Air Sealing Opportunities in New Construction

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ABSTRACT

Advanced air sealing methods are an integral part of energy-efficient new construction programs such as the ENERGY STAR® New Homes program or Energy Trust of Oregon's Energy Performance Score (EPS) New Homes program. In an effort to isolate the impact of specific air sealing, Energy Trust tested two different pilots and is in the process of conducting a third.

The first Air Sealing Pilot test, conducted in 2012, considered the house-tightness impact of a simple foam gasket, installed by wall insulation contractors, when applied to the top plate of interior and exterior walls of the top floor of a residential structure. The top-floor-only approach was used to address the leaks in the building that experience the highest pressure and to keep installation costs low. Airtightness testing was performed on 50 homes that received the gasket treatment, along with a control group of another 40 homes that didn't receive the gasket treatment. The tests revealed an ACH50 of 5.38 untreated homes and 4.58 in treated homes, a drop of 0.8 ACH50 in homes that received the top plate gasket.

The second Air Sealing Pilot test, completed in February of 2014, involved using a blown fiberglass wall system in 20 new homes. The air tightness of these homes was compared to the airtightness of homes with an R-21 batt installed in the walls. This study used a matched pair design to help minimize other housing characteristics that affect house tightness. The average ACH50 for the non-treated homes was 5.76 ACH50 and 4.72 for the treated home.

Introduction

Over the last few years, Energy Trust has conducted a series of pilots to test the impact and market acceptance of various air sealing strategies. In addition to finding savings in non-whole house energy efficiency program homes, the Air Sealing Pilots were designed to help builders find simpler, more cost-effective methods of reducing air leakage in new construction. Program field staff reports that many builders still find it difficult to identify cost-effective air sealing strategies. As building codes become increasingly stringent, the need for builders to properly air seal homes is more important than ever – especially given the high cost and difficulty of retroactively air sealing homes.

The Air Sealing Pilots described in this report were intended to identify and examine the effectiveness of new and inexpensive measures that could be easily incorporated by the majority of builders, not just the builders who build high-performance homes. The Air Sealing Pilots were also conducted as a market test to determine the feasibility of leveraging subcontractor measure acceptance as a cost-effective way to influence a large number of builders.

The Top Plate Pilot

The use of a top plate gasket has been a part of the airtight drywall approach (ADA) to air sealing in new construction since the late 1980s (BSC 2009). While the approach has been practiced since the 1980s, very little research has been undertaken to determine the effectiveness of the individual air sealing measures that comprise ADA. This knowledge gap was an additional reason Energy Trust conducted the 2012 Air Sealing Pilot.

While only a part of an ADA, the top plate gasket was considered for pilot for three main reasons. The first is its low cost, therefore offering a possibility of it being a cost- effective measure; second, the relatively low level of training needed for its installation and third, that only one sub-trade (the insulator) was involved in its installation

Product Description

Sill sealer was used as the material to form the gasket. Typically used in construction between the top of the foundation wall and the baseplate as a capillary break and as part of an air barrier, sill sealer is a polyethylene foam product designed to last the life of a house. In its application as a gasket between dry wood and Sheetrock, it is not exposed to water or UV light, and therefore is not likely to degrade. The product is 3and ½ inches wide and approximately 3/8 inch thick. The sill sealer was placed on the face of top plates, of both interior and exterior walls, that would eventually be sheet rocked on the top floor of the house. It formed a gasket between the sheetrock and the top plate.

The Top Plate Pilot project was jointly carried out by Energy Trust, PECI and Fluid Market Strategies (now CLEAResult). PECI was the project lead in contractor training, contractor outreach and program management. CLEAResult aided with contractor outreach, conducted the field measurements and analyzed the data. There was a high degree of cooperation between all parties in this pilot, which aided in its successful completion. This report focuses on the in-field inspection/diagnostics and the results of those efforts.

Figure 1. Pink material is sealer applied to top plate. *Source:* Bruce Manclark.

Research Design

The project involved the airtightness testing of two groups of newly constructed homes. The untreated sample tested 39 homes without treatment and the treated sample tested 40 homes with top plate gaskets installed. The homes were limited to single-family. No homes greater than 3,500 sq. ft. were tested. The builders were recruited for testing by telephone and site visits. The homes were tested at “final” with all trim, carpeting and painting completed. Homes participating in energy-efficient home programs such as ENERGY STAR New Homes or EPS were excluded from the study.

Incentives

Insulation contractors were paid an incentive of $125 to install the measure, and builders that allowed the program to test untreated homes were paid an equal amount.. The $125 amount represented the market price at the time of the study. Contractors were trained to use the tilt-up method of placing the drywall on the vertical wall surface. The slide-up method can cause the sill sealer to double up and cause gapping problems. Using this tilt-up method, no “nail pops” were encountered by the builders

Tests Conducted

All homes were tested for airtightness using a Minneapolis blower door in conjunction with a DG-700 manometer. The homes were depressurized to minus 25Pa and minus 50pa. The flow exponent was calculated to validate the tests. An extensive checklist was utilized to ensure that the homes were uniformly prepared for the testing. This included such items as crawlspace ventilation placed in the open position, window latches placed in the locked position and exterior garage door closed. In addition to the diagnostic pressure measurements, all homes with treatment were visually inspected from the attic for presence of the sill sealer. Figures 2 and 3 demonstrate the presence of the sill sealer.

Figure 2. Attic view of sill sealer. *Source:* Bruce Manclark.

Housing Characteristics

The average conditioned square footage of the homes in the study was 1,944 sq. ft.; the average square footage of untreated homes was 2,055, and the average square footage for treated homes was 1,837. Figure 4 shows the distribution of house size for both groups. . All homes in the study were constructed by production builders. 95% percent of the homes were two story homes; all had composite wood siding installed over building wrap. All were built over ventilated crawlspaces with 2X10 floor joists. All the homes had forced air systems with the majority of the ducts located outside the conditioned space. Oregon code requires “fire caulking” around all plumbing and wiring penetrations. The fire “caulking” was performed on both the treated and untreated homes. Windows and doors and door openings were caulked. Sill plates were not caulked.

One insulator accounted for over 80% of the insulation subcontracting for both groups. They were also the installers of the top plate gasket and the sheetrock in these homes. All homes in the study used R 21 batts. They were “speedy” batts, implying no stapling at the flanges to the wall studs. None of the homes had interior vapor barriers.

One builder accounted for almost half the homes in both groups. The difference between in the average between the untreated and treated homes for this builder was .7 ACH50Pa similar to the reduction for the larger populations

All blower door testing was conducted during late summer and early fall. Access was gained upon final and before the buyers moved in. The temperature differences between inside and outside were usually small and less than 10 degrees. Baseline pressures differences were accounted for (again these tended to be very minor) A standard protocol set used for set up of the homes. These protocol included taping off dryer ducts, p traps,, opening of crawl space vents, and closing the exterior garage door All test were a two point test, performed at 25Pa and 50Pa

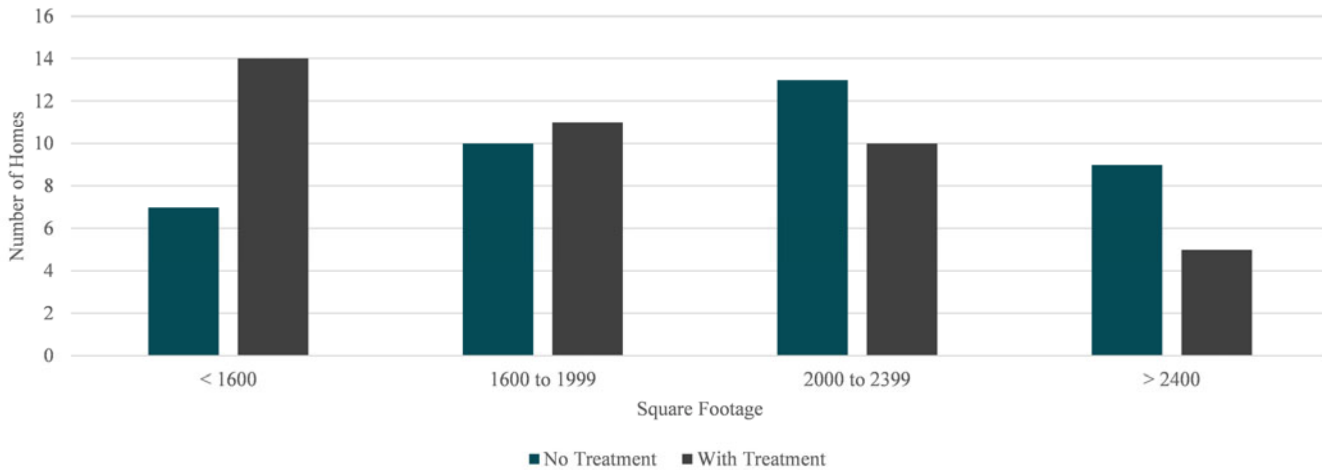

Figure 3. Treated and untreated homes by square footage range.

Findings

House tightness is most typically expressed in air changes per hour at 50 Pascals (ACH50). While this metric is useful, it can show a bias when comparing homes of unequal sizes. Compared to smaller homes, larger homes usually have more square footage of conditioned space per square footage of total heat loss surface area. These areas include all exterior walls, door, window, ceiling and floors. Home leaks occur at the exposed surface areas, such as floors, walls and ceilings. Figure 5 illustrates the general trend of larger homes and the decreasing ACH50 value. At the time of study, there were no state-wide tightness code requirements.

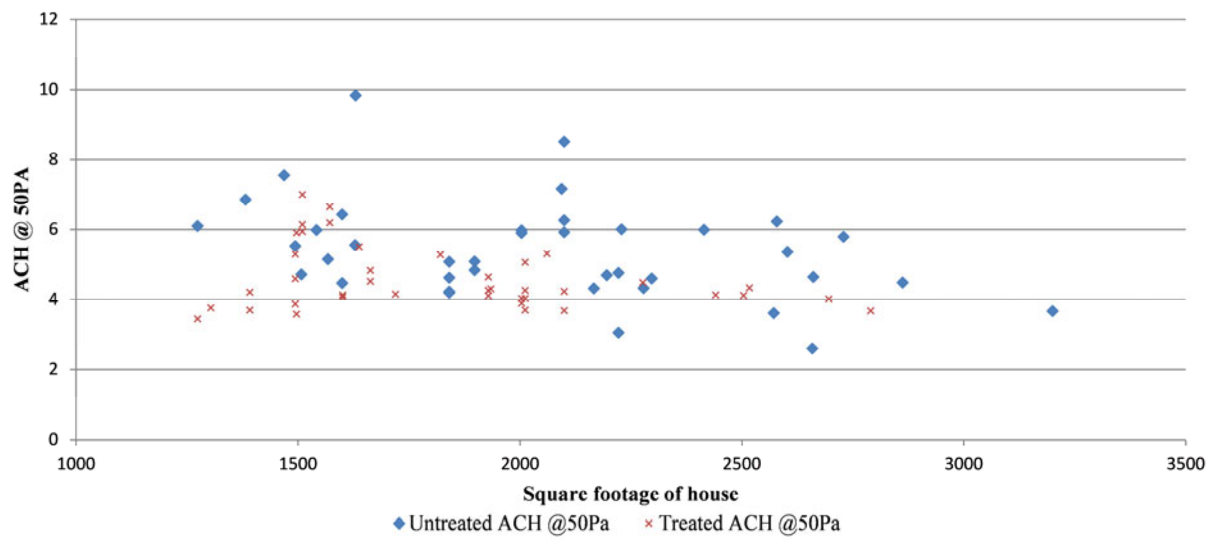

Figure 4. ACH50 vs. square footage.

ACH50

ACH50 was calculated as a means of comparison with other programs. As shown in Figure 5, the average ACH50 for the untreated homes was 5.38. The same leakage rate for treated homes was calculated at 4.58, indicating a difference of 0.8 ACH50 between the two groups.

CFM50/Sq. Ft

To minimize the bias that house size introduces on reported house tightness, this report uses a ratio of cubic feet per minute at 50 Pascals per square foot (CFM50/sq. ft.), as shown in Table 1.

Table 1. CFM50/sq. ft

	Without Treatment	With Treatment	Difference
Average CFM50/sq. ft.	0.76	0.65	0.11
Standard Deviation of Average CFM50/sq. ft.	0.20	0.12	0.07
Average sq. ft.	2,055	1,836	

This data indicates that, for example, an untreated 2,000 sq. ft. house would have a CFM50 reading of 1,520, while an identical house with the measure would have a CFM50 reading of 1,300 – for a difference of 220. This represents a leakage reduction of 15 percent.

Regression Analysis Results

The figure below shows the results of a regression model, with measured ACH 50 taken as a linear function of house size and treatment status. The estimated effect of the top plate sealing – adjusting for differences in square footage – was one fewer air change per hour, with 95% interval spanning -1.5 to -0.5. This treatment effect was highly significant with p-value < 0.001.

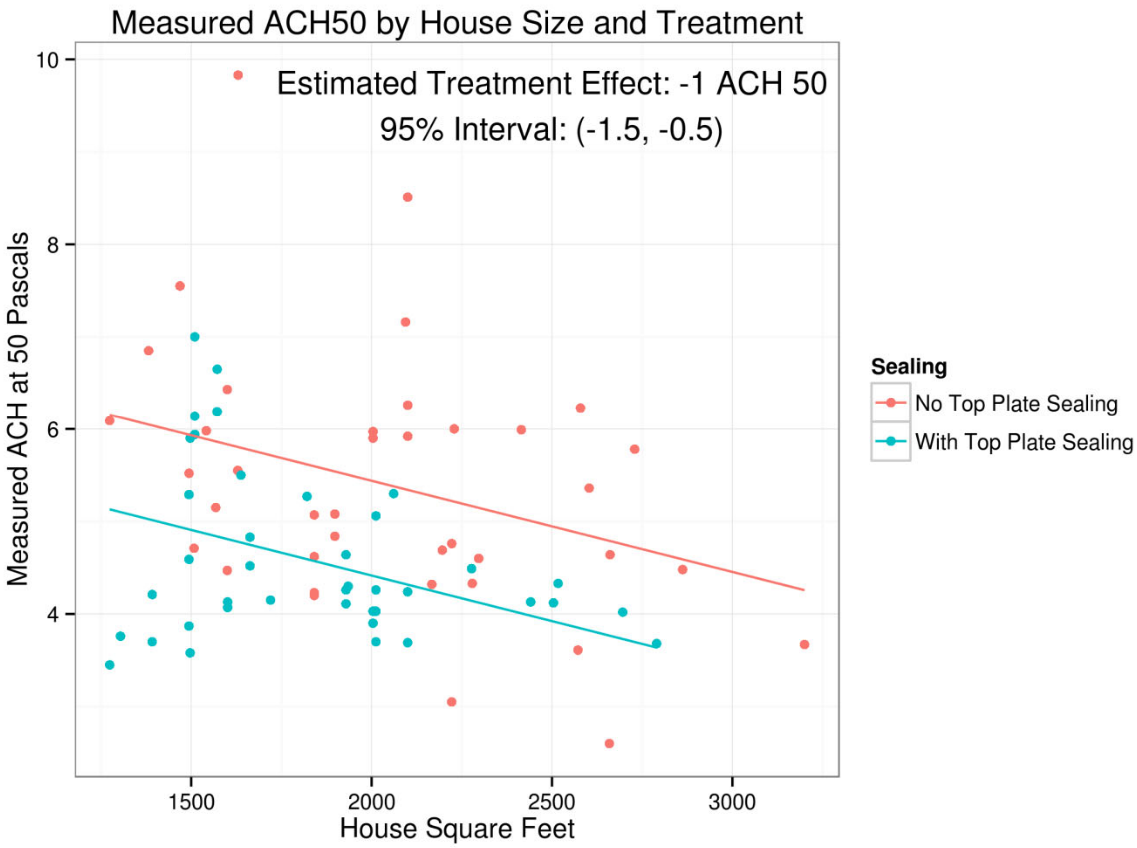

Figure 5. ACH50 by group and insulation type.

As the difference between the two groups in this dataset was highly significant, the main question is the extent to which the findings generalize. This was not a large random sample. Site selection was accomplished by finding builders willing to to participate and by general house type. As pointed out elsewhere in this paper homes were kept as similar to each other to the greatest extent possible.

The Energy Trust study is not the only study to demonstrate that sealing the top plate with sill sealer has an impact on whole house leakage. Field and lab studies conducted by Owens Corning found a .3 to 1.6 ACH reduction from top the plate gasket (Wolf 2012). By comparison, Energy Trust's study averaged a .7 ACH reduction. Owens Corning found a .3 to .7 CFM50/sq. ft. reduction, while Energy Trust's study found a slightly higher reduction of .81 CFM50/sq. ft. The Owens Corning study further concludes that top plate air sealing has a very high CFM reduction for the cost.

Energy Savings

Ecotope of Seattle, Washington, was commissioned to generate energy savings using the energy modeling software SEEM 94 (Simplified Energy and Enthalpy Model). The three base case homes that the Regional Technical Forum (RTF) uses to model energy-efficient measures were used in these simulations. These homes represent typical Northwest homes of 1,344 sq. ft., 2,200 sq. ft. and 2,688 sq. ft. The homes were assumed to be built to Oregon code levels and were modeled in both Portland and Redmond, Oregon. The heating system for the gas heated homes was assumed to have an AFUE of 83 percent and the heat pump system was assumed to have an annual operating COP of 2.2.

Additionally, it was assumed that these homes had a 50 CFM exhaust fan running four hours per day. This ventilation rate is the standard rate (4 hours per day) used in the modeling of the RTF base case homes. The modeled house nearest to the homes found in the sample is the 2,200 sq. ft. house. It is a two-story house typical of the style that dominated the homes tested in this project. Estimated therm savings for a variety of house sizes and climate zones are shown in Tables 3 and 4 for electric- and gas-heated homes, respectively. In both tables, Heating Zone 1 reflects climatic conditions in western Oregon and heating Zone 2 is reflective of central and eastern Oregon.

Table 2. Modeled annual energy savings estimates for treated homes with electric heat

Energy Model	Air Infiltration Metric	Heating Zone	Home Size (sq. ft.)	Baseline Homes: Energy Used for Heating (kWh)	Treated Homes: Energy Used for Heating (kWh)	Energy Savings (kWh)
SEEM	CFM/sq. ft.	1	1,344	2,196	2,126	70
SEEM	CFM/sq. ft.	1	2,200	4,110	3,969	141
SEEM	CFM/sq. ft.	1	2,688	3,414	3,288	126
SEEM	CFM/sq. ft.	2	1,344	3,617	3,520	98
SEEM	CFM/sq. ft.	2	2,200	6,464	6,271	193
SEEM	CFM/sq. ft.	2	2,688	5,478	5,304	174

Table 3. Modeled annual energy savings estimates for treated homes with gas heat

Energy Model	Air Infiltration Metric	Heating Zone	Home Size (sq. ft.)	Baseline Homes: Energy Used for Heating (therms)	Treated Homes: Energy Used for Heating (therms)	Energy Savings (therms)
SEEM	CFM/sq. ft.	1	1,344	199	193	6
SEEM	CFM/sq. ft.	1	2,200	373	360	13
SEEM	CFM/sq. ft.	1	2,688	310	298	11
SEEM	CFM/sq. ft.	2	1,344	328	319	9
SEEM	CFM/sq. ft.	2	2,200	587	569	17
SEEM	CFM/sq. ft.	2	2,688	497	481	16

The most typical home size scenario is 2,200 sq. ft., which, using the SEEM estimates, was associated with 13 therms per year in gas homes and 141 kWh per year in electric homes in western Oregon. Savings were slightly higher for central and eastern Oregon, as expected.

Measure Life Assessment

As mentioned earlier, sill sealer is designed to last the life of a house and is not likely to degrade when applied as a gasket between dry wood and Sheetrock. The RTF deems shell measures in residential new construction with a life of 70 years, while Energy Trust generally deems shell measures with a life of 45 years (Rubado 2013). In addition, several subcontractors commented in the post-participation interviews that they believed sill sealer was much less prone to degrading and failing over time than caulk or other alternatives and would likely last the life of the structure. For these reasons, it is probably safe to assume that this air sealing measure will have a longer life than the 30 years initially assumed for the purposes of this pilot.

Measure Cost-Effectiveness

In order to test the sensitivity of measure life on the total resource cost (TRC), test results for various measure lives are shown below. The authors believe this to be important given the marginal cost-effectiveness of the gas homes. Tables 5 and 6 show the cost-effectiveness test results of the air sealing measure for a typical 2,200 sq. ft. home in western Oregon with three different measure life assumptions. The TRCs for gas- and electric-heated homes are presented in separate tables. The total cost of the measure is equal to the incentive amount paid to the subcontractor, which was assumed to cover the entire cost of installation. The total benefits include the net present value of the energy savings based on the assumed measure life. The RTF deems shell measures with a life of 70 years, and this study finds no reason to disagree.

Table 4. TRCs for the air sealing measures installed in a typical 2,200 sq. ft. home in western Oregon with electric heat

Energy Model	Air Infiltration Metric	Measure Life	Total Cost	Total Benefit	TRC
SEEM	CFM/sq. ft.	30	$125	$246	1.97
SEEM	CFM/sq. ft.	45	$125	$288	2.30
SEEM	CFM/sq. ft.	70	$125	$316	2.53

Table 5. TRCs for air sealing measures installed in a typical 2,200 sq. ft. home in western Oregon with gas heat

Energy Model	Air Infiltration Metric	Measure Life	Total Cost	Total Benefit	TRC
SEEM	CFM/sq. ft.	30	$125	$114	0.91
SEEM	CFM/sq. ft.	45	$125	$131	1.05
SEEM	CFM/sq. ft.	70	$125	$316	2.53

Blown-In Wall System Pilot

Blown-in wall insulation is a system that utilizes a blown fiberglass product installed in wall cavities prior to application of Sheetrock. The product utilizes a netting material attached to wall studs to hold the insulation in place and achieve required densities. All major loose-fill fiberglass manufacturers have a product that can be applied in this manner. The acronym BIBS® is a registered trademark of BIBCA (Blown-in Blanket Contractors Association). Not all blown-in fiberglass manufacturers belong to this organization, and hence the acronym cannot be applied to all blown-in wall insulation systems. The product used in this study was CertainTeed InsulSafe® SP fiberglass blown-in insulation. The untreated homes in the study used the CertainTeed R-21 Speedy® batt.

The product is tested in accordance to ASTM C522 - Air resistance of Acoustical Materials. Results from the CertainTeed manufacturer's test indicated that when applied at densities of 2.2 per cu. ft., the material has the same resistance to airflow as cellulose at 3.5 lbs. (CertainTeed 2013). This documented ability to resist airflow led to Energy Trust's interest in piloting the product.

Figure 6. Staff checking density. *Source*: Bruce Manclark.

Research Design

The project utilized a matched-pair design approach. Identical or near identical homes were separated into two groups; one with the treatment and one without. The original plan was to have 20 homes in each group. Due to the inability to find a well matched pair for all homes in the project, the final split was 23 homes with the blown-in wall treatment and 17 homes without. The non-matched homes are included in the analysis unless otherwise noted.

Building Characterization

Homes in this pilot averaged 1,642 sq. ft., including the four duplex buildings. Average square footage, minus the duplexes, was 1,728. Table 7 shows additional detail on the size of participating homes. Thirty six of the homes were by the same builder, using the same subcontractors. Four others were built by another builder. All homes were insulated by the same insulator. Eight of the units were duplexes comprising four buildings. These were treated in a similar fashion with two buildings being treated with the blown-in product (including the party wall) and with the Speedy batt.

In addition to the blown-in wall treatment, all homes had the top plates gasketed with sill sealer. Thirty six of the homes (all by the same builder) used a post and beam flooring system utilizing 2X6 tongue-and-groove car decking. This system is referred to as the "Oregon Floor." It is known to be leakier than the more common floor system comprised of joist and sheathing, and we suspect this led to a leakier base case. All homes were built over ventilated crawlspaces.

Table 6. Average square footage of homes in pilot

	All Homes	Batt Wall, All	Blown Only	Duplex Only, Batts and Blown	All Non-Duplex Sits	Non-Duplex, Blown Only	Non-Duplex, Batt Only
Avg. sq. ft.	1,643	1,609	1,678	1,352	1,728	1,759	1,694

Incentives

The insulation contractor was paid an incentive of $500 for each of the treated homes. This was negotiated in advance and is considered market price.

Tests Conducted

All homes were inspected at rough in and visually inspected for air sealing details, such as top plate gasket completeness and electrical and plumbing penetration sealing as required by code. These penetrations were sealed at the top and bottom plates of exterior and interior walls. Duct systems were inspected for disconnects and sealing details. Homes with the blown-in wall system had density checks conducted in at least four random spots. After one failed job for low density early in the program, all subsequent homes exceeded minimum density requirements of 2.3lbs/cu. ft.

Findings

In addition to the ACH50 and CFM50 metrics, this pilot also utilized the CFM50 per exterior sq. ft. metric in an attempt to normalize results over a wider range of square footage. All three metrics showed a decrease in the leakage rate of the homes. Exterior surfaces included all exterior walls, windows, doors, ceilings and floors. It does not include interior walls ceilings and floors.

The duplexes in the study were found to be leakier than the non-duplex homes by slightly more than .4 ACH50. The reasons for this are undetermined. The party walls were also treated with the blown-in wall system. The duplexes were tested as a single home with the adjoining unit opened to the outside to simulate an outside wall. Below, Tables 8 and 9 respectively demonstrate our results for all homes and our results with duplexes excluded.

Table 7. Blower door test results, all homes

Measurement	Batt	Blown-in Wall	Difference
ACH50	5.77	4.72	-1.04
CFM50	1,314	1,114	-199
CFM50/sq. ft.	0.83	0.68	-0.15
CFM50/exterior sq. ft.	0.31	0.25	-0.055

Table 8. Blower door test results, duplexes excluded

Measurement	Batt	Blown-in Wall	Difference
ACH50	5.31	4.25	-1.05
CFM50	1,300	1,080	-221
CFM50/sq. ft.	0.77	0.62	-0.16
CFM50/exterior sq. ft.	0.29	0.23	-0.057

ACH50

In all cases, the treated home in the matched pair was tighter than the untreated home. The average difference was the ACH50 average dropping from 5.76 to 4.72 ACH50 for a delta of slightly over 1 ACH.

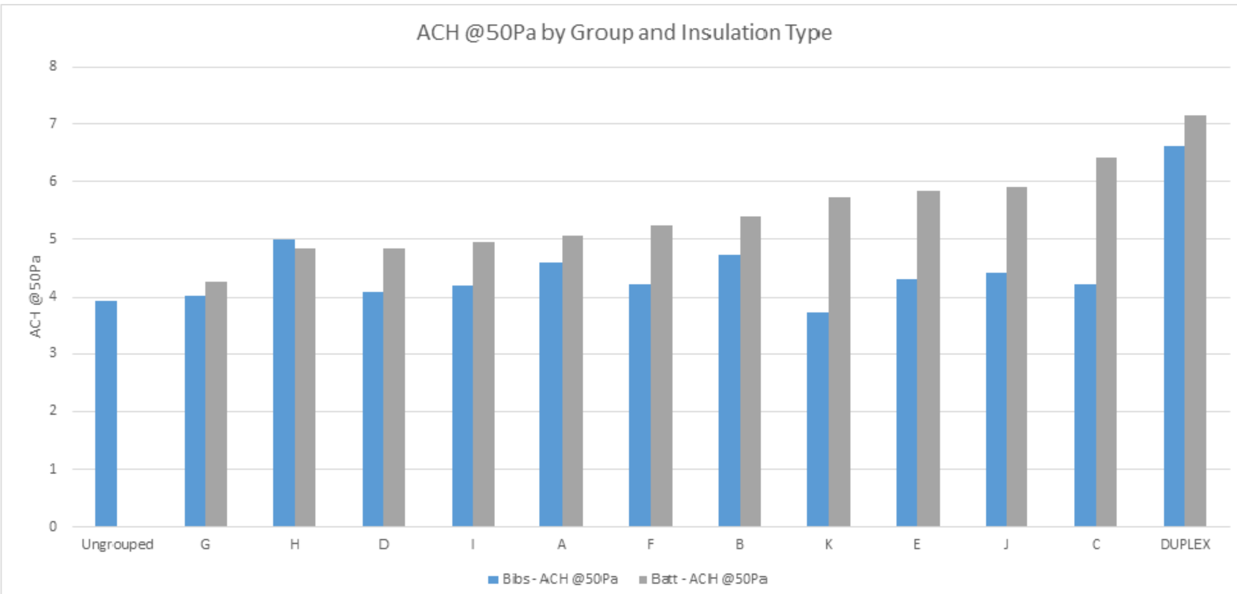

Figure 7. ACH50 by group and insulation type.

CFM50/Sq. Ft

The decrease in this metric was from .83 CFM50 to .68 for a decrease of .151. Once again, the influence of the duplexes can be seen. As Figures 7 and 8 indicate, removing the duplexes changed the metric considerably. Without the duplexes, the impact of the measure is substantially more consistent across the various square footages.

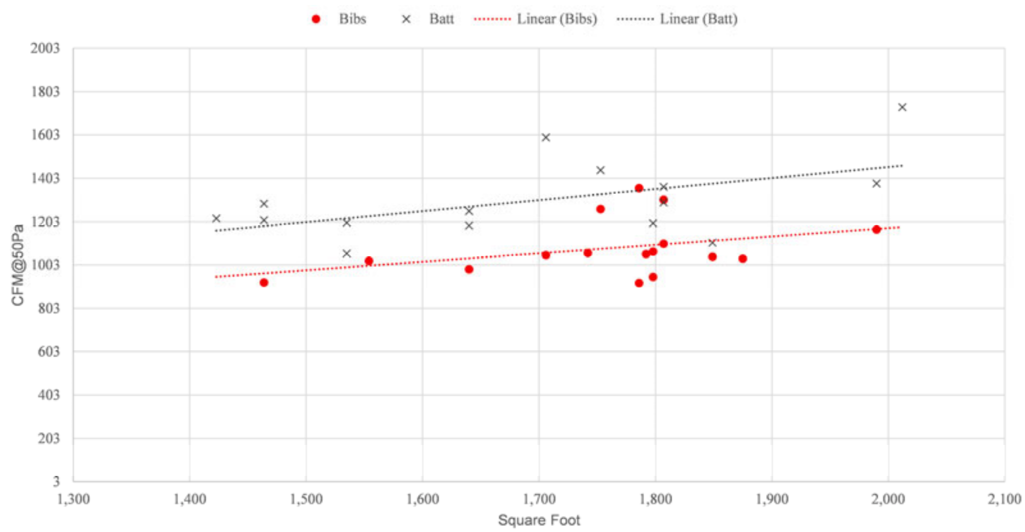

Figure 8. CFM 50 vs. square footage, duplexes excluded.

FM50/Exterior Surface Sq. Ft.

The metric was chosen in an effort to minimize the effect of the size of the house on reported leakage reduction. To eliminate the ACH50 bias, the total exterior surface area of the house was used, thereby capturing all the planes of the house that do indeed leak. In fact, commercial air leak standards for large building use this metric (USACE 2012). Removing the duplexes from the sample once again had a large impact. Note the results in Figure 9 include duplexes, whereas Figure 10 shows only the non-duplex lines. As expected, the impact of the measure is more consistent using this metric, especially for the treated homes.

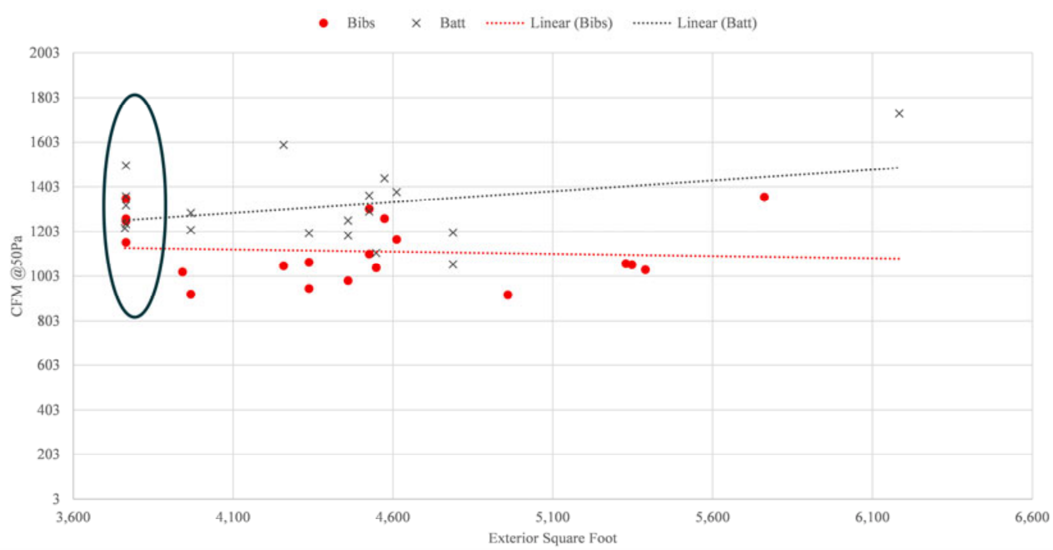

Figure 9. CFM50 vs. exterior square footage, duplexes included.

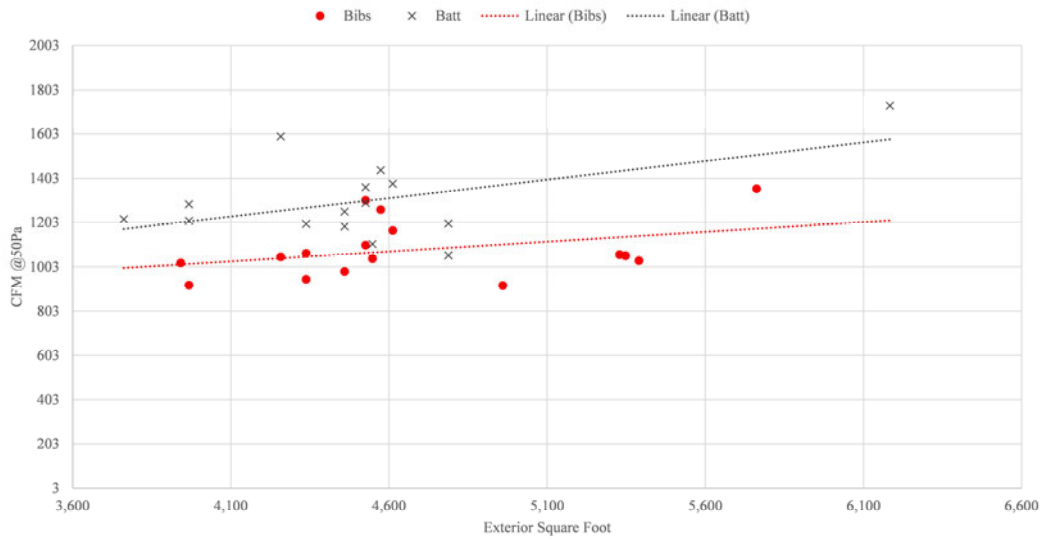

Figure 10. CFM50 vs. exterior square footage, duplexes excluded.

Comparisons between Pilots

There were significant differences in ACH50 leakage rates between the two pilots. The homes in the treatment group of the Top Plate Pilot and the non-treated homes in the Blown-in Wall System Pilot could be presupposed to be similar as both groups feature code homes with top plate gaskets. This did not prove to be true. The difference in ACH50 between the samples is significant as demonstrated in Table 10 below. Reasons for this include the "Oregon floor" found in blown-in homes, the smaller house size and perhaps small differences in construction detail between builders and their subcontractors.

Table 9. ACH comparisons, duplexes excluded

Pilot	Group	ACH50
Top Plate	Average ACH, no top plate gasket batts	5.38
Top Plate	Average ACH with top plate gasket batts	4.57
Blown-in Wall	Average top plate gasket batts	5.3
Blown-in Wall	Average top plate gasket blown walls	4.25

Energy Savings and Cost-Effectiveness

SEEM was used to model energy savings. Once again, the three RTF control homes were used. The treated homes were given a 1 ACH50 improvement over the untreated homes. In addition, the treated homes were assigned an R-23 nominal R wall for the wall assembly and the non-treated homes had their R-21 batts de-rated to R-19 to accommodate for the typical gaps and voids found in code-level homes.

List Assumptions

As demonstrated in Table 11, below, the TRC was generally lower than 1. If natural gas prices rise, the measure may become cost-effective. In addition, there is no attempt to monetize other benefits of the blown-in wall system. It is worth noting that the main builder in the program has switched over to building all their homes with the blown-in system, stating "the homeowners like how quiet it is and I can sell quiet."

Table 10. Modeled energy savings and cost-effectiveness for treated homes

Heating Equipment	RTF Home Model	Energy Savings	Cost	Benefits, 30-Year Life	TRC, 30- Year Life	Benefits, 45-Year Life	TRC, 45-Year	Benefits, 70-Years	TRC, 70-Years
Gas furnace with AC	1344	13.43 therms	$500	$118	0.24	$124	0.25	$148	0.30
	2200	24.79 therms		$217	0.43	$229	0.46	$272	0.54
	2688	19.36 therms		$170	0.34	$179	0.36	$213	0.43
Gas furnace without AC	1344	12.49 therms		$110	0.22	$116	0.23	$137	0.27
	2200	24.38 therms		$214	0.43	$226	0.45	$268	0.54
	2688	19.29 therms		$169	0.34	$178	0.36	$212	0.42
Electric Zonal	1344	298 kWh		$498	1.00	$531	1.06	$643	1.29
	2200	579 kWh		$968	1.94	$1,032	2.06	$1,248	2.50
	2688	482 kWh		$806	1.61	$859	1.72	$1,039	2.08
HP, 7.9 HSPF	1344	109 kWh		$182	0.36	$194	0.39	$235	0.47
	2200	228 kWh		$381	0.76	$407	0.81	$492	0.98
HP, 9.0 HSPF	1344	104 kWh		$174	0.35	$185	0.31	$224	0.45
Group Avg.	N/A	N/A		$334	0.67	$355	0.71	$428	0.86

Conclusion

Both studies suggest that house tightness can be lowered with the two measures outlined in this report on homes of similar design and construction quality. Further studies are needed to determine if these results can be duplicated over a wider range of typical production homes in Oregon. In additional, both measures were found to be easy to incorporate into the building process for the participating builders and their subcontractors. These traits are both necessary to capture savings in code homes not participating in more comprehensive programs with high levels of quality management.

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