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Re-Side Right: A Systems Approach to High-Performance Re-Siding Projects

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Re-Side Right: A Systems Approach to High-Performance Re-Siding Projects

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Principal Investigator:
Christine Liaukus, R.A.
Center for Building Knowledge at the New Jersey Institute of Technology
University Heights
Newark, NJ 07102

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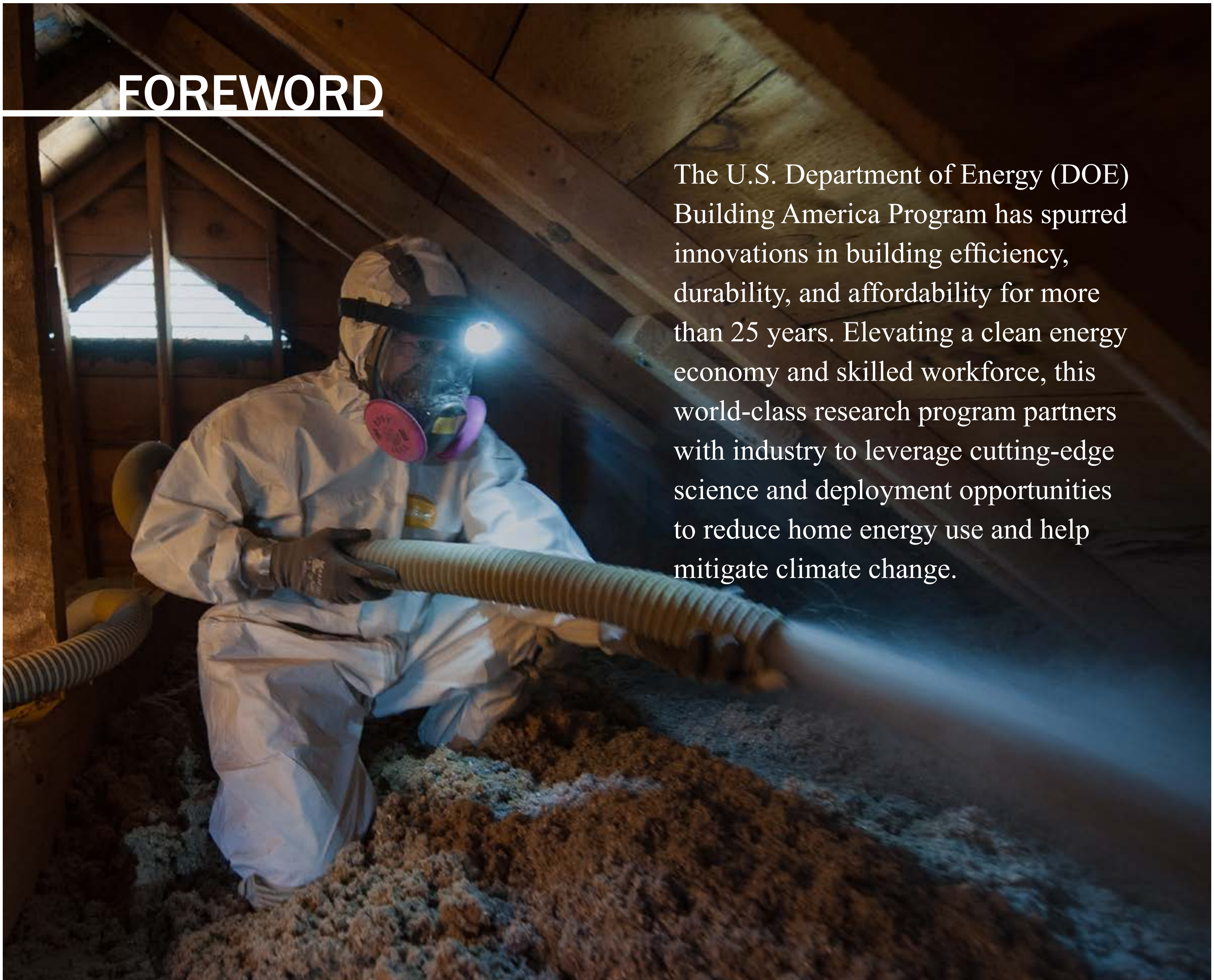
The work presented in this EERE Building America report does not represent performance of any product relative to regulated minimum efficiency requirements.

The laboratory and/or field sites used for this work are not certified rating test facilities. The conditions and methods under which products were characterized for this work differ from standard rating conditions, as described.

Because the methods and conditions differ, the reported results are not comparable to rated product performance and should only be used to estimate performance under the measured conditions.

FOREWORD

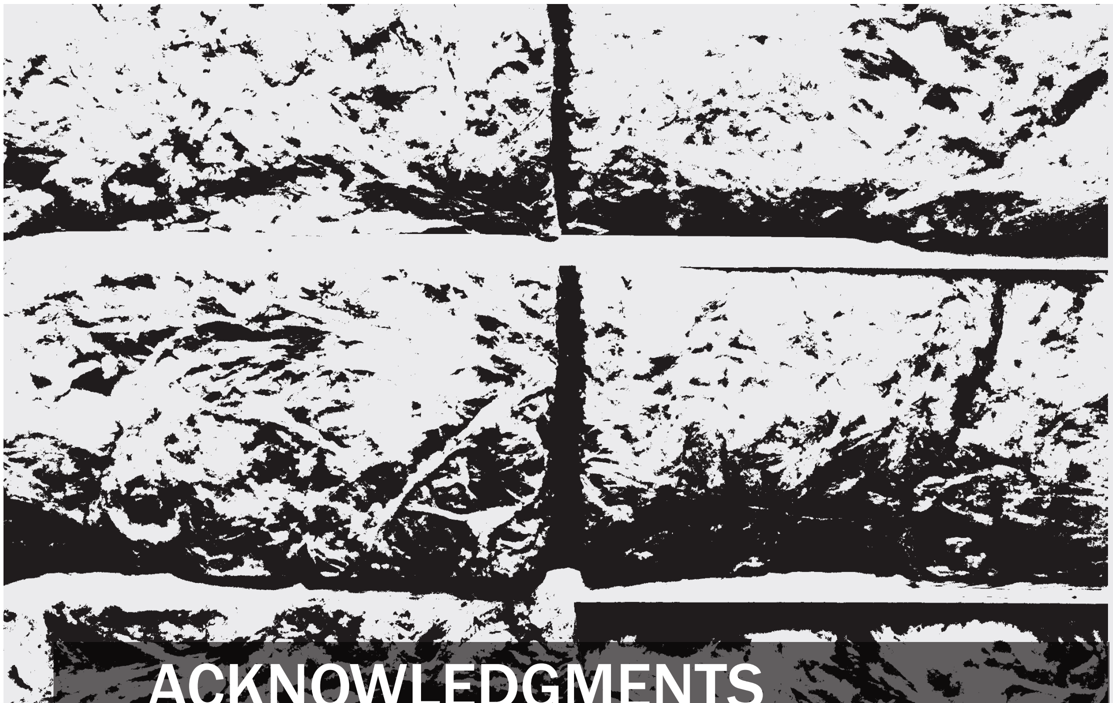


The U.S. Department of Energy (DOE) Building America Program has spurred innovations in building efficiency, durability, and affordability for more than 25 years. Elevating a clean energy economy and skilled workforce, this world-class research program partners with industry to leverage cutting-edge science and deployment opportunities to reduce home energy use and help mitigate climate change.

In cooperation with the Building America Program, the New Jersey Institute of Technology team is one of many Building America teams working to drive innovations that address the challenges identified in the Program's Research-to-Market Plan.

This report, *Re-Side Right: A Systems Approach to High-Performance Re-Siding Projects*, explores adding one inch of rigid insulation detailed as an air and water-resistive barrier as part of a standard re-siding project.

As the technical monitor of the Building America research, the National Renewable Energy Laboratory encourages feedback and dialogue on the research findings in this report as well as others. Send any comments and questions to building.america@ee.doe.gov.



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LIST OF ACRONYMS

DOE	U.S. Department of Energy
NJIT	New Jersey Institute of Technology
SIR	savings-to-investment ratio

EXECUTIVE SUMMARY

Problem Statement

Every year more than 1 million homes in the United States are re-sided (1,034,000 in 2019) (Harvard Joint Center for Housing Studies, 2021) without being optimized for reducing air leakage and/or adding insulation. Compounding the problem is the fact that re-siding jobs typically occur only about once every 25 years, with the result that current practice essentially locks in energy inefficiencies that will not be remedied for decades to come.

This led the New Jersey Institute of Technology's (NJIT's) Building America research team to propose improving the efficiency of a home while it was being re-sided with the installation of an insulating layer that also serves as an air barrier and water resistive barrier, known as Re-Side Right. Instead of trying to "push" efficiency measures as stand-alone projects undertaken for energy reasons alone (as done in the majority of utility-based energy efficiency programs in the country), the Re-Side Right approach layers energy efficiency upgrades onto home improvement projects that are happening anyway.

Research Questions

The NJIT team designed the Re-Side Right project to answer the following research questions:

- Will the addition 1" of continuous insulation detailed as a water resistive barrier and air barrier to a standard re-siding job (Re-Side Right) prove to be attainable at a reasonable incremental cost?
- Will durability risks be addressed with best practice installation methods?
- Will the assembly adequately manage moisture?
- Will the Re-Side Right approach be a value-added package that re-siding customers are willing to pay for?
- Will re-siding contractors readily learn the Re-Side Right approach and want to offer it to their customers?

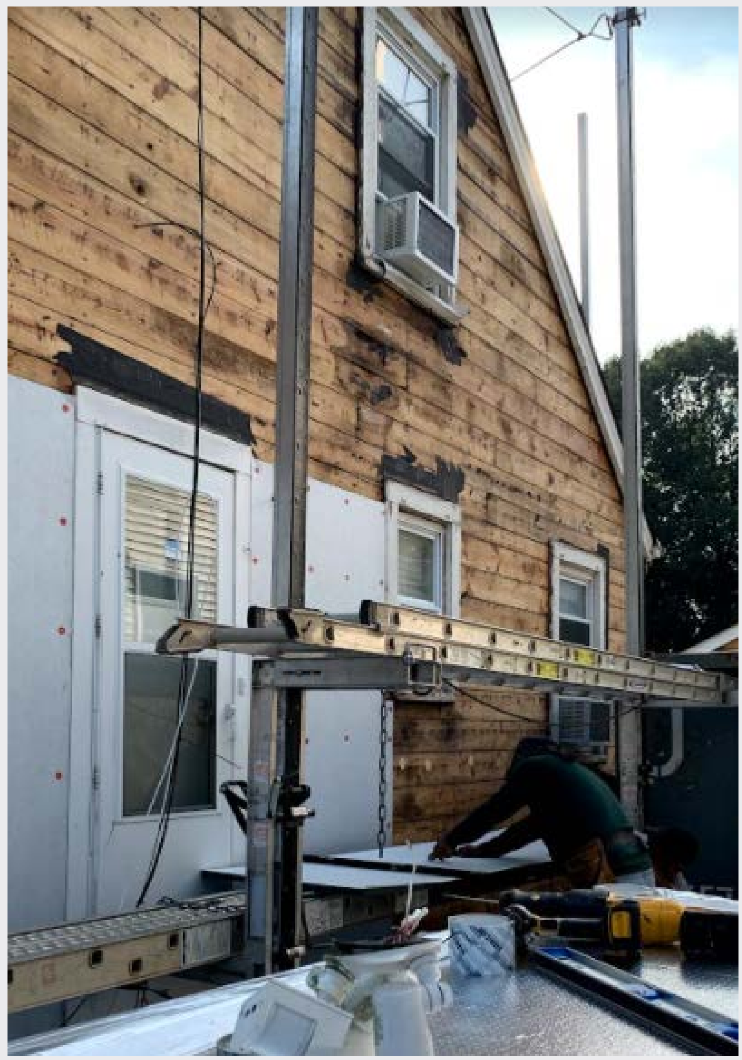
Project Objectives

The objectives of this project were to test and validate the incorporation of an air barrier and 1" of continuous thermal insulation into standard re-siding jobs to create a more durable, better performing envelope as part of a retrofit project that homeowners will do anyway.

Methods of Data Gathering

This project tested the Re-Side Right approach by re-siding 10 houses with the incorporation of 1” of rigid insulation detailed as a water resistive barrier and air barrier through the following steps.

1. The NJIT team sought out and selected siding contractors working in climate zones 4 and 5 that typically execute standard re-siding jobs. The contractors were then trained how to Re-Side Right via an online session.



2. Once trained, the contractors identified candidate siding jobs with a focus on “typical” re-siding projects that were broadly representative of re-siding jobs in northern New Jersey in terms of type, age and condition of the home, siding materials, and underlying structure.

3. NJIT performed building diagnostics and documented existing conditions to support costing data and energy modeling of the selected homes. Pre-siding condition documentation included combustion safety testing, blower door testing, infrared scans (when conditions allowed), building measuring, and documentation to support energy modeling.

4. Oak Ridge National Laboratory installed dataloggers at one Re-Side Right house to measure the moisture accumulation in the assembly layers and calibrate a hygrothermal model of the monitored assembly and other assembly configurations.

5. The contractors installed Re-Side Right on 10 homes. NJIT observed construction at the siding jobs. Construction observation included photo and video documentation of the process and fielding questions from contractors.

6. Once the jobs were completed, the NJIT team performed blower door and combustion safety tests. NJIT also performed infrared scans of each home's exterior (as conditions allowed), documenting the reduction in thermal bridging through the envelope.

7. Using pre- and post-siding test data, including infiltration rates and the change in wall R-value, NJIT modeled the change in projected energy use of each house in the project from the increased wall R-value and the new air leakage measurements.

8. NJIT then determined the project cost based on the time and materials data collected for each re-siding job and calculated savings-to-investment ratios (SIRs) for the 10 installed Re-Side Right packages using the cost and modeled energy savings.

9. The NJIT team created a survey for the Re-Side Right homeowners to gauge their response to and acceptance of the retrofit approach used during the project.

10. Finally, NJIT created educational material on the implementation of Re-Side Right for contractors.

Findings

At the conclusion of the study, we found:

- An average drop in air infiltration of about 9%.
- An average modeled yearly home energy use reduction of about 9%.
- The monitored Re-Side Right assembly stayed below the moisture durability threshold.
- The simulated Re-Side Right assembly indicated no moisture durability issues with the existing wall construction before and after the addition of an inch of exterior rigid foam insulation.

- An incremental cost increase of $1.07 per square foot of facade in materials[1] and 8–16 person hours of labor.
- Consumers are price sensitive, so incentives such as the Inflation Reduction Act for energy efficiency improvements or the inclusion of exterior insulation as part of a Home Performance with ENERGY STAR® package may be necessary for a successful Re-Side Right program.
- Contractor training is key to control costs and ensure quality.
- Material availability can cause delays.[2]
- Siding contractors are very capable of installing the Re-Side Right package.

1 Vinyl siding with fanfold was calculated to be $20.74 per square foot in materials: ¼" leveling rigid insulation (.30), self-adhered flashing (.44), vinyl siding (20.00). Vinyl siding with the Re-Side Right approach was $21.81 per square foot: Neopor insulation (.94), construction seam tape (.09), self-adhered flashing (.44), liquid flashing (.33), cap nails (.01), vinyl siding (20.00).

2 This was likely exacerbated in this study by COVID-19 supply chain issues.

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1 Introduction

1.1 Problem Statement

Every year more than 1 million homes in the United States are re-sided (1,034,000 in 2019) (Harvard Joint Center for Housing Studies, 2021) without being optimized by reducing air leakage and/or adding insulation. Compounding the problem is the fact that re-siding jobs typically occur only once every 25 years or so, with the result that current practice essentially locks in energy inefficiencies that will not be remedied for decades to come. The Re-Side Right research aims to demonstrate how to harness the opportunity re-siding jobs provide for building performance improvement by incorporating 1" of rigid insulation detailed as a water resistive barrier and air barrier. The impact of this approach on the siding/retrofit industry could be significant; if even 1 in 10 re-sided homes takes this approach, over 100,000 homes could have improved performance.

Re-siding contractors typically install water resistive barriers as part of a re-siding project but with little regard to optimizing water resistive barrier performance as an air barrier. Added insulation is typically used as an underlayment to provide a level nailing surface and is too thin (at ¼" or less) to add much insulating value. Re-Side Right combines the air/thermal/water barrier capacity of rigid insulation and liquid flashing so that siding contractors can re-side with a comparable amount of labor to a standard re-siding job, while improving building performance.

1.2 Objectives of the Study

While the energy impacts of effective air sealing and continuous exterior insulation are both well-established for new construction, the potential for incorporating these efficiency upgrades into existing homes is less researched. Water resistive barriers are typically installed as part of a standard re-siding job but, as the New Jersey Institute of Technology's Center for Building Knowledge has observed, these water resistive barriers are not typically detailed to serve as air barriers, and flashing around windows is often poorly executed. Exterior insulation that gets installed is characteristically thin and not sealed at the joints. The Re-Side Right project team addressed this gap and tested the potential for combining air sealing and continuous exterior insulation in standard re-siding jobs, specifically with respect to real-world issues of constructability, cost-effectiveness, and the energy impacts of these strategies at the whole-house level.

The Re-Side Right project aimed to use the build out portion of the project to demonstrate whether this form of "opportunistic retrofit"—catalyzed by new insulation and flashing products—is both technically feasible and potentially economically compelling.[1]

The Re-Side Right build out was documented so that actionable technical guidance could be created from it for contractors and energy efficiency programs across the United States.

[1] This is discussed further in the Results section.

1.3 Research Questions

- Will the addition of an air barrier and continuous insulation to a standard re-siding job (Re-Side Right) prove to be attainable at a reasonable incremental cost?
- Will durability risks be addressed with best practice installation methods?
- Will the assembly adequately manage moisture?
- Will the Re-Side Right approach be a value-added package that re-siding customers are willing to pay for?
- Will re-siding contractors readily learn the Re-Side Right approach and want to offer it to their customers?

These research questions address the cost-effectiveness, marketability, and implementation merit ability of the Re-Side Right initiative. Without an adequate impact on energy savings, the cost for materials and labor needed for the Re-Side Right initiative will not be justifiable within a reasonable payback period. If the Re-Side Right approach doesn't manage moisture, wall durability will be compromised. If homeowners are not convinced that the Re-Side Right approach is a desirable upgrade to their siding project, there will not be market demand. If the risks inherent to adjusting the building envelope are not identified and addressed, contractors and customers will not promote the propagation of the approach. And finally, if siding contractors do not incorporate the Re-Side Right approach with relative ease and the potential to gain more customers and/or increase profits, they will not want to make the shift or offer it to their customers.

1.4 Literature Review/Previous Work

The Center for Building Knowledge completed a grant-funded project in 2013 called "Re-Side Tight/Ventilate Right" (Center for Building Knowledge, 2013). This project analyzed opportunities for improved energy efficiency when homes are being re-sided, specifically in the area of infiltration reduction, and focused on detailing and installing water-resistive barriers such that they could serve as air barriers as well. Industry partners included DuPont, Pactiv (now Kingspan), Sto, and Panasonic. The project air sealed 17 homes from the exterior while they were being re-sided. This was done at a modest incremental cost per house, with typical reductions in infiltration of 20% and up to 38%, with calculated whole-house energy savings of between 3% and 5%.[2] Re-Side Tight also demonstrated that siding contractors were very capable of incorporating energy efficiency measures into their work as long as proper training was provided and the potential for increased revenue was present. The Center for Building

[2] The savings calculated in the Re-Side Tight study were based on projections from The Energy Conservatory Tectite 4.0 Building Airtightness Test Analysis Program and cross-checked with a multiplier derived from an evaluation of Ohio's Home Weatherization Assistance Program. The savings in the current study are from BEopt™ 2.8.

Knowledge proposed Re-Side Tight as a pilot program for the New Jersey Clean Energy Program, but it was not adopted.

The Re-Side Tight project served as the conceptual foundation for the Re-Side Right initiative. Adding insulation and reducing infiltration could up our projected savings. During the Re-Side Tight project, one home did have rigid insulation installed as the water resistive barrier. At that time the contractor had difficulty using self-adhered flexible flashing with the rigid insulation at window openings. That difficulty influenced the team exploring the use of liquid flashing for Re-Side Right, which was anticipated to simplify the installation.

More recent background work included research on the innovative water resistive barrier and rigid insulation materials in the marketplace. Not all rigid insulation is a water-resistant barrier and/or vapor permeable. Having both properties in one material is less common. This is usually achieved by perforating the thin plastic layer over the insulation. The perforation has to be done in a way that does not overly compromise the material's water resistive properties. The Neopor product used for Re-Side Right, NEOPOR ThermaPlus water resistive barrier + continuous insulation + air barrier is an R-5 material with a vapor permeance of >1, making it a Class III vapor barrier. Combining the step of house wrap and insulation as one product is key to the success of Re-Side Right.

2 Methodology

2.1 Research Sequence

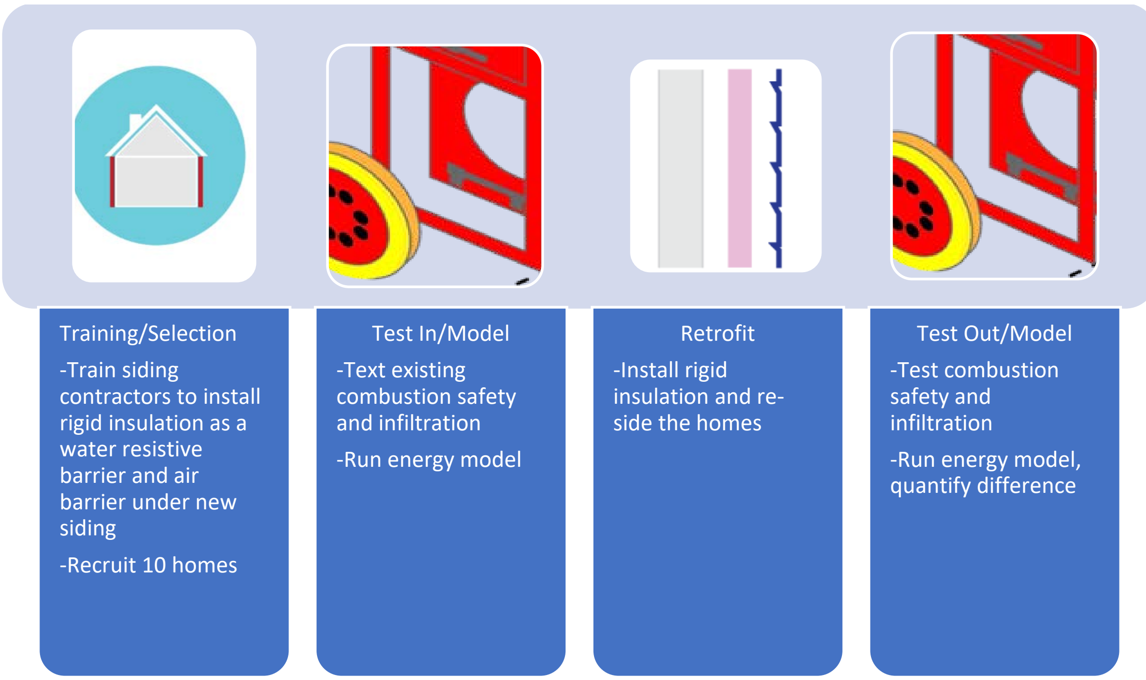


Figure 1. Re-Side Right research sequence

The Re-Side Right research was conducted as follows:

2.1.1 Contractor Screening, Selection, and Training

NJIT worked with contractors in climate zones 4 and 5 that were relatively local to Newark, NJ. Proximity to Newark allowed NJIT architecture students to participate in the field observation and data collection tasks of the research. We looked for contractors that were siding specific, not general contractors or energy efficiency specialists. We worked with the Vinyl Siding Institute and the Better Business Bureau as contractor sources. NJIT emailed and/or called siding companies that had positive Better Business Bureau records and/or Vinyl Siding Institute certifications. Unfortunately, cold calling and emailing were not successful. Ultimately three contractors participated in Re-Side Right. One had been a Re-Side Tight participant previously in 2013, the second had a client that read about the NJIT study through a university press release and contacted the Center for Building Knowledge, and the third contractor was referred by a material supplier.

Re-Side Right training was offered to the project contractors online. The training addressed the building science supporting Re-Side Right, the performance advantages of the Re-Side Right approach, and the installation methods, leveraging partner installation guides and technical information. NJIT enlisted the help of architectural students at the university to help create the training content and collaborated with BASF on its development. NJIT and BASF presented the training material during an hourlong webinar. The training was augmented with on-site guidance from the NJIT team and representatives from BASF.

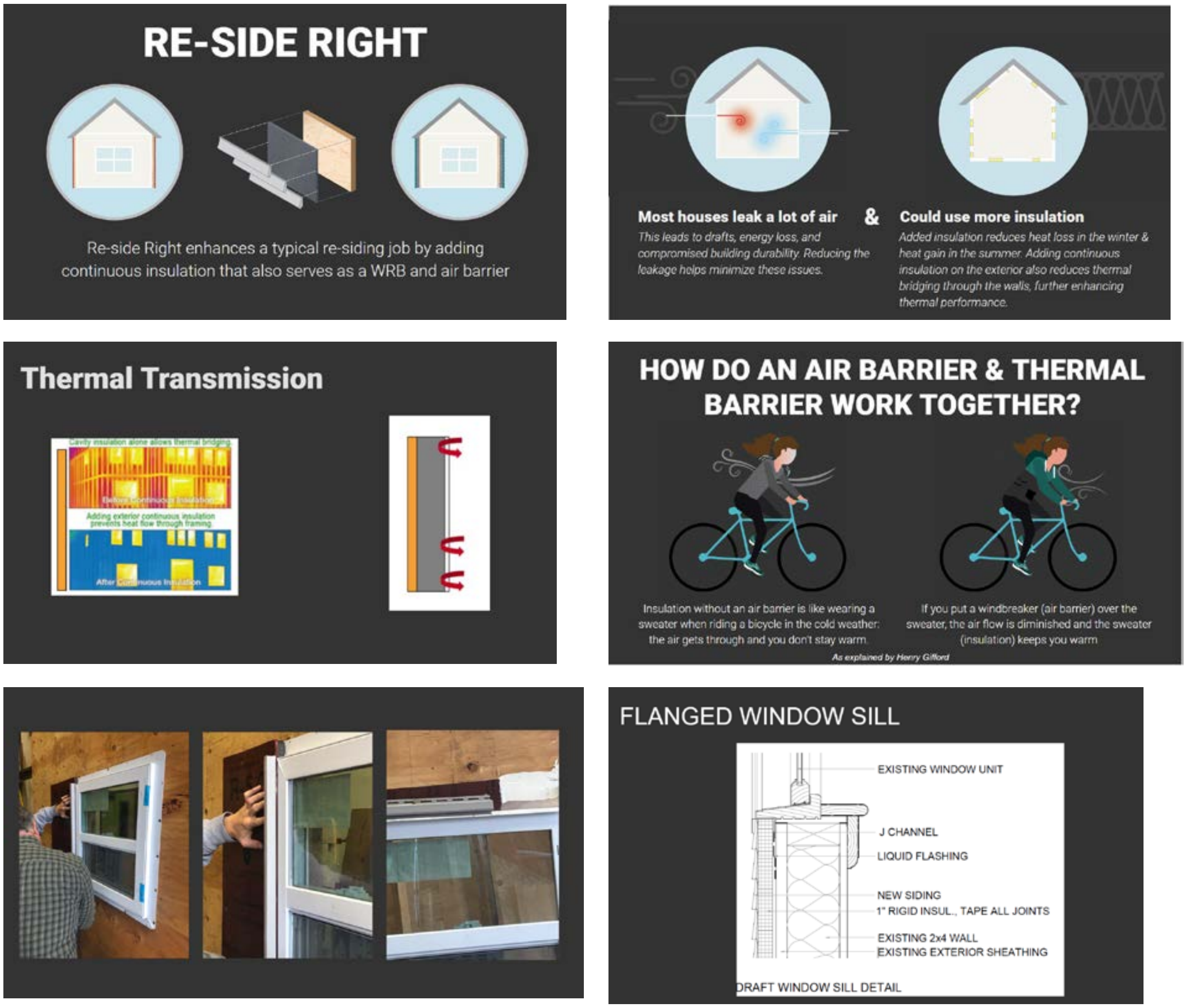


Figure 2. Example slides from contractor training webinar

2.1.2 Test House Recruitment, Selection, and Participation

Each contractor was asked if they had a client or potential client that might be interested in the Re-Side Right study. Contractors were told that the focus was on "typical" re-siding projects that were broadly representative of re-siding jobs in terms of age and condition of the home, siding materials and underlying structure, etc. Home age was anticipated to span anywhere from the late 1800s to the 1970s. These homes were built before the DOE Building Energy Codes program existed, presumably having suboptimal insulation and air sealing. Homes had to be in fairly good condition, so that the project was not bogged down with potential code compliance issues that might arise with dilapidated structures. Homes had to have existing siding that was primarily intact. Windows had to be in good working condition and were to remain (window replacement was not part of the Re-Side Right scope of work), and there could not be existing flooding or combustion safety issues. The vast majority of existing single-family homes in the project's targeted area are stick built with siding. Homes that had a majority of brick veneer, stucco, or some other masonry cladding material (other than fiber cement siding) were not considered. If the home was suitable, the contractor would give the homeowner a one-page flyer that explained the study and its benefits as well as contact information for the principal investigator should any questions arise. The number one question people asked was if the research would pay for the re-siding job. It did not, but it did cover the incremental cost of the insulation and air sealing. This proved to be beneficial enough to recruit 10 homeowners and their houses for the study.

2.1.3 Existing Condition Data Collection

Each house was tested for combustion safety and to determine its air infiltration level prior to the re-siding work. The contractors also provided a full take-off list for each house using HOVER tool reports. These reports show the facade areas, window areas, and three dimensional views.

Combustion safety testing was completed on each home following combustion appliance zone testing procedures as defined in the Building America Solution Center (Office of Energy Efficiency and Renewable Energy, 2017). If a house did not pass combustion appliance zone testing, it was not included in the study or the issue was remedied before continuing.

The infiltration rates were determined through blower door testing using a Minneapolis Blower Door Tectite Express 5.0 Software and the depressurization method.

2.1.4 Re-Side Right Installation, Observation, and Documentation

The Re-Side Right package was installed over a 2-year period on the 10 study homes. The installation steps are shown in Figure 3 through Figure 12.The NJIT team was on-site for varying durations at each house. It was most important to see each contractor’s first house at all critical points to ensure that the proper installation techniques were followed. This provided the contractors with real-time technical support, but also allowed the team to observe how materials were being installed, whether installation steps needed to be changed, the types of existing conditions that slow down or hinder the Re-Side Right approach, and ways to simplify the installation process.

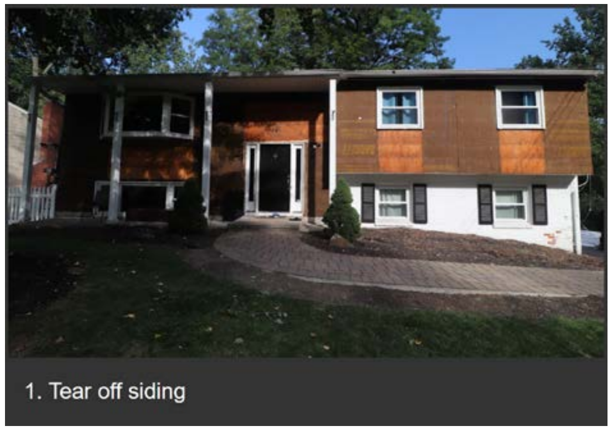


Figure 3. Installation Step 1

The first step of tear-off was no different than standard practice. Being on-site for tear-off allowed NJIT to see what the existing sheathing and siding consisted of at each house.

Note: all photos in this report are by the Building America research team.

Figure 4. Installation Step 2

Next, the contractor repaired the substrate as needed using spray foam, plywood, or scraps of rigid insulation.

Figure 5. Installation Step 3

The joint between the framing and the foundation gets sealed as needed. This again was typically done with spray foam.

Figure 6. Installation Step 4

Drip edge is installed at the sheathing base. This joint is sealed with liquid flashing, which leads into the next installation step.

Figure 7. Installation Step 5

The liquid flashing is installed before the rigid insulation goes up. It provides a seal between the rigid insulation and the sheathing at the top and bottom of the wall and around window and door openings.

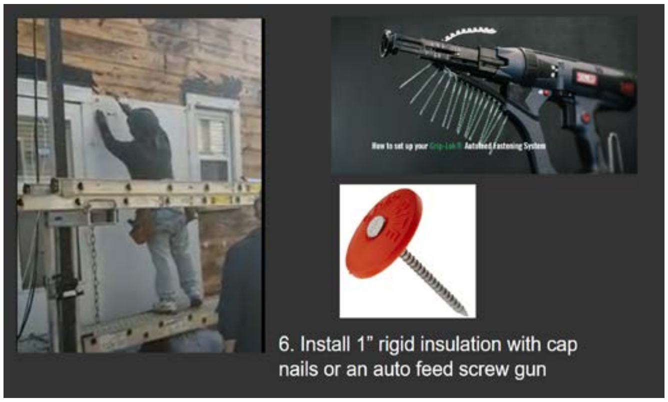


Figure 8. Installation Step 6

Then the rigid insulation is installed. The team used cap nails for most of the houses in the study, but for two houses they used an auto feed screw gun for the installation.

Figure 9. Installation Step 7a

Joints between insulation panels are taped with 3” construction tape. This is essential for the insulation to provide an air barrier and a continuous drainage plane.

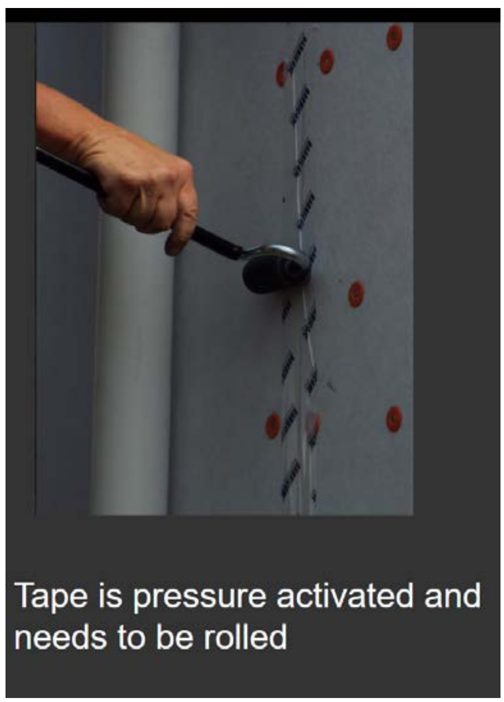


Figure 10. Installation Step 7b

The tape is rolled to fully activate its chemical adhesive. This step is critical and requires diligence from the installers.

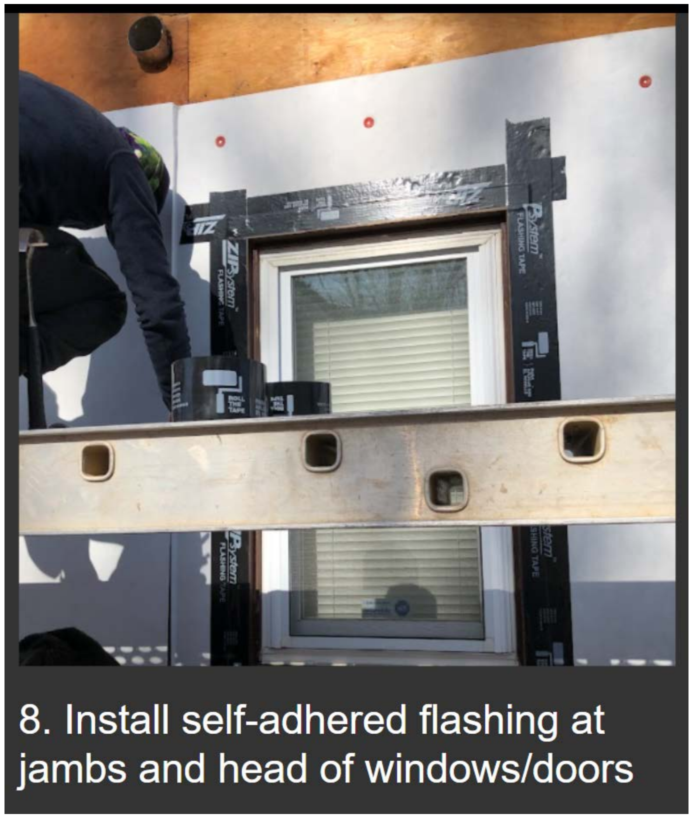


Figure 11. Installation Step 8

Self-adhered flashing is installed at the window jambs and head. If the window sits proud of the rigid insulation, then a rigid cap flashing can be installed over the head trim, and self-adhered flashing can seal the top joint.

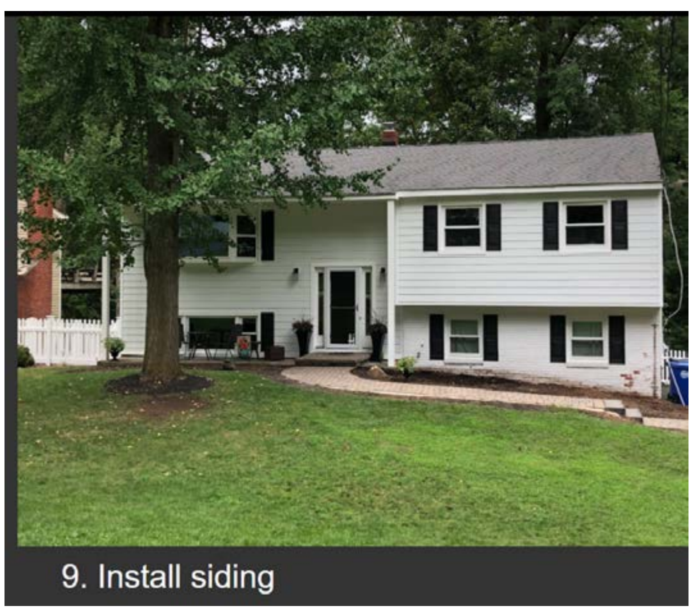


Figure 12. Installation Step 9

Finally, the siding is installed.

2.1.5 Post Re-Side Right Data Collection

After the houses were re-sided, each house was re-tested for combustion safety and to determine its altered infiltration level.

2.1.6 Energy Modeling

Energy modeling was done using BEopt™ 2.8.0.0. Wall cavity insulation R-values were estimated based on each home's age and/or non-invasive observations (behind switch plates, or at sheathing openings). Any existing conditions that were estimated for the model (for example, plug load schedules) remained consistent for the post re-sided model. When specific information was not available, the default values within BEopt for a Standard Retrofit, Single-Family Detached home were used. Each house was modeled using BEopt 2.8, first with existing conditions and then with the new wall assembly and infiltration rate.

2.1.7 Costing Analysis

Cost data for materials were collected from local supply houses and manufacturers. The amount of material used was tracked on-site and when unclear was verified through photos and take-off documents. Labor costs were based on site observations and contractor input.

2.1.8 Homeowner Survey

An important component of the Re-Side Right initiative is future adoption of the practices by siding contractors. As such, customer demand for the Re-Side Right approach is critical. A post-siding customer survey was designed to gauge customer interest. The homeowner survey[3] was an online tool created using Survey Monkey. The 10-question survey was based on a similar tool created for the Re-Side Tight (Center for Building Knowledge, 2013) research project.

2.1.9 Contractor Interviews

Contractor interviews were conducted via conference call or video call. Each contractor was asked about their participation in Re-Side Right, how the experience was for them, and whether they would offer the Re-Side Right approach.

2.1.10 Contractor Training

Using field photos and video and the recorded training for the study contractors, NJIT created an online tutorial[4] for Re-Side Right (Center for Building Knowledge at NJIT, 2022).

2.2 Measured Results

The field measured results from the 10 Re-Side Right houses are shown next.

[3] Available at https://www.surveymonkey.com/r/JRKSFV9.
[4] Available at https://resideright.org/.

2.2.1 Infiltration Rates

Table 1. House Pre and Post CFM50 and ACH50

Infiltration Rates				
House	Existing CFM50	Existing ACH50	Post-Siding CFM50	Post-Siding ACH50
1	2835	17.81	2103	13.21
2	3473	9.47	3136	8.55
3	3344	9.12	3558	9.7
4	2125	7.84	1902	7.02
5	3013	12.2	2832	11.47
6	3258	7.84	2926	7.04
7	2652	11.22	2418	10.23
8	3387	9.07	3307	8.86
9	3246	8.85	2828	7.71
10	3672	10.01	3312	9.03
Average	3101	10.3	2832	9.3

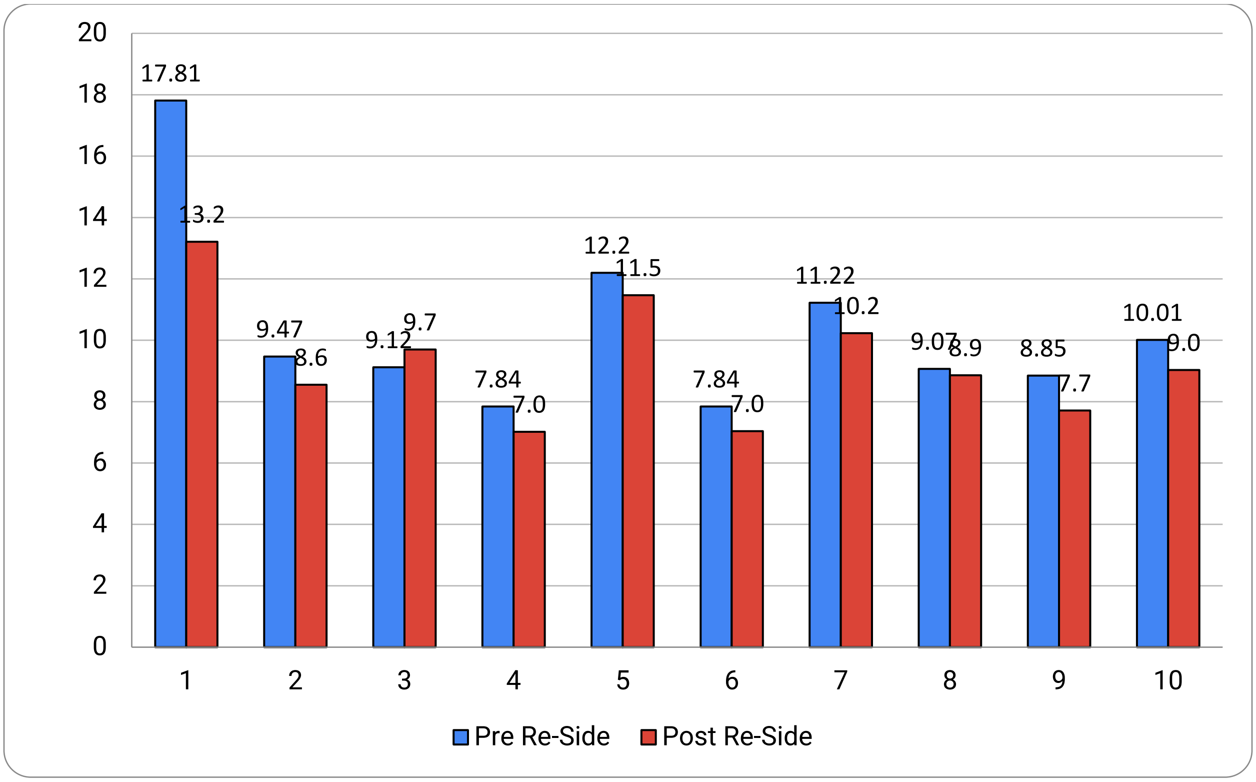


Figure 13. Pre and post ACH50

2.2.2 House Age and Infiltration Rates

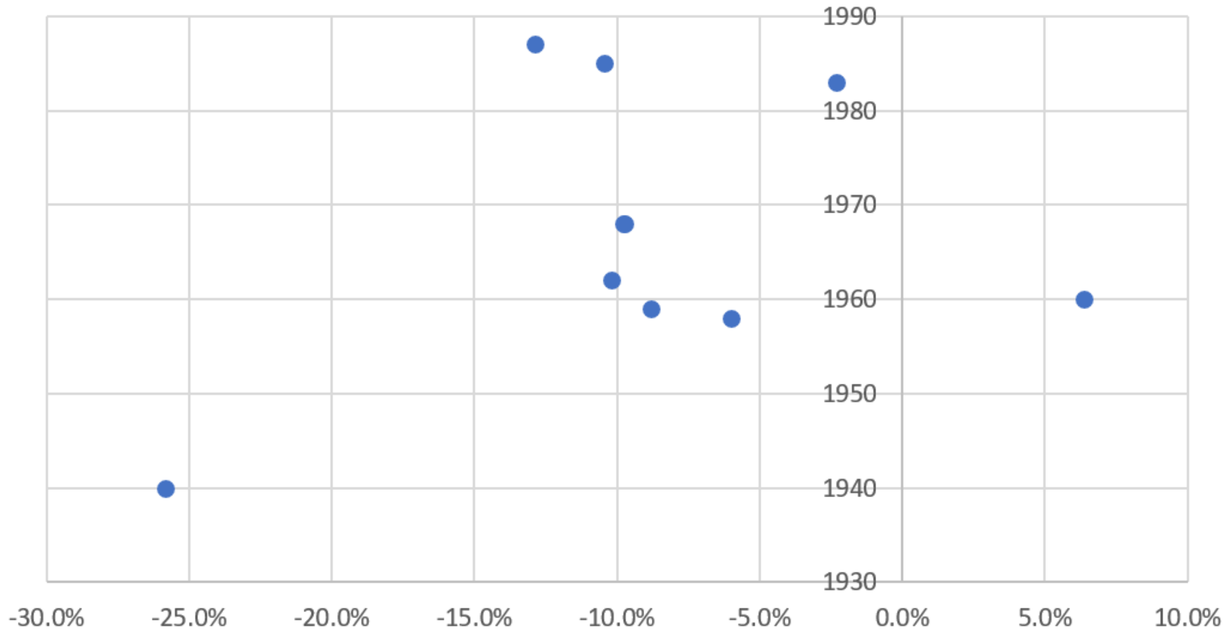


Figure 14. House age and infiltration reduction percentage

Most of the houses had a reduction in infiltration of about 10%. The oldest house (House 1) had the greatest reduction in infiltration; it also had the highest existing leakage at 17.81 ACH50. Once the siding was removed from this house, it became apparent that the exposed sheathing was pine boards rather than plywood. This most likely contributed to the home's high infiltration rate and strong potential for improvement. Before work began, a core sample at the wall showed fiberglass cavity insulation; however, later in the process the contractor discovered that the insulation was incomplete and was only installed in about half of the first-floor wall area. As a result, cellulose was installed in the remaining areas. Therefore, even though the house had great potential for infiltration reduction because of its plank sheathing, the actual reduction due to the Re-Side Right approach alone is not known.

2.2.3 Facade Area and Infiltration Reduction Percentage

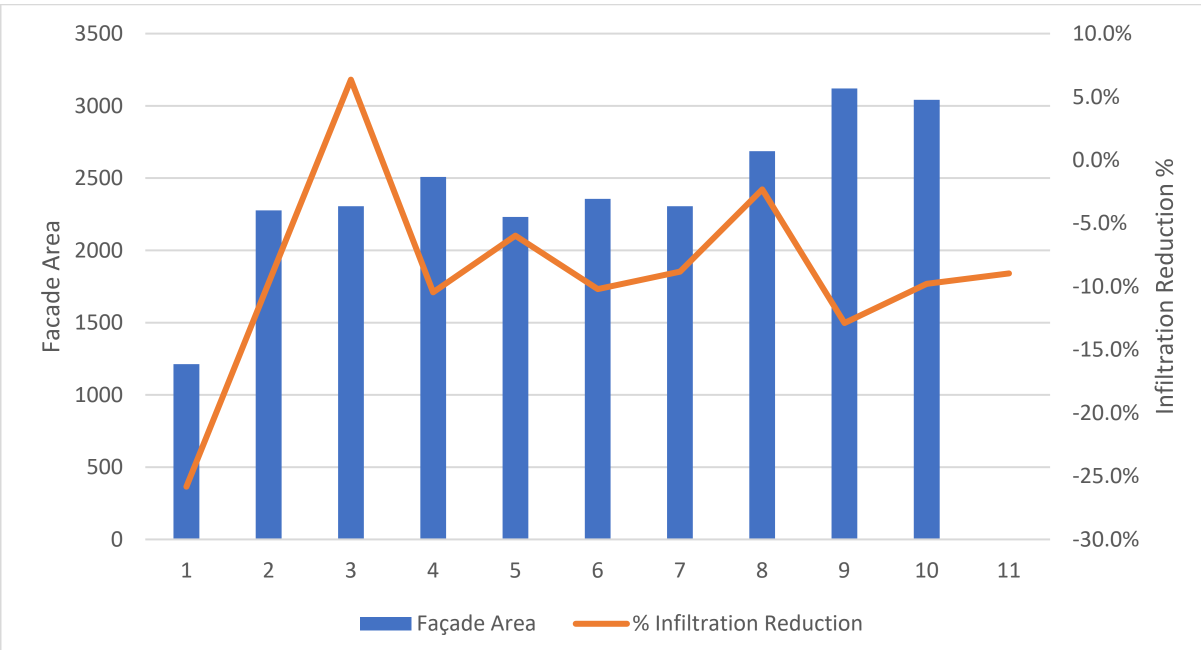


Figure 15. Facade area and infiltration reduction percentage

Re-Side Right infiltration reduction is limited to building facade area. Figure 15 shows the overall facade area and the infiltration reduction percentage. More facade area might be associated with a greater reduction in infiltration, but the limited data set does not show a clear correlation.

Each house had an increase in nominal opaque wall R-value of R-5. All of the houses had existing insulation of between R-11 and R-13.[5]

[5] As mentioned, House 1 was missing fiberglass for half of the first-floor wall areas. Cellulose was installed in the empty stud bays prior to the exterior insulation installation.

2.2.4 Hygrothermal Data Collection

Oak Ridge National Laboratory collected hygrothermal data from House 6 using multiple sensors at the sheathing, connected to a datalogger in the attic. These sensors monitored the moisture content at the sheathing underneath the new rigid insulation for a period of one year from the installation. This is a separate effort that offered Oak Ridge an opportunity to collect real-world data to validate their model and provided NJIT's model with data on the hygrothermal performance of the wall. The resulting data in Figure 16 show that the sensors on all four sides of the house read below 80% relative humidity, considered the moisture durability threshold.

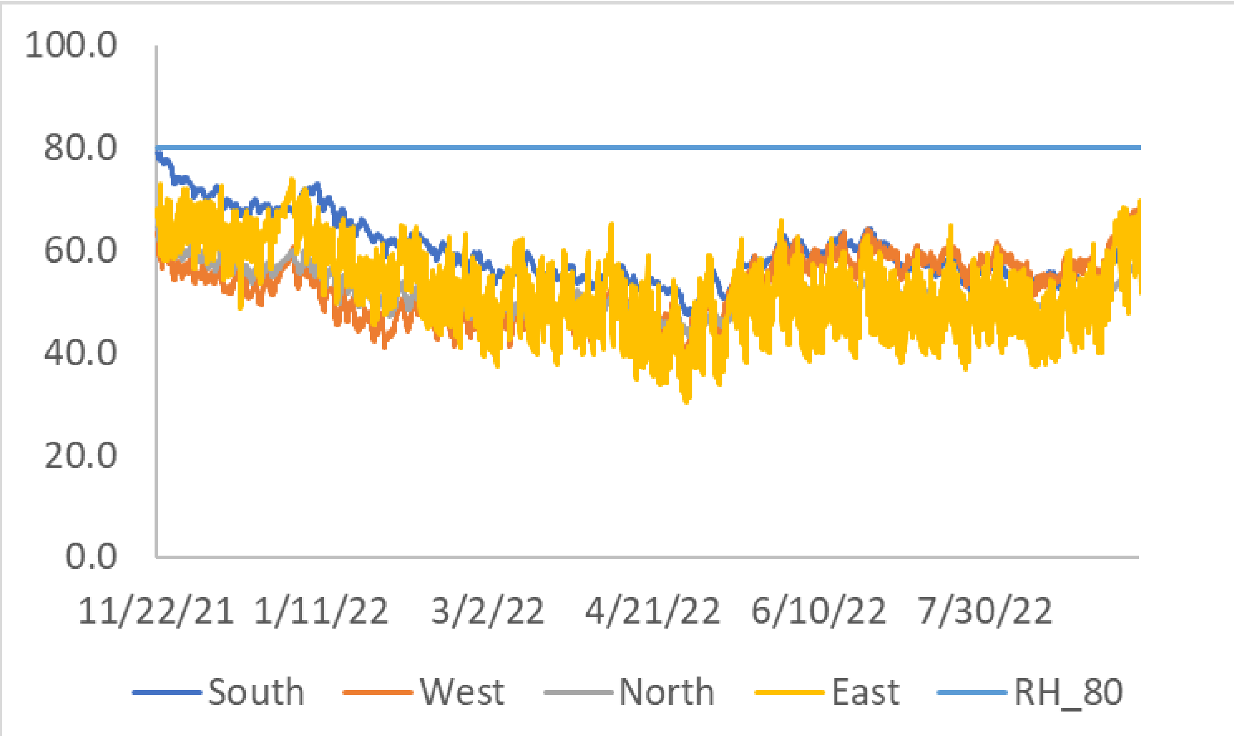


Figure 16. Relative humidity measurements at House 6 sheathing

Figure from (Aldykiewicz, 2022)

2.3 Modeled Results

2.3.1 Pre and Post Source Heating and Cooling

Table 2. Modeled Pre and Post Re-Side Right Heating and Cooling (MMBtu/yr)

House	Pre Heating	Pre Cooling	Pre Total	Post Heating	Post Cooling	Post Total	% Total Reduction
1	60.3	9.4	69.7	47.6	8.9	56.5	18.94
2	62.6	27.1	89.7	54.9	26.5	81.4	9.25
3	60.4	26.9	87.3	57.4	26.7	84.1	3.67
4	45.3	27.1	72.4	40.1	26.2	66.3	8.43
5	59.6	38.7	98.3	51.8	37.9	89.7	8.75
6	60.8	39.8	100.6	52.8	38.8	91.6	8.95
7	48	27.1	75.1	42.3	26.7	69	8.12
8	52.6	24.8	77.4	46.7	24.3	71	8.27
9	67.5	29.3	96.8	58.1	27.5	85.6	11.57
10	57.5	25.8	83.3	50.4	25.5	75.9	8.88
Average	57.5	27.6	85.1	50.21	26.9	77.1	9.35

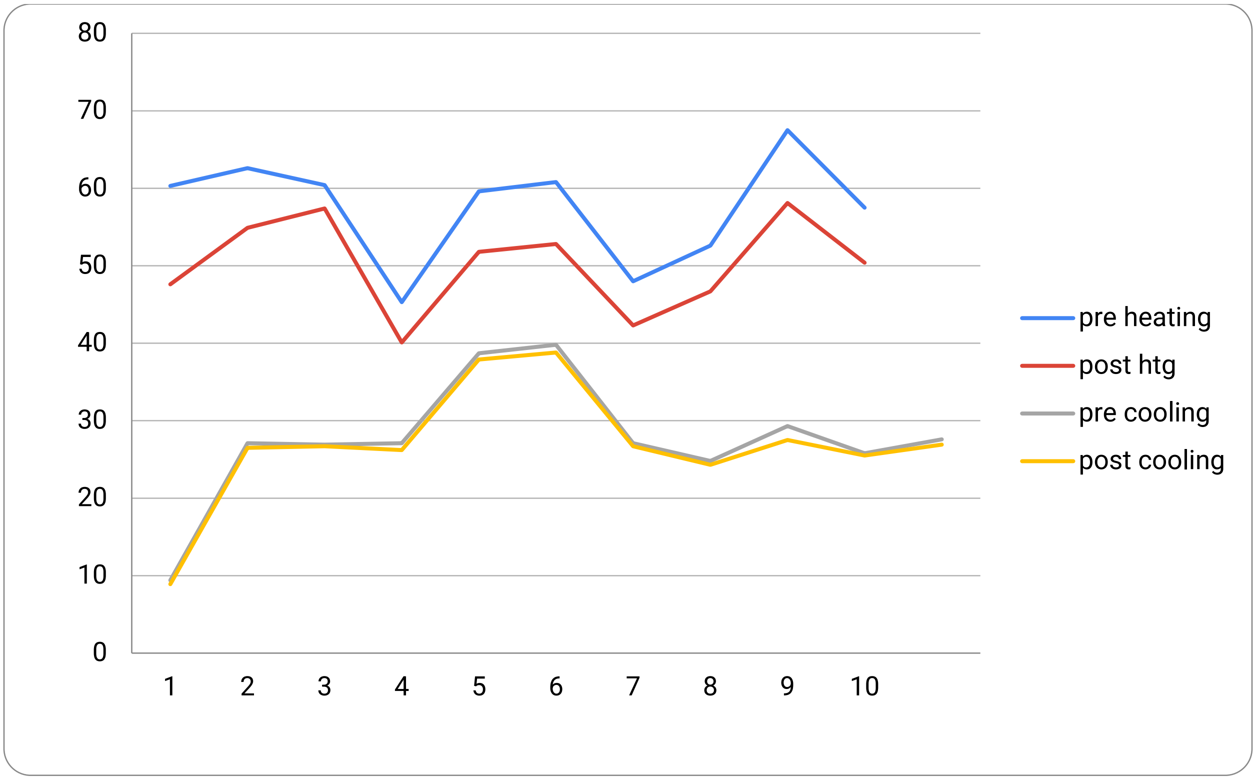


Figure 17. Pre and post siding source energy (MMBtu/yr)

The energy use comparison was done using source energy rather than site energy.[6] As shown in Figure 17, the impact on modeled cooling source energy is minimal. The modeled heating source energy reduction is fairly uniform, with differences primarily driven by the infiltration reduction in each home.

2.3.2 Savings-to-Investment Ratio

Costs for the Re-Side Right portion of the siding jobs were analyzed using savings-to-investment ratio (SIR). These were calculated based on .1614/kWh, .95\therm, a 25-year analysis period, and present day energy costs as done by the Weatherization Assistance Program. The costs for the Re-Side Right material and labor were calculated using the per square foot material costs noted in Footnote **Error! Bookmark not defined.** multiplied by the opaque wall area plus the estimated labor cost as provided by the contractors. The calculated SIRs show that only House 1 exceeds an SIR of 1; however, with presumed increasing energy costs over time, the SIR will become more favorable.

[6] The Environmental Protection Agency recommends using source energy when comparing buildings for a more accurate evaluation of building operation energy use (Environmental Protection Agency, 2023).

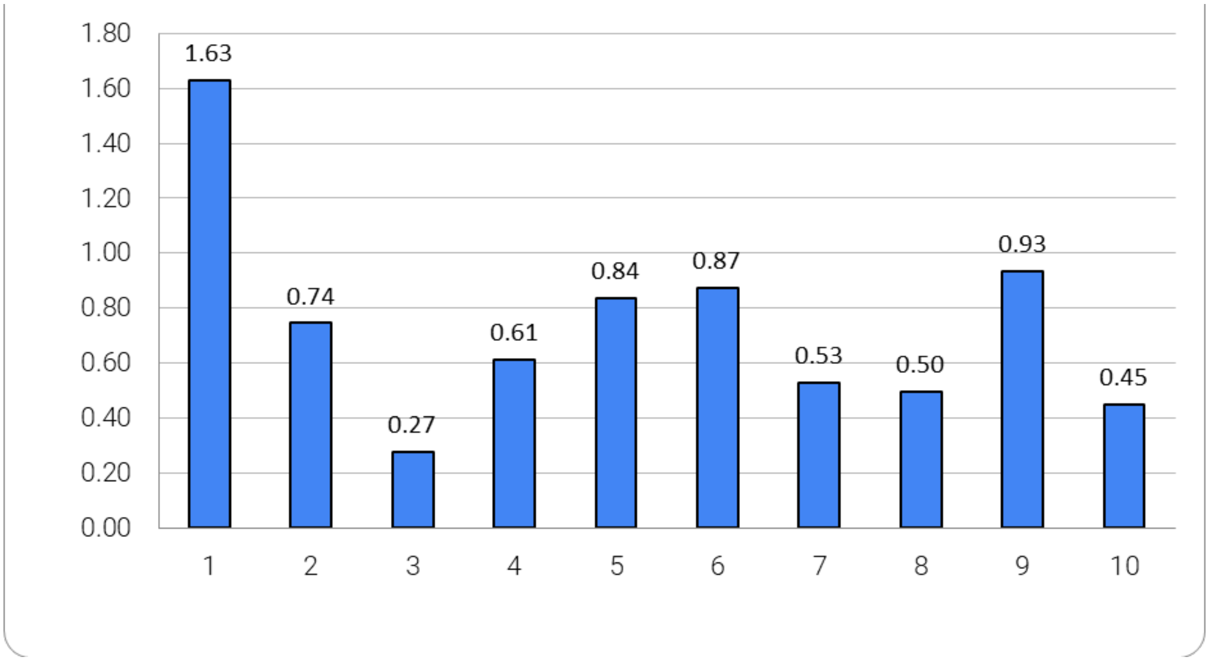


Figure 18. Savings-to-investment ratio for Re-Side Right houses

2.3.3 Modeled Energy Use vs. Year Built

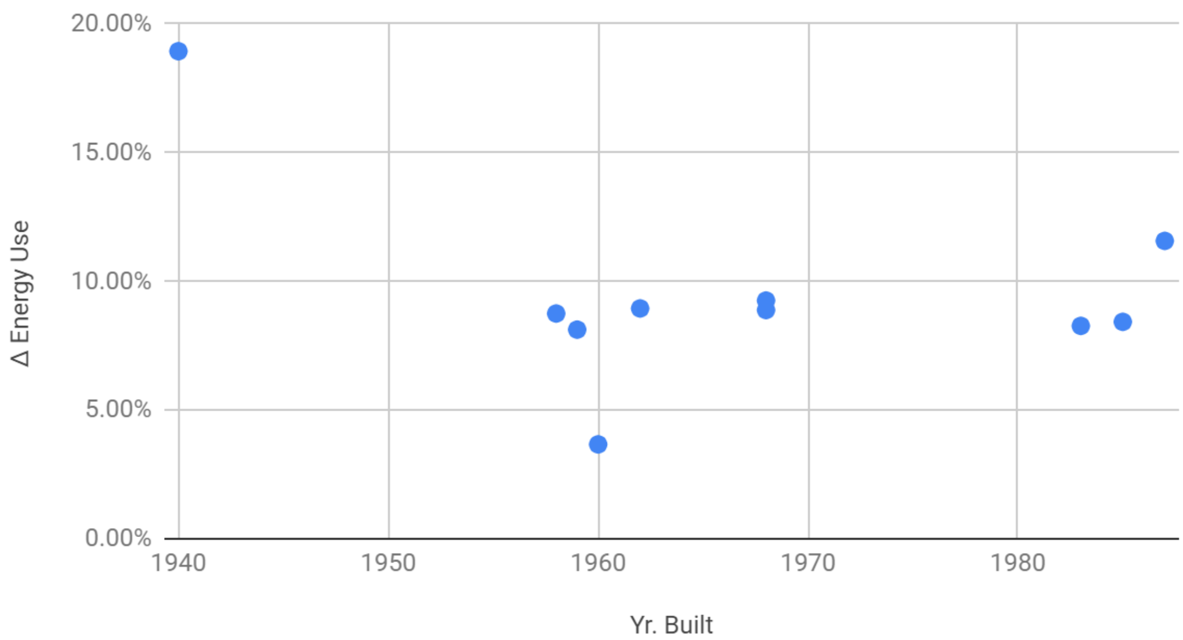


Figure 19. Change in modeled energy use vs. year built

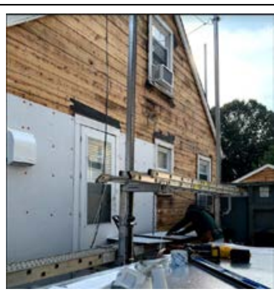
The oldest house in the study (House 1, built in 1940) saved the most energy, but as noted earlier this house had cellulose added during the retrofit. The only other outlier for energy reduction was House 3, built in 1960. This home had the lowest energy reduction, based only on insulation as the infiltration increased by 6.4%. This house is a split-level home (as is 1 other, and there are 3 bi-levels) with an attached garage, which are notoriously difficult to air seal.

2.4 Individual House Measured and Modeled Results

The tables that follow contain photos, measured and modeled data, as well as field observations for each house.

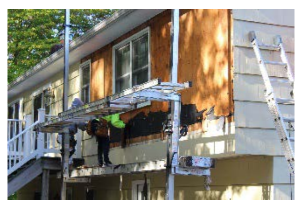
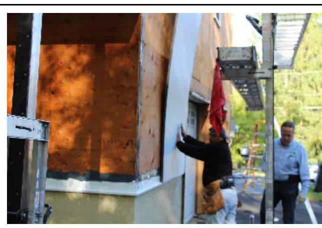
Table 3. House 1

<table>
<tr><td colspan="3">House 1

Living Area - 982 Square Feet,
Volume - 9,550 Cubic Feet</td><td colspan="3"></td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2">Pine board sheathing</td><td colspan="2">Non-flanged windows</td><td colspan="2">Liquid flashing application</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2">Neopor insulation installation</td><td colspan="2">Neopor joint taping</td><td colspan="2">Rolling seam tape</td></tr>
<tr><td></td><td colspan="2">ACH 50</td><td>MMBtu/yr Heating</td><td colspan="2">MMBtu/yr Cooling</td></tr>
<tr><td>Existing Conditions</td><td colspan="2">17.81</td><td>60.3</td><td colspan="2">9.4</td></tr>
<tr><td>Post-Siding Results</td><td colspan="2">13.21</td><td>47.6</td><td colspan="2">8.9</td></tr>
<tr><td colspan="6">Modeled Annual Saving $144.30</td></tr>
<tr><td colspan="6">Savings-to-Investment Ratio 1.62</td></tr>
</table>

Our first Re-Side house did not include infrared images because the temperature difference was less than a few degrees. The exposed sheathing was pine boards rather than plywood. This most likely contributed to the high infiltration rate. The windows were non-flanged, with replacement windows inside the original frames. The first-floor window heads were snugged right up to the frieze board at the roof eaves. This limited the space for sealing/insulating in that location. Generally, though, the house was well suited to the approach. Its simple geometry allowed for a straightforward installation. As noted previously, a core sample at the wall before work began showed fiberglass insulation; however, further on the contractor discovered that the insulation was incomplete and was only installed in about half of the first-floor wall area. As a result, cellulose was installed in the remaining areas. This skews the before and after blower door results.

Table 4. House 2

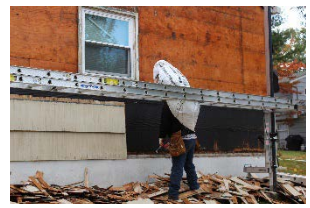
House 2 Living Area – 2,678 Square Feet Volume – 22,002 Cubic Feet		
		
Plywood sheathing	Non-flanged windows	Liquid flashing installation
		
Neopor insulation installation	Insulation cap nailing	Nailed, taped Neopor

	ACH 50	MMBtu/yr Heating	MMBtu/yr Cooling
Existing Conditions	9.47	62.6	27.1
Post-Siding Results	8.55	54.9	26.5
Modeled Annual Saving $101.53			
Savings-to-Investment Ratio .75			

House 2 is a split-level with a tuck under garage. The infiltration reduction was modest on this house.

Table 5. House 3

<table>
<tr><td colspan="6">House 3

Living Area – 2,603 Square Feet
Volume – 22,125 Cubic Feet</td><td colspan="6"></td></tr>
<tr><td colspan="4"></td><td colspan="4"></td><td colspan="4"></td></tr>
<tr><td colspan="4">Plywood sheathing</td><td colspan="4">Front bay window</td><td colspan="4">Non-flanged windows</td></tr>
<tr><td colspan="4"></td><td colspan="4"></td><td colspan="4"></td></tr>
<tr><td colspan="4">Liquid flashing at widow jamb</td><td colspan="4">Neopor insulation installation</td><td colspan="4">New siding</td></tr>
<tr><td colspan="3"></td><td colspan="3">ACH 50</td><td colspan="3">MMBtu/yr Heating</td><td colspan="3">MMBtu/yr Cooling</td></tr>
<tr><td colspan="3">Existing Conditions</td><td colspan="3">9.47</td><td colspan="3">60.4</td><td colspan="3">26.9</td></tr>
<tr><td colspan="3">Post-Siding Results</td><td colspan="3">8.55</td><td colspan="3">57.4</td><td colspan="3">26.7</td></tr>
<tr><td colspan="12">Modeled Annual Saving $37.96</td></tr>
<tr><td colspan="12">Savings-to-Investment Ratio .27</td></tr>
</table>

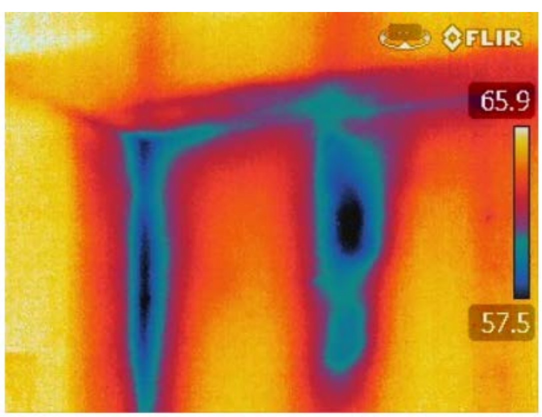


Figure 20. House 3 interior infrared image of wall between family room and garage

Figure 21. House 3 interior infrared image of bedroom window

Like House 2, House 3 is a split-level home, although the garage is attached rather than tuck under. Both types present exterior air sealing challenges. Six of the Re-Side Right homes were some kind of split-level design, four with tuck under garages, because they are a prevalent typology from the 1960s. Even though in House 3 infiltration actually increased slightly, the homeowner commented that the living room was much more comfortable and less drafty since the front bay window was insulated and air sealed from the exterior.

An interior infrared scan of the wall between the family room and the attached garage shows leakage at the top plate and stud bays. This top plate was covered by the garage roof; as such, the Neopor continuous insulation stopped above this area and did not help remedy the leakage. Post-siding infrared imaging indicated that air sealing around the windows needed improvement.

This led to a change in the installation method. Going forward, the windows were sealed using liquid flashing and self-adhered flashing. The self-adhered flashing would seal between the windows and the sheathing (see Figure 22) and the liquid flashing would seal between the self-adhered flashing and the rigid insulation (see Figure 23).

Figure 22. Self-adhered flashing sealing window to sheathing

Figure 23. Liquid flashing sealing self-adhered flashing to rigid insulation

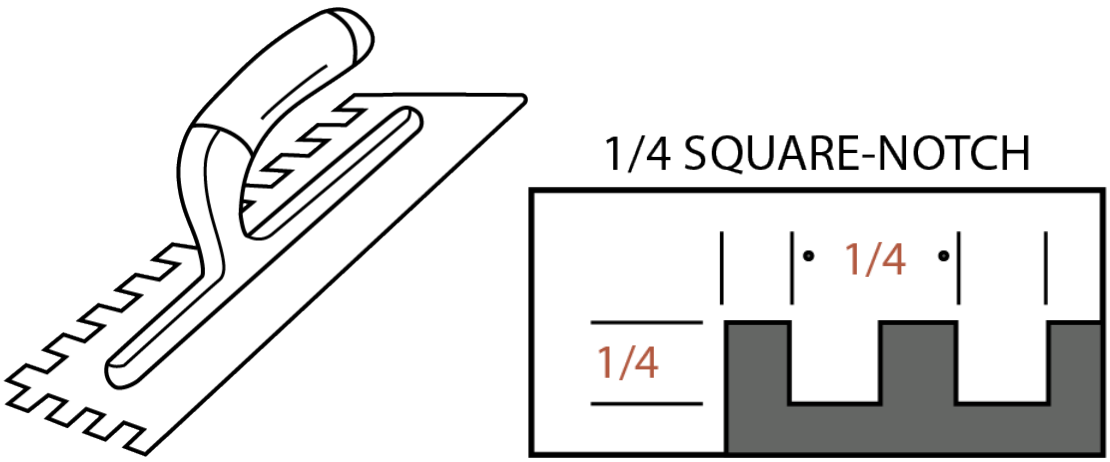
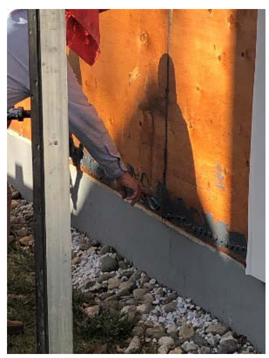
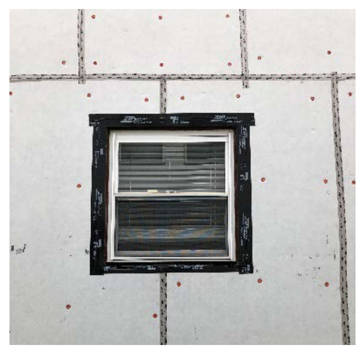


Figure 24. Trowel profile

When implementing this approach on House 4 (see Table 6), the contractor suggested that the order be reversed, using the liquid flashing to seal between the windows and the sheathing (see the bottom left image in Table 6), and the self-adhered flashing at the joint between the window and the rigid insulation (see the bottom right photo in Table 6). The contractor noted that the self-adhered flashing allowed for a cleaner joint in preparation for the siding trim work. House 4 has a front overhang and a tuck under garage, as well as can lighting that communicates with the attic. These were less than ideal conditions, but fairly typical. On House 4, the team also experimented with different ways to apply the liquid flashing at the bottom and top of the sheathing. Typically, the contractor was creating a sine pattern with a caulk gun (the flashing comes in sausage-like tubes), and then spreading the bead into a wide band. This made for varying levels of thickness. For greater uniformity, the contractor used a ¼" square notch tile mortar trowel to create a set depth of flashing.

Table 6. House 4

House 4 Living Area – 1,822 Square Feet Volume – 16,262 Cubic Feet	

		
Plywood sheathing	Overhang with duct	Non-flanged windows
		
Liquid flashing at widow jamb	Liquid flashing at bottom of sheathing to seal Neopor	Self-adhered flashing at window

	ACH 50	MMBtu/yr Heating	MMBtu/yr Cooling
Existing Conditions	7.84	45.3	27.1
Post-Siding Results	7.02	40.1	26.2
Modeled Annual Saving $91.97			
Savings-to-Investment Ratio .61			

During the post-siding blower door test for House 4, the team used a smoke pencil to see whether there was leakage between the continuous insulation Neopor and the sheathing at the bottom of the wall. Conditions were too mild to use the infrared camera. It was difficult to pinpoint whether there was leakage in this area specifically, but it did appear that there was a good seal between the continuous insulation Neopor and sheathing.

Table 7. House 5

House 5 Living Area – 1,627 Square Feet Volume – 14,156 Cubic Feet		
		
Plywood sheathing	Overhang with dirty insulation	Non-flanged windows
		
Spray foam at eave	Liquid flashing at jamb and top of sheathing	Self-adhered flashing at window

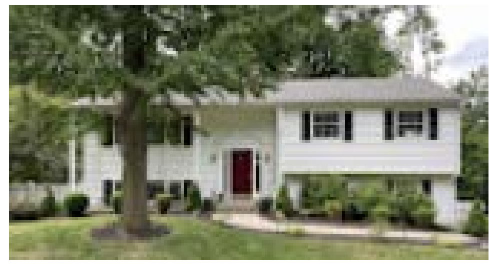
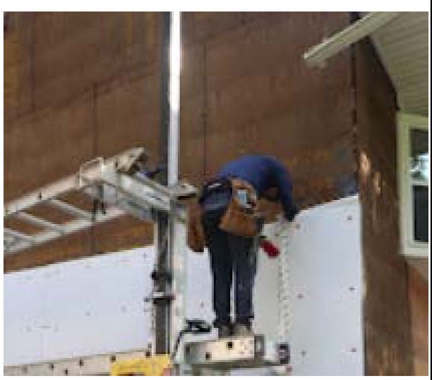
	ACH 50	MMBtu/yr Heating	MMBtu/yr Cooling
Existing Conditions	12.2	59.6	38.7
Post-Siding Results	11.47	51.8	37.9
Modeled Annual Saving $111.94			
Savings-to-Investment Ratio .84			

The existing exterior walls in House 5 from outside to inside were: insulated vinyl siding/1” foam insulation/wooden shakes/building paper/plywood/fiberglass/gypsum. This was unusual as the other houses did not have exterior insulation. The project partner, BASF, took a sample of the rigid insulation to assess the present R-value.[7] Even though this house had 1” of rigid insulation, it may not have been a true R-5 insulation. The continuous insulation product used in

[7] We do not yet have those results.

this project, Neopor, is not supposed to lose R-value over time, so even though this house had 1" of rigid insulation, it may not have been a true R-5 insulation. House 5 has non-flanged windows, and often the sheathing is about an inch shy of the window framing. As such, the contractor filled in those gaps with wood so that the liquid flashing could be effectively installed. Upon completion, the house's air infiltration dropped 6%.

Table 8. House 6

House 6 Living Area – 1,424 Square Feet Volume – 11,748 Cubic Feet		
		
Plywood and fiberboard sheathing	Overhang and moisture sensor wires	Non-flanged windows
		
Rigid insulation installation	Self-adhered flashing at door/window	Furring strips over insulation

	ACH 50	MMBtu/yr Heating	MMBtu/yr Cooling
Existing Conditions	7.84	60.8	39.8
Post-Siding Results	7.04	52.8	38.8
Modeled Annual Saving $123.30			
Savings-to-Investment Ratio .87			

House 6 has a tuck under garage and some overhangs. The existing siding was a combination of wooden shingles and clapboard. The sheathing is plywood and fiberboard. While the sheathing was exposed, Oak Ridge National Laboratory installed multiple sensors at the sheathing, connected to a datalogger in the attic. These sensors monitor the moisture content at the sheathing underneath the new rigid insulation. There is no baseline data from before the insulation was installed. However, since the building is in climate zone 5, adding continuous insulation reduces the potential for moisture accumulation in the exterior sheathing because we are reducing the vapor pressure drive and condensation potential from the building interior to the sheathing by reducing the temperature difference between the two locations.

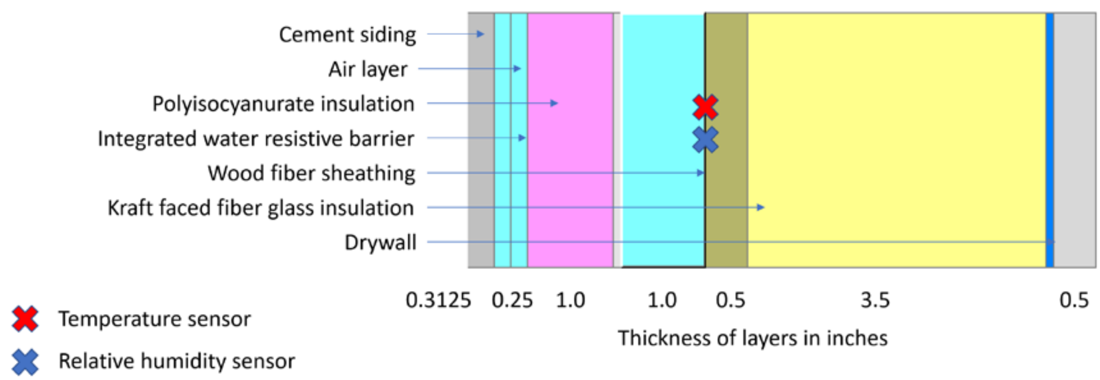


Figure 25. Retrofit wall construction and sensor locations

Figure from Oak Ridge National Laboratory

The monitored data showed that the walls stayed below an 80% moisture durability threshold.

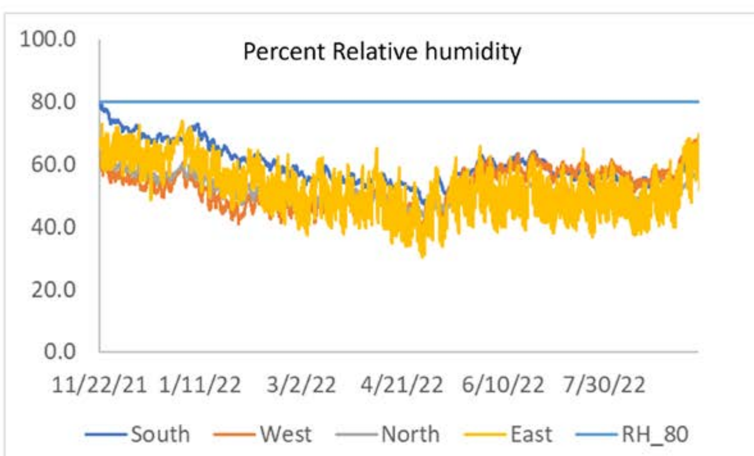


Figure 26. House 6 relative humidity compared to 80% value as a measure for moisture durability threshold

Oak Ridge National Laboratory also did hygrothermal modeling to determine whether the wall assembly without furring strips would also stay below the moisture durability threshold.

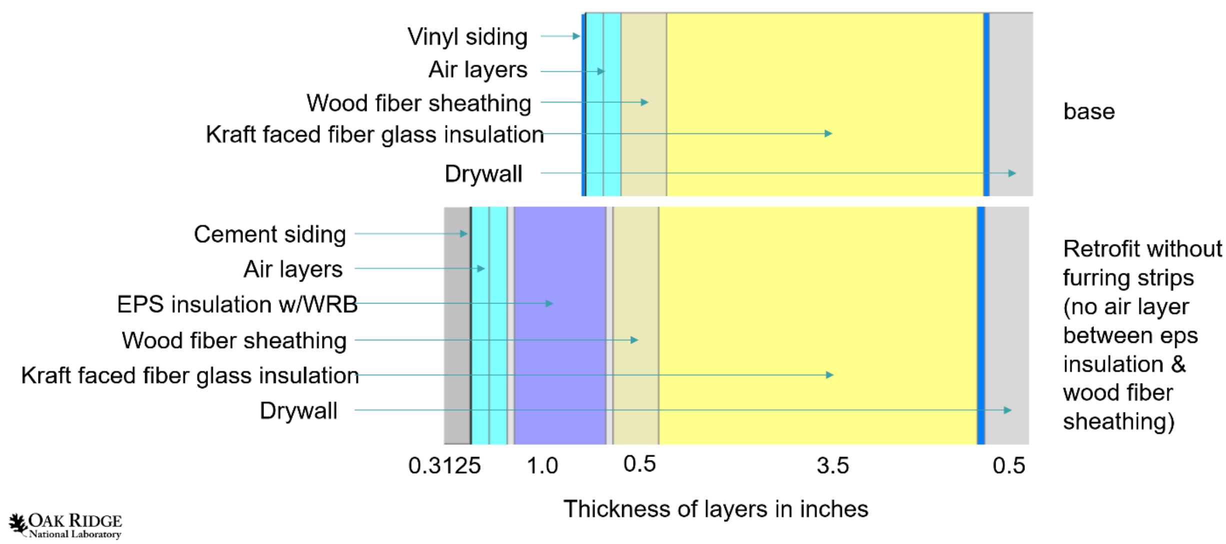


Figure 27. Hygrothermal simulation without furring strip

The modeling results show that the assembly continues to dry over time even without the air space provided by the furring strips.

moisture content	base		retrofit_no_fs	
	start	end	start	end
total (lb/ft^2)	0.13	0.09	0.20	0.20
eps_wrb (lb/ft^3)	0.01	0.01	0.01	0.01
wood fiber (lb/ft^3)	2.21	1.67	2.21	1.43
fiber glass (lb/ft^3)	0.03	0.02	0.03	0.02
drywall (lb/ft^3)	0.54	0.34	0.54	0.34

moisture content	difference (start - end)	
	base	retrofit_no_fs
total (lb/ft2)	-0.04	0.00
eps_wrb (lb/ft3)	na	0.00
wood fiber (lb/ft3)	-0.54	-0.78
fiber glass (lb/ft3)	-0.01	-0.01
drywall (lb/ft3)	-0.20	-0.20

The assembly is drying over time reflected by the decrease in moisture content of the components in the wall assembly.

OAK RIDGE National Laboratory

Figure 28. Moisture accumulation over three-year simulation period

This house saw a 10.2% drop in infiltration.

Table 9. House 7

House 7 Living Area – 1,512 Square Feet Volume – 12,474 Cubic Feet	

		
Fiberboard sheathing	Thin rigid insulation over cementitious shingles over fiberboard	Degradation of materials around the windows
		
Rigid insulation installation	Self-adhered flashing and liquid flashing at window	Spray foam and liquid flashing at window

	ACH 50	MMBtu/yr Heating	MMBtu/yr Cooling
Existing Conditions	11.22	48	27.1
Post-Siding Results	10.23	42.3	26.7
Modeled Annual Saving $73.07			
Savings-to-Investment Ratio .53			

House 7 was the second house in the study that had fiberboard sheathing rather than plywood. House 7's existing walls were built up over time. From the studs out, this house had: USG Fireproof Asphalted Sheathing, cementitious shingles (suspected to contain asbestos), ¼" fanfold type extruded polystyrene, vinyl siding. Much of the fiberboard had broken down and was in poor condition. As a result, the conditions around the windows were ragged and not substantially smooth or firm enough to receive liquid flashing. This led to using spray foam where there were irregular openings around the windows, followed by self-adhered flashing to stabilize and secure the joint. At this point, the typical Re-Side Right method was used: liquid flashing under the Neopor continuous rigid insulation, and self-adhered flashing to connect the window to the Neopor board. The Neopor continuous insulation on this house was attached with screw guns (Grip-Lok Fastening System with SENCO-DS-311-18V-auto Feed Batter Screw Gun) and cartridges (TGProngBugle - 1K Thermal-Grip Solid cap washer for bugle head screws with pre-spotting prongs). This helped speed the installation and was particularly beneficial because the cementitious shingles that were left in place were brittle and would have cracked with nailing. House 7 went from an 11.22 ACH50 to a 10.23 ACH 50, achieving an 8.8% drop in infiltration.

Table 10. House 8

House 8

Living Area – 2,160 Square Feet

Volume – 17,820 Cubic Feet

	ACH 50	MMBtu/yr Heating	MMBtu/yr Cooling
Existing Conditions	9.07	52.6	24.8
Post-Siding Results	8.86	46.7	24.3
Modeled Annual Saving $79.70			
Savings-to-Investment Ratio .50			

House 8 was another bilevel home with a tuck under garage. Only a modest drop in infiltration was achieved at this home.

Table 11. House 9

House 9 Living Area – 3,065 Square Feet Volume – 27,585 Cubic Feet	

		
Plywood sheathing	Overhang with exposed joists and fibrous insulation	Rigid insulation installation
		
Marked up photo to flash second floor windows and head of one first floor window	Marked up site photos/punchlist items to tape at the corner	Marked up site photos/punchlist item to tape all insulation joints

	ACH 50	MMBtu/yr Heating	MMBtu/yr Cooling
Existing Conditions	8.85	67.5	29.3
Post-Siding Results	7.71	58.1	27.5
Modeled Annual Saving $174.44			
Savings-to-Investment Ratio .93			

House 9 is a late 1980s home with a combination of fibrous cavity insulation and sections of spray foam. The sheathing is plywood and the windows are flanged. House 9's combustion safety test revealed that the boiler flue needed further inspection by the homeowner's boiler maintenance company. The boiler mechanic came out to do an additional test and called for the chimney to be re-lined. The homeowner arranged for this work to be done. The homeowner also removed their whole-house fan that was exhausting to the attic. House 9 had a 12.9% drop in infiltration.

Table 12. House 10

House 10 Living Area – 2,752 Square Feet Volume – 23,392 Cubic Feet	

		
Plywood and fiberboard sheathing	Wood rot behind downspout location	Fragmented fiberboard at window flange
		
Liquid flashing application at sheathing base	Rigid insulation installation	Self-adhered flashing, liquid flashing and rigid insulation installation

	ACH 50	MMBtu/yr Heating	MMBtu/yr Cooling
Existing Conditions	10.01	57.5	25.8
Post-Siding Results	9.03	50.4	25.5
Modeled Annual Saving $81.64			
Savings-to-Investment Ratio .45			

House 10 has fiberboard sheathing in the field and plywood at the corners (as did House 6). House 10 has two types of windows, replacement windows upstairs and flanged older windows on the first level. The plywood sheathing at the northwest corner showed rot and infestation damage, likely due to a leaky downspout. This and other areas of decay were repaired by the contractor before the Re-Side work commenced. Degraded fiberboard sheathing was evident surrounding the windows and doors. As such, this house was detailed the same way House 7 was done, self-adhered flashing at the joint between the window/door and the sheathing, followed by liquid flashing, continuous insulation, and topped with self-adhered flashing on the jambs and head. This self-adhered flashing was not installed between the Neopor and the window sill, to allow liquid water to drain at that location if necessary. When windows aren't being replaced, there is the constant tension between tightening up the walls and allowing for drainage. Not causing water damage is the higher priority and that drove the decision to detail the bottom of existing windows this way. The post-siding blower door test on House 10 showed a drop of about 10%, down to 9.03 ACH50.

2.5 Homeowner Survey Results

Our homeowner survey was completed by the project participants. The majority of our participants would recommend having their home sided this way and had a positive experience overall. This was to be expected as the incremental cost of the Re-Side Right approach was absorbed by the study. These homeowners get all the benefits of Re-Side Right, and the only cost was their time and accommodation of some field tests.

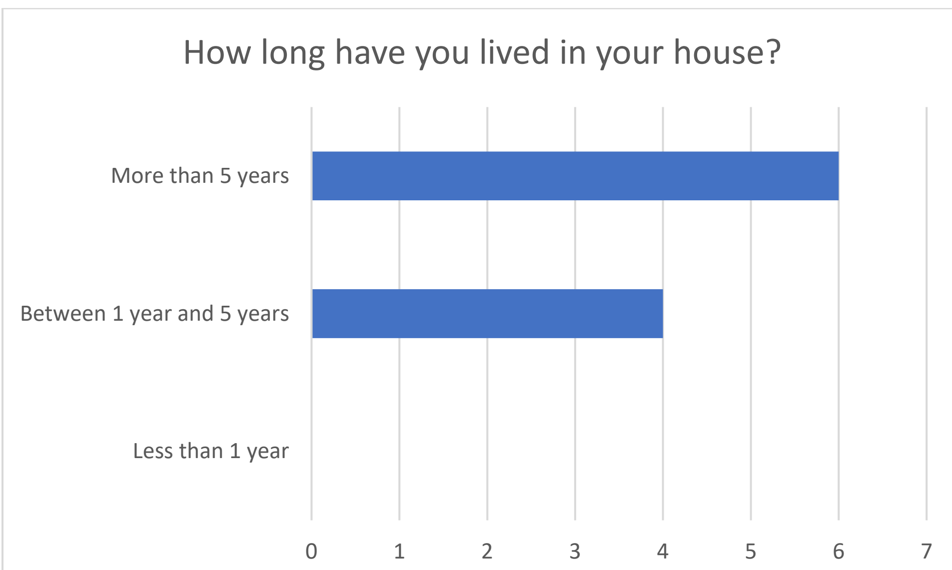


Figure 29. Survey: Length of time in home

All of the participants had been in their homes at least a year, and as such had experienced heating and cooling seasons in them.

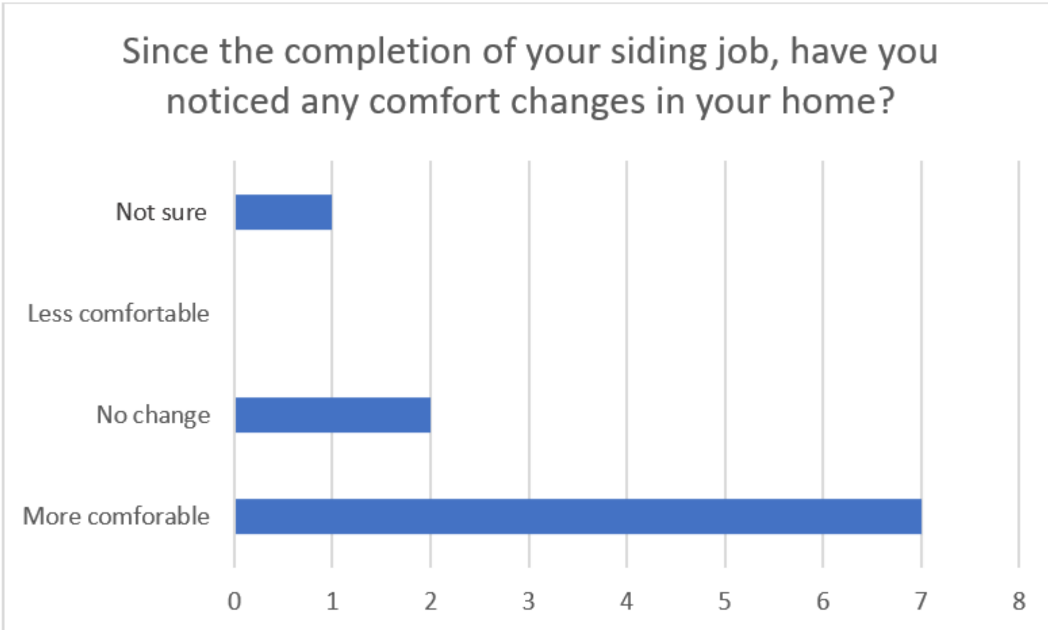


Figure 30. Survey: Comfort changes

The majority of participants, even in the brief period following the installation of Re-Side Right, were more comfortable in their homes. And we found that even anecdotally on the job sites, people would comment that their drafty bay window in the living room was not drafty anymore, or that their heat system ran less often and kept their home comfortable longer. Our survey results on comfort track well with those site interactions.

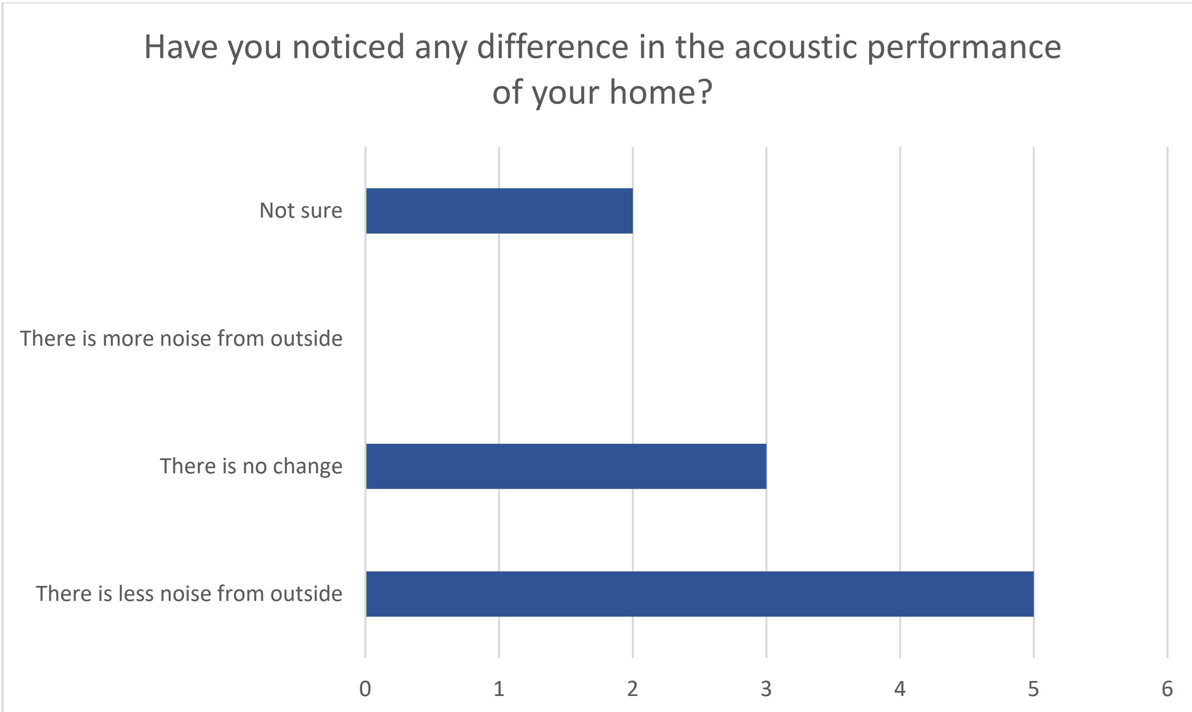


Figure 31. Survey: Acoustic change

Half the participants noticed less noise from outside. This question was included based on our last study, Re-Side Tight, where we installed the house wrap of a re-siding job as an air barrier. One participant in that study in particular lived on a very busy street and they were struck by how much quieter their house was after the re-siding. We did not do acoustic testing during that study or Re-Side Right.

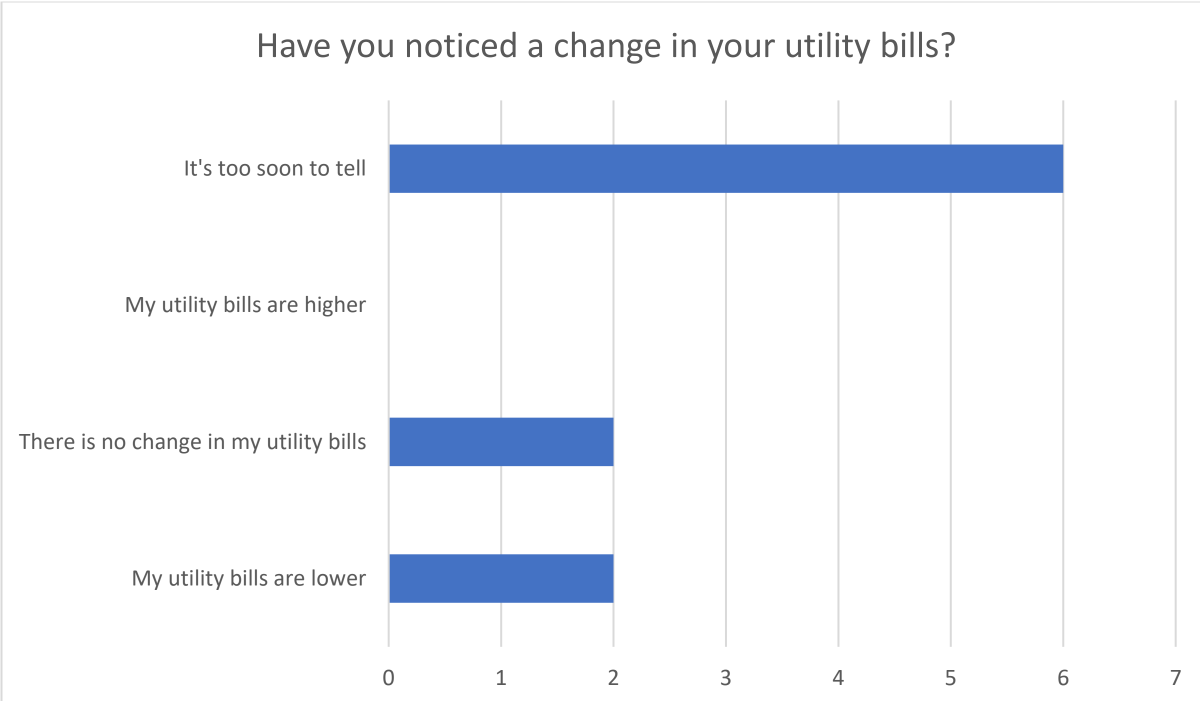


Figure 32. Survey: Utility bill change

Our study did not cover enough time for a year's worth of utility bill comparison. Despite that, we asked this question to see if some of the first participants noticed a difference. We do not have weather normalized before and after utility bill data.

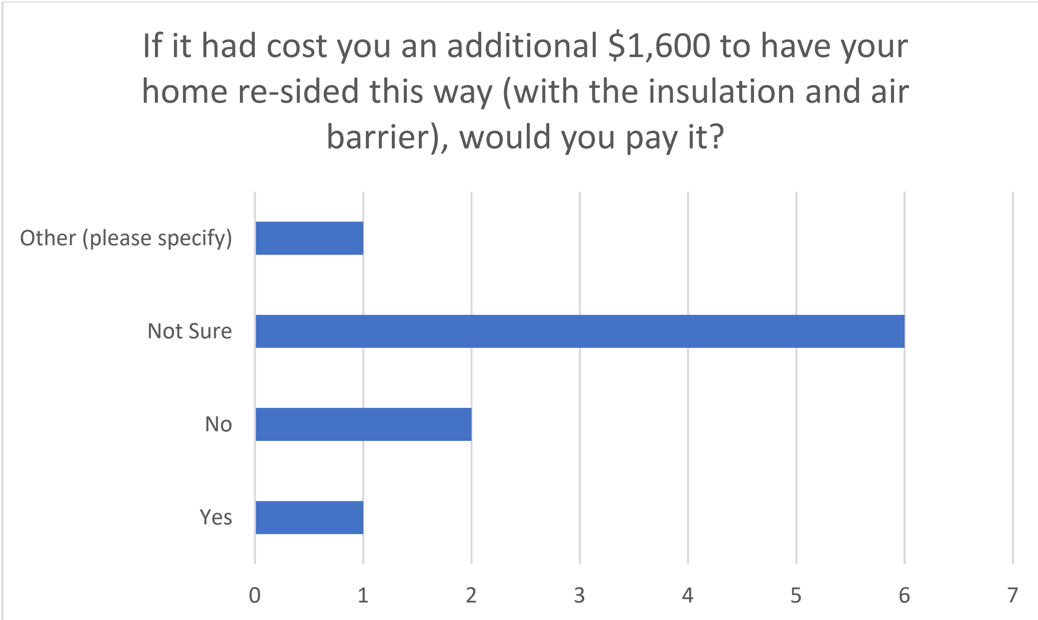


Figure 33. Survey: Pay $1,600 more?

Our calculations showed that Re-Side Right costs about 7% more in materials and 8–16 person hours (which is anticipated to go down with experience). Labor rates vary, but the $1,600 price differential is on the low side of estimates. Yet even at this price increase, most participants were not sure they would re-side their home this way.

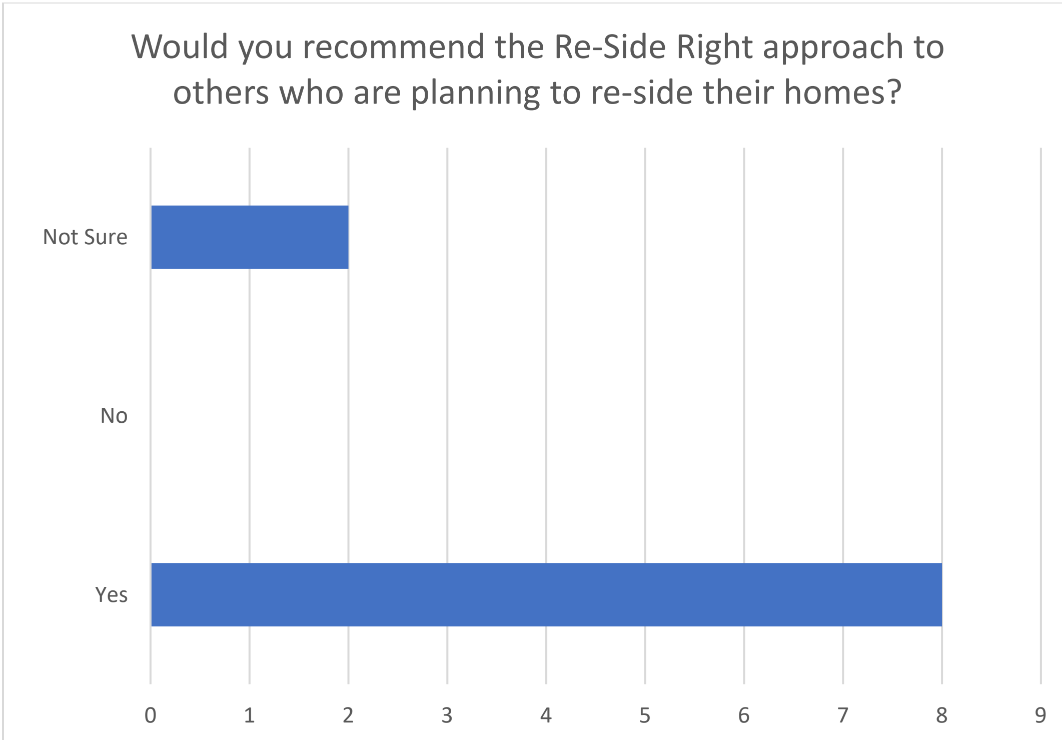


Figure 34. Survey: Recommend Re-Side Right?

Most participants would recommend the Re-Side Right approach to others that are planning to re-side, but the previous question shows that cost would be a major factor. As has been noted, an incentive program for Re-Side Right may be necessary for wider adoption.

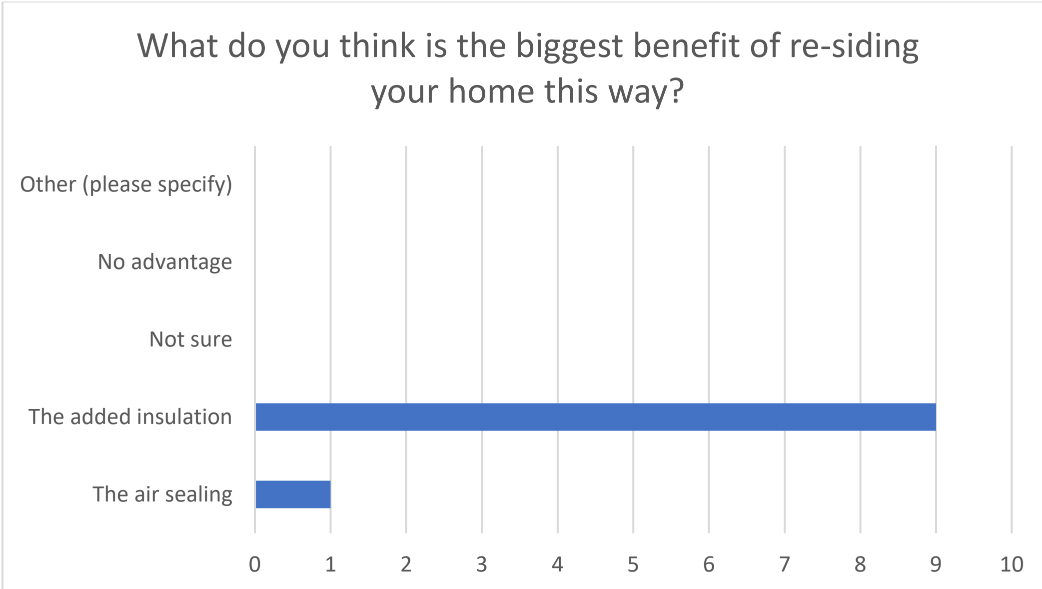


Figure 35. Survey: Biggest benefit

Most participants thought the biggest benefit of re-siding their home this way was the added insulation, with two homeowners choosing the air sealing as the biggest benefit. The insulation is easier to see and understand, so it is reasonable that the main perceived value is that added material. As such, the insulation should be stressed when promoting this approach.

2.6 Contractor Interviews

The contractors were interviewed after the program was completed. Their summarized/paraphrased responses are presented next.

Table 13. Contractor Interviews

Question	Contractor 1	Contractor 2	Contractor 3
How was it for you to participate in Re-Side Right?	It went well, only issues were first time using fiber cement, discovered houses didn't have plywood sheathing so all connections had to be made into the studs. Also, with the thickness of the insulation we had to use furring strips over the insulation and through the 5/8" fiberboard to get to the studs. Supply chain issues came into play because of COVID-19. The materials weren't that hard to get, compared to other things.	Overall good experience, different than what was expected and took longer than expected.	Good experience, saw value in offering to customers, some good, benefits, being able to offer it for free to existing customers. Learning about the product and the intricate details, the taping screws and plugs, the liquid flashing. Right now, exterior insulation is a small part of our business.
How was it for the people in the field?	This is not difficult, it didn't faze our field guys. Our learning curve was a day or two. We had 2 different crews.	It took longer than expected. The self-adhered flashing can be tricky.	First one was challenging, more involved, we usually just do ½" fanfold to flatten the existing wall. After one, then it was easier.
What would you change?	May not be feasible, if sausages could be replaced with slow curing expanding foam, apply easier and faster?	No change, didn't know we'd have to go down to the sheathing. And that took longer, normal siding. Ripping off old shingles and nails, have someone else come in and do that.	Lead time on the products was a killer, getting in early and getting the material in the storage unit in bulk in advance would have helped.
What was the most difficult aspect of it?	Nothing really difficult, once it was figured out, figuring out how to best address the different type of window situations. Make sure they're all sealed and watertight given certain situations. Window flashing was most difficult.	Learning curve, first sealant around windows one way, and have to do it differently, sealant on all edges versus certain edges, once that was sorted out, it got easier. Beginner jitters, not ironed out right away.	Materials getting to the site on time was an issue. It was mostly logistical issues.
Do you think it would become	Definitely over time. Get comfortable with technique and application, it's a little different. Like the idea of being able to put it down and trowel it, zig zag	Yes	Yes

Question	Contractor 1	Contractor 2	Contractor 3
easier over more jobs?	wasted material. Roofing cement, similar consistency, sell in 1-, 3- and 5-gallon cans. If sausage was in a can, scoop it out and apply like mortar?		
Roughly How much more time did it take to do the job this way?	About a day	Probably took 3x longer, because I was solo, and had a lot of rotten wood and damage to repair. With a normal crew and planning and better substrate, would have added 1 or 2 days.	Remove siding, install water barrier, then trim and then siding, 3 days 5 for a larger house.
Will you do this again? Offer it?	Would do [Re-Side Right] again, it sets [company] apart from the average siding guy, no insulation better to blow in first can get R-15 if already have insulation in walls. R-value per inch for Neopor as compared to extruded poly or expanded poly. Compare cost for house wrap and insulation vs. Neopor.	A good selling point for Re-Side Right is that it's green, better insulated and can decrease heating and cooling costs, especially if there's an incentive cost. Higher labor cost, in long run you'll have energy saving in the long run. But if there are old windows, does it still make sense? Replace doors and windows then more improvement.	Have not, have offered insulation recently, but most insulation are for vinyl product. Blown in insulation complicated fiber cement. above 1" have to do furring strips, Foam backed product on vinyl so expensive cost to Fiber cement cost. Premade product for insulated siding.
Are customers satisfied?	Yes	Customer was satisfied.	Customers were satisfied with it. All worked out.

2.7 Contractor Training

The online contractor training created by NJIT reviews the building science behind Re-Side Right, steps to take before beginning, the installation process, and pricing and sales. The video can be seen at www.resideright.org.

Figure 36. Screenshot of Re-Side Right training video

3 Conclusions

3.1 Costs/Benefits

The first research question for this project was: Will the addition of an air barrier and continuous insulation to a standard re-siding job (Re-Side Right) prove to be attainable at a reasonable incremental cost?

- Re-Side Right achieved approximately 9% reduced source energy use at an incremental cost increase of $2,000–$4,000. The incremental cost for Re-Side Right is not insignificant. However, anticipated subsidies for residential energy upgrades through the Inflation Reduction Act (U.S. Congress 2022), as implemented by State Energy Offices, could support Re-Side Right by reducing the cost and bringing the benefit of the Inflation Reduction Act subsidies to contractors that would not otherwise be included in energy efficiency programs.

Our second research question was: Will durability risks be addressed with best practice installation methods?

- Our hygrothermal data from House 6 shows that the sheathing did not reach the 80% moisture durability threshold.
- As noted earlier, for all the houses, adding continuous insulation will reduce the potential for moisture accumulation in the exterior sheathing because we are reducing the vapor pressure drive and condensation potential from the building interior to the sheathing by reducing the temperature difference between the two locations.
- The flashing around windows in the 10 Re-Side Right houses was typically incomplete or non-existent. Sheathing decay was evident at the sill corners of windows in the majority of homes. The added liquid and self-adhered flashing should improve draining water away from the sill corners and down the water resistive barrier face of the insulation.

Our next research question was: Will the Re-Side Right approach be a value-added package that re-siding customers are willing to pay for?

- As can be seen in the homeowner survey results, when the Re-Side Right participants were asked if they would pay an additional $1,600 for the Re-Side Right approach, the majority were not sure or would not. This cost is actually lower than the costs that were determined at the end of the study. The authors believe subsidies would be needed for a strong program rollout.

Our final research question was: Will re-siding contractors readily learn the Re-Side Right approach and want to offer it to their customers?

- For contractors to readily offer Re-Side Right, an on-bill financing program or some kind of rebate will most likely be needed. As can be seen in our contractor interview section, one participant would offer it again. A second contractor would offer it, but wondered if it is better to replace doors and windows. The third contractor sees insulated vinyl as the direct competition to Re-Side Right, and he is not sure his customers would pay for Re-Side Right.[8]

Ultimately, Re-Side Right can help prime homes for electrification and reduce greenhouse gas emissions. This is because Re-Side Right's reduction in infiltration and improved overall R-value can help reduce loads and be a part of the enclosure upgrade needed to move homes from fossil fuel-burning heat sources to electrification (e.g., heat pumps).

3.2 Impact

Re-Side Right has the potential to catalyze a paradigm shift in how energy upgrades are implemented in existing homes: instead of trying to push efficiency measures as stand-alone projects undertaken for energy reasons alone (as done in the majority of utility-based energy efficiency programs in the country), the Re-Side Right approach layers energy efficiency upgrades onto home improvement projects that are happening anyway. With this approach, the incremental costs of the upgrades are less onerous—since the bulk of the home improvement is being paid for anyway—and the resulting paybacks would be relatively short. Re-Side Right also puts the work in the hands of the re-siding contractor because they are already dealing with the exterior of the home, and are uniquely positioned to provide the continuous exterior air sealing and insulation. Re-Side Right explored all these benefits and their potential to motivate contractors to venture beyond conventional approaches to adopt "energy-enhanced" re-siding as part of standard practice.

The target market for the Re-Side Right initiative is re-siding contractors in U.S. climate zones 3, 4, and 5, which covers large portions of the Northeast, Midwest South, and West. Climate zones 1 and 2 may not see enough saving from Re-Side Right to make the approach worth the effort. In climate zones 6 and 7, depending on the existing cavity insulation, the continuous insulation may have to be increased to avoid the potential for condensation within the wall assembly.[9] The New Jersey Better Business Bureau lists more than 800 siding contractors in the state (Better Business Bureau 2022). It is anticipated that similar numbers apply in the 40 states that include areas in climate zones 3, 4, and 5. The Center for Building Knowledge estimates somewhere between 30% and 50% of the more than 1 million homes re-sided every year will be located in climate zones 3 to 5—a total of between 300,000 and 500,000 re-siding projects per year could be implemented by roughly 3,000 to 5,000 re-siding contractors.

[9] For new construction, the 2018 IECC requires R-10 continuous insulation for climate zones 6, 7, and 8 if the cavity insulation is R-13.

3.3 Installation

Following are takeaways from our contractors' experience installing Re-Side Right.

- The additional time needed for the Re-Side Right approach should decrease as contractors do more jobs.[10]
- The liquid flashing was unfamiliar to most of the installers. It is not yet widely used in residential retrofits.
- 1" of rigid insulation can be easily accommodated by standard trim materials and details.[11]
- The biggest impact on the time and cost of the installations was the condition of the wall substrate. This would impact any re-siding job, but this is particularly true for Re-Side Right, since the substrate has to provide a viable surface for air sealing and shingle fashion installation of liquid and self-adhered flashing.
- Installing the rigid insulation with cap nails can slow the job significantly if the nail length isn't as short as possible while still providing adequate connection, 1-3/4".
- If the house sheathing is brittle or in poor condition, an auto feed screw gun should be used.[12] For a full program rollout, there would need to be a way to handle QA/QC, potentially by spot checking a certain percentage of jobs once a contractor is properly trained. Requiring photo submissions at each stage could be an effective strategy.

3.4 Actionable Guidance

A Re-Side Right report card, or leave behind, could be very useful to help homeowners continue on their journey toward energy efficiency. Leaving an actionable list of suggested additional measures (like air sealing in the attic and basement) and ways homeowners can connect with their local Home Performance with ENERGY STAR® (Office of Energy Efficiency and Renewable Energy) program could be a powerful way to leverage existing programs.

The Re-Side Right training (www.resideright.org) is available now for any siding contractor or siding company that wants to use it. Although it is beyond the scope of this project, it may be of interest to the Vinyl Siding Institute and other trade organizations, as well as siding

[10] One contractor completed 7 jobs, one completed 2 jobs, and the third contractor re-sided 1 house. As expected, the contractor that completed one house has the biggest time increase for the work as his learning curve did not benefit further jobs.

[11] NJIT found that the trim around windows and doors had a minimal time/cost impact to cover the 1" of exterior insulation. All the houses in the study were able to accommodate the insulation thickness without special trim details or additional material.

[12] The gun itself costs about $425 and the screws with the proper washers for the insulation install cost $160.52 per 1,000 count at the time of the study. Each insulation panel requires about 34 screws if following the manufacturer's nailing schedule, and the average house panel count is 72, so each house requires about 2,500 screws, or 2.5 cartons of screws, for a cost of about $400. 1-3/4" cap nails cost about $15/1000, so less than 1/10 the price. Whether the speed and accuracy provided with this attachment system can justify the extra cost is dependent on the contractor, the volume of siding jobs they do, and their scheduling. The screw gun also offers the quality assurance of not compromising the water resistive barrier on the rigid insulation during attachment.

manufacturers and rigid insulation companies to facilitate more siding jobs being done that also improve energy performance.

3.5 Future Work

Re-Side Right was the next step after Re-Side Tight, which added an air barrier while re-siding but no insulation. NJIT's next project continues the opportunistic retrofit approach while re-siding with Renew-Wall. Renew-Wall increases the exterior insulation to 2" and includes an exterior high-performance storm window at all windows using a "Thermal Buck" window surround. The increased R-value can significantly increase the savings and expands the application to colder climate zones.

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