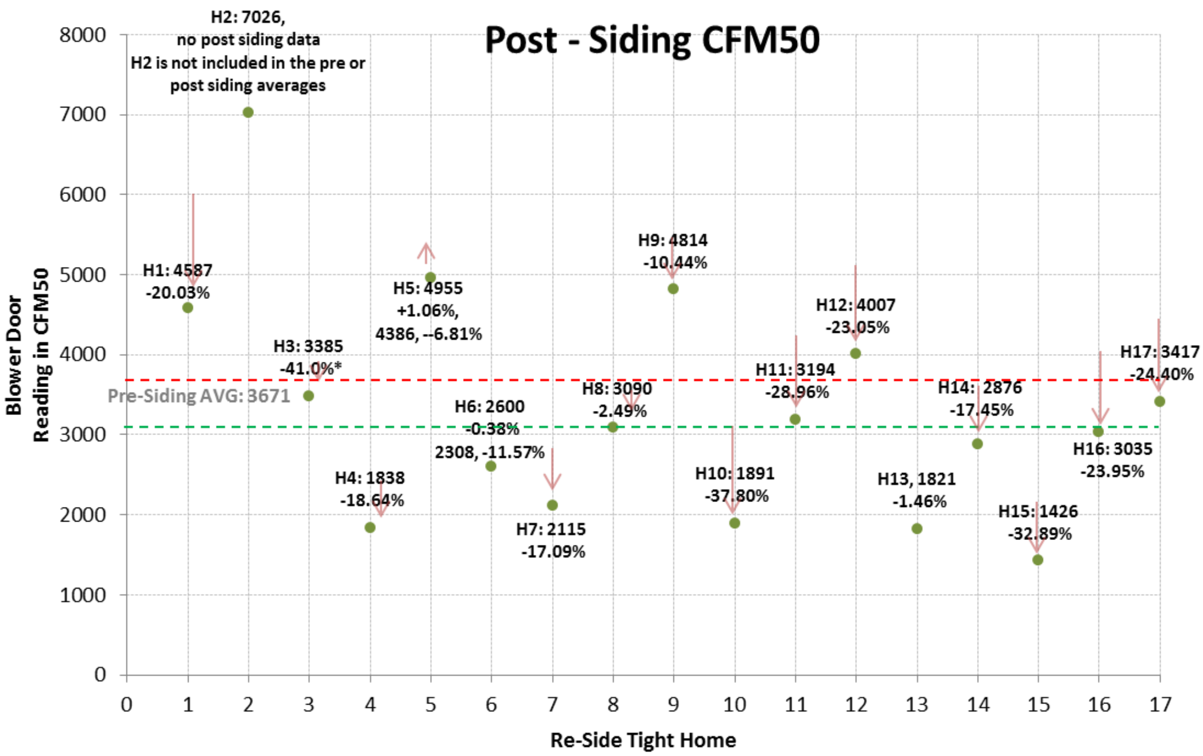

Figure 3. Pre and post infiltration rates.

Among the study homes, four had less than a 2.5% reduction in infiltration, houses 5,6,8 and 13. Among the four homes, two issues emerged that appear to have influenced the suboptimal results:

Improper WRB Installation – Houses 5, 8 and 13

In houses 5 and 8, the WRB was not installed correctly in key locations. In house 5 the window heads were not properly detailed and in house 8 the WRB was not continuously sealed at the base of the sheathing. In house 13, a liquid applied WRB was installed on existing shingles. While originally the team was told the shingles would be an appropriate substrate, subsequent technical support personnel stated that it was not a good application[9].

New Vented Roof – Houses 5 and 6

In houses 5 and 6, the existing roofs were unvented. As part of the siding jobs, new vented roofs were installed. As such leakage between the house and the attic may have been exacerbated by the additional venting.

The remaining 14 homes had infiltration reduction results in the expected range.

[9] The same contractor used the liquid applied WRB on two other homes in the study (House 15 and House 17) with greater infiltration reduction percentages (32.39% reduction and 24.4% reduction respectively).

Energy Use Projections

The Tectite software used to run the blower door testing also provides the estimated cost of air leakage. This estimate was used to determine the projected energy savings (or increase) because of the WRB/air barrier installation. For each house, pre and post blower door tests were compared.

These results were crosschecked with a multiplier derived from an evaluation of Ohio's Home Weatherization Assistance Program (HWAP). In this evaluation, the energy savings achieved in over 2,000 single-family homes in the HWAP were assessed using weather-normalized energy use based on utility data. Analysis of this data led to the finding that for each CFM50 reduction, 0.08 – 0.09 therms were saved annually among the homes in the study. (Blasnik, 1999) The Re-Side Tight team contacted the author of the Ohio evaluation study and found that for New Jersey's climate, each CFM50 reduction could result in a savings of 0.07 therms annually. The author also noted that for cooling, savings of about 10 kWh/100 CFM50 reduction may be possible for a home with a SEER 11 central AC, uninsulated basement ducts, and a cooling set point of 74F[10].

Methods and Calculations for Results

Building area and volume. The building square footage and volume were calculated from field measurements of each home.

CFM50 and ACH50. Cubic feet per minute at 50 Pascals (CFM50) measurements were taken using a blower door and following the standard testing protocol as set forth by the Energy Conservatory (The Energy Conservatory 2011).

Air changes per hour at 50 Pascals are calculated by multiplying CFM50 by 60 minutes per hour and dividing that by building volume (WAPTAC 2011).

Combustion safety testing. The team performed combustion safety testing at the re-side tight houses to ensure that combustion appliances were venting properly, even under worst case conditions and that during combustion carbon monoxide levels did not exceed safe limits. This health and safety measure should be performed whenever air-sealing work is executed in existing homes.

Building Tightness Limit (BTL). The building tightness limit (BTL) was calculated using the DOE Weatherization Program's calculation:

BTL= (.35xVOLUMExN)/60.

The N factor accounts for building height and exposure to wind and is determined based on an n-Factor Table from Lawrence Berkeley Laboratory. (WAPTAC 2011)

[10] The total cooling use per year would be about 2100 kWh in a 2000 square foot home. The savings would be lower in a home that is cooled less consistently throughout the summer. (Blasnik, 2012)

Estimated Savings

Estimated savings were derived using Tectite™4.0 Building Air Tightness testing software. For natural gas a price of $1.18 per hundred cubic feet (ccf) was used, based on average prices in New Jersey in 2012 (U.S. Energy Information Administration 2013). For homes heated with fuel oil, a price of $4.10 per gallon was used, based on New Jersey's average fuel oil price in 2012. (U.S. Energy Information Administration 2013). Cooling savings were based on a kilowatt/hour cost of $0.12/kWh based on utility bill data.

Savings to Investment Ratio (SIR)

A savings to investment ratio is calculated by dividing an energy conservation measure's lifetime savings by the initial investment (WAPTAC 2009). The discount rate for the SIR calculation is 3% (NIST, 2013). The Weatherization program requires an SIR of one for a measure to be implemented. The measure cost assumed for the SIR was $1,500. This is based on the re-side tight contractors who estimated that they spent 10 – 15 extra minutes per window, or about five additional hours of labor for the windows on each re-side tight home. They also spent about three to seven additional hours for taping joints between courses of building wrap and at the top and bottom of walls. Total additional time was between 5 and 15 hours and declined with each successive job. The material costs were calculated only for the additional sealants, flashings and tapes. The WRB material itself would ordinarily be purchased for a siding job and so was not included in the price difference. While manufacturers recommend that flashing, tape and sealants be used in specific locations with their products, many contractors do not. As such, those items were considered additional costs. Specific costs were derived from material costs and average amounts used among the re-side tight homes.

Table 4. Materials, Labor and Testing Costs

Re-Side Tight Average Material, Labor and Testing Costs	
Contractor tape	$30
Flashing	$175
Sealant	$40
Labor	$1,000
Combustion Safety Testing	$250
Total increase	Approximately $1500

Contractors may increase this cost with an overall markup. For the purpose of the SIR calculations, $1500 was used as the initial investment. The cost may ultimately be lower or higher. Over time it is anticipated that the labor costs will reduce to near zero, especially considering the 2012 International Energy Conservation Code® (IECC) requirement for a continuous air barrier in the building envelope (PNNL 2012). While this code applies to new construction and additions, installing an intact air barrier will become a more common practice and requirement among siding contractors that work on both new and existing homes. The measure lifetime was set to 20 years, the typical siding warrantee.

Cost Effective Infiltration Reduction

A common post weatherization infiltration reduction goal is 20%. This infiltration reduction was achieved in twelve of the seventeen study homes, and lessons learned from this research could make that level of reduction more reliably met in more homes. An SIR of one or greater was achieved in nine of the 17 homes. With the $1500 price point for the re-side tight approach, annual savings of $75 or more is required to achieve an SIR of "1".

Scaling Up the Re-Side Tight Approach

Contractor Training

To make the re-side tight approach more widespread, siding contractors need to be trained in the installation of the WRB as an air barrier. As part of the re-side tight study, the project team created online contractor training, as seen in Figure 4. This online training can serve as a standalone or supplemental resource for contractors to learn the re-side tight techniques.

Figure 4.Re-Side tight training website.

Potential Market

One of the clear benefits of the re-side tight approach is the broader opportunity for greater energy efficiency in existing homes. Considering New Jersey alone, in 2009 the NJ HPwES program made energy efficiency upgrades to 3,310 homes (NJ Clean Energy Program 2012). There were 1,136,000 re-siding jobs done in the US in 2009. New Jersey has approximately 2.6 percent of the housing units in the United States. If the 2.6 percent is multiplied by the total U.S. re-siding jobs, the sum is 28,400 New Jersey re-siding jobs. If even one in ten of those homes is re-sided using the re-side tight method, the number of homes with infiltration reduction measures being implemented would nearly double.

If siding contractors know how to quantify the benefits of exterior air sealing when re-siding, they could potentially take advantage of Clean Energy Program rebates through the NJ HPwES program. The re-side tight approach could also be a stand-alone incentive program, whereby utilities or HPwES provide an incentive for installing an air barrier while re-siding if performance or prescriptive installation measures are met.

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