Portland State
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OREGON BEST COMMERCIALIZATION GRANT PROGRAM

FINAL REPORT

Project: Development, Testing, and Pilot Scale Evaluation of a new Retrofit Window Insulation Product—The Indow Window

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PRODUCT OVERVIEW:

The Indow Window is a retrofit window insulation product intended to be installed on the interior of an existing window to improve the thermal barrier, reduce air leakage, and reduce noise penetration into the building. Indow Windows are sheets of acrylic glazing edged with a patent-pending spring bulb made out of silicone and filled with urethane foam. The spring bulb serves as the seal, as an expansion joint, as a spring force to hold the product in place, and as an architectural detail that matches existing home architecture so well that the product almost disappears when installed.

The Indow Windows company custom fabricates each insert to fit into the inside ledge of the window frame. Indow Windows are designed to be slightly oversized so that when pressed into place, the spring bulb partly compresses. This compression provides the force needed to hold the Indow Window in place. Two discreet safety straps, which hide behind the bulb, attach the Indow Window to the window frame. Details of the Indow Window product can be found at www.indowwindows.com.

The project described within this report includes several components: laboratory testing; pilot home measurements; and whole-building energy simulation. Each aspect of the study is aimed at providing performance information to assist in improving the product and provide quantitative information for marketing efforts.

LABORATORY MEASUREMENTS:

Several Indow inserts (32.5” by 38.5” sheet of 1/8” acrylic) with an extruded silicone bulb gasket were tested using a mock-up of a window frame in the Green Building Research Laboratory (GBRL) test facility at Portland State University. The window frame includes a single pane of standard 1/8" thick glass. When installed, the Indow insert produces an air gap of approximately 3/4" between the insert and the glass. Tests conducted on the Indow inserts focused on U-factor reduction and noise abatement and were conducted using an insulated 6’ by 4’ by 4’ plywood enclosure (see **Figure 1**) with air supplied by a Thermotron® thermal chamber. The U-factor reduction was measured by comparing the steady state heat flux through the window system with and without the Indow insert. Noise abatement was measured by comparing the decibel reduction with and without the insert using a standard white noise sound source inside the enclosure. After conducting these tests the Solar Heat Gain Coefficient (SHGC), the fraction of transmitted Visible, UV, and Infrared radiation were measured using a hand-held Window Energy Profiler (WP4500 from EDTM company).

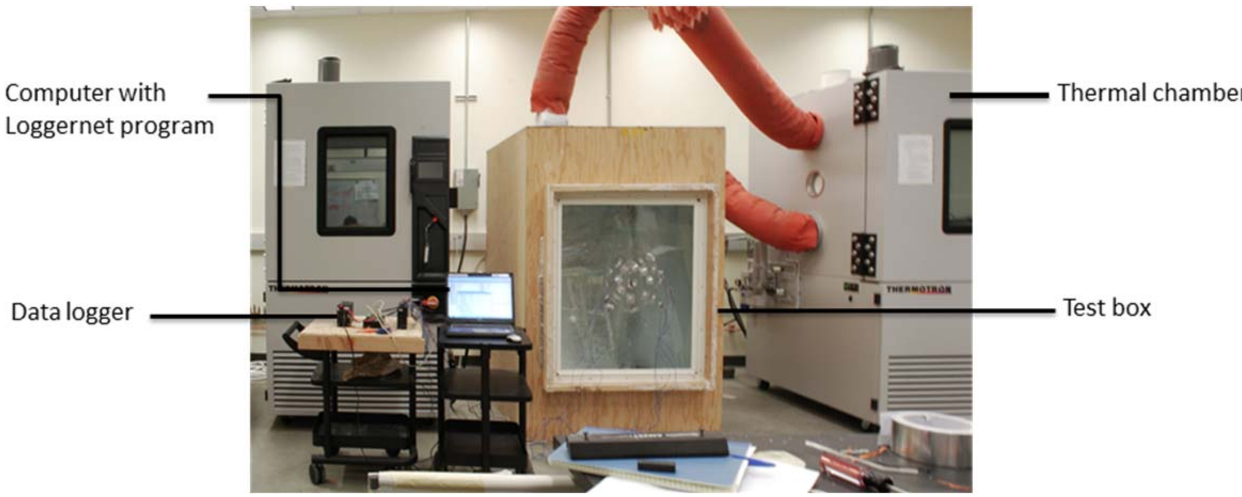

Figure 1. Insulated test enclosure located within the Green Building Research Laboratory (GBRL) at Portland State University.

U-Factor Testing:

Center of glass U-factors were determined using the surface temperature method consistent with ASTM Standard C1199-09 (without a calibration run with a Calibration Transfer Standard). The insulated enclosure simulates the ASHRAE defined winter design conditions on both sides of the window system. The outdoor environment, or the “weather side”, is simulated by maintaining the inside of the enclosure at 0^{o}F (+/- 1 ^{o}F) using air piped in from the Thermotron® thermal chamber. The desired indoor environment, or the “room side” is simulated using the ambient laboratory conditions, which are maintained at 70^{o}F (+5/-1 ^{o}F). During tests, the laboratory environment was nominally controlled based on zone thermostat settings within the Engineering Building that houses the GBRL. While the laboratory space is rather large (nominally 25,000 cubic feet), long-term experiments running the thermal chambers result in increases in laboratory temperature of up to 5 ^{o}F. This drift in laboratory temperature is relatively slow, occurring over the span of 6-8 hours, and as such, has little effect on our ability to conduct experiments nominally at steady state as required by the ASTM standards. As shown in **Figure 2**, a set of T-type thermocouples (8 on the inside, and 8 on the outside) was affixed to each window surface to enable calculation of heat flux through the window system. The testing procedure involved first determining the center of glazing U-factor of the single pane of glass by itself. Then, the Indow insert was placed into the window frame and the U-factor of the complete system was measured. The difference in the two measurements is taken as the reduction in U-factor due to the presence of the Indow insert. All U-factors are reported with the air film convection coefficients included, determined from the ASHRAE Handbook to be 5.1 and 1.31 BTU/hr*ft^2*^{o}F for the exterior and interior, respectively. The overall center of glass window U-factor for the single pane of glazing was thus calculated to be 1.005 Btu/hr*ft ^{2}*^{o}F. This value is within 3.5% of the nominal value presented in ASHRAE Fundamentals 2009 (U= 1.04 Btu/hr*ft ^{2}*^{o}F). Test results are summarized below in **Table 1**.

Figure 2. Close-up view of the instrumented Indow Window as installed in the thermal test fixture.

Noise Abatement Testing:

Noise abatement testing was conducted using the same enclosure used for the U-factor tests as illustrated in **Figure 3**. Outdoor-Indoor Level Reduction (OILR) of each Indow insert was tested in accordance with ASTM E966. Omega HHSL1 sound level meters were used for all sound level measurements. Sound level results were integrated by the HHSL1 over a frequency range of 31.5 to 8000 Hz and are reported in dBA. Sound was generated inside of the enclosure with an incident angle of approximately 45 degrees on center of glass (per ASTM E966 section 8.2.3.1). Using white noise as the sound source, inside and outside sound levels were measured at the center of glass, with the microphone approximately 1/8" away from the surface. First, background noise was measured both inside and outside the enclosure. According to the ASTM standard (E966, section 8.1), indoor and outdoor levels produced by the loudspeaker must be at least 5dB above the respective background noise levels in all measurement bands. Additionally, if the level produced by the test loudspeaker is between 5 and 10 dB above the background level, adjustments for background noise must be applied. In our test, the measured levels were outside of this band, so a background noise correction was not required. Before measuring the OILR through the window, a flanking test was performed to determine sound transmission through the surrounding surfaces of the test enclosure. This test blocked the window cavity from sound transmission by covering it with highly absorbent materials. With the window blocked, the indoor environment (outside of the box) sound level was measured. This measurement indicates the amount of sound “leakage” through all elements of the enclosure other than the window. The sound level measured in this test was 6 dB and is treated as background noise, which is subtracted from the subsequently measured sound level differences. Then, the OILR for the single pane of glass can be evaluated as:

$$OILR = L_{out} – L_{in} – 6 \text{ dB}$$

After determining OILR for the single pane of glass, the Indow insert was placed in the window frame and the test repeated. The difference in OILR measurements is the sound abatement due to the presence of the insert.

It must be noted that all noise reduction results are applicable only under the conditions of this specific test. OILR measurements of each installation will differ, including but not limited to the effects of: sound source location and characteristics, room geometry and absorption, outdoor environment geometry and absorption, sound measurement location, and the effect of background and flanking noise.

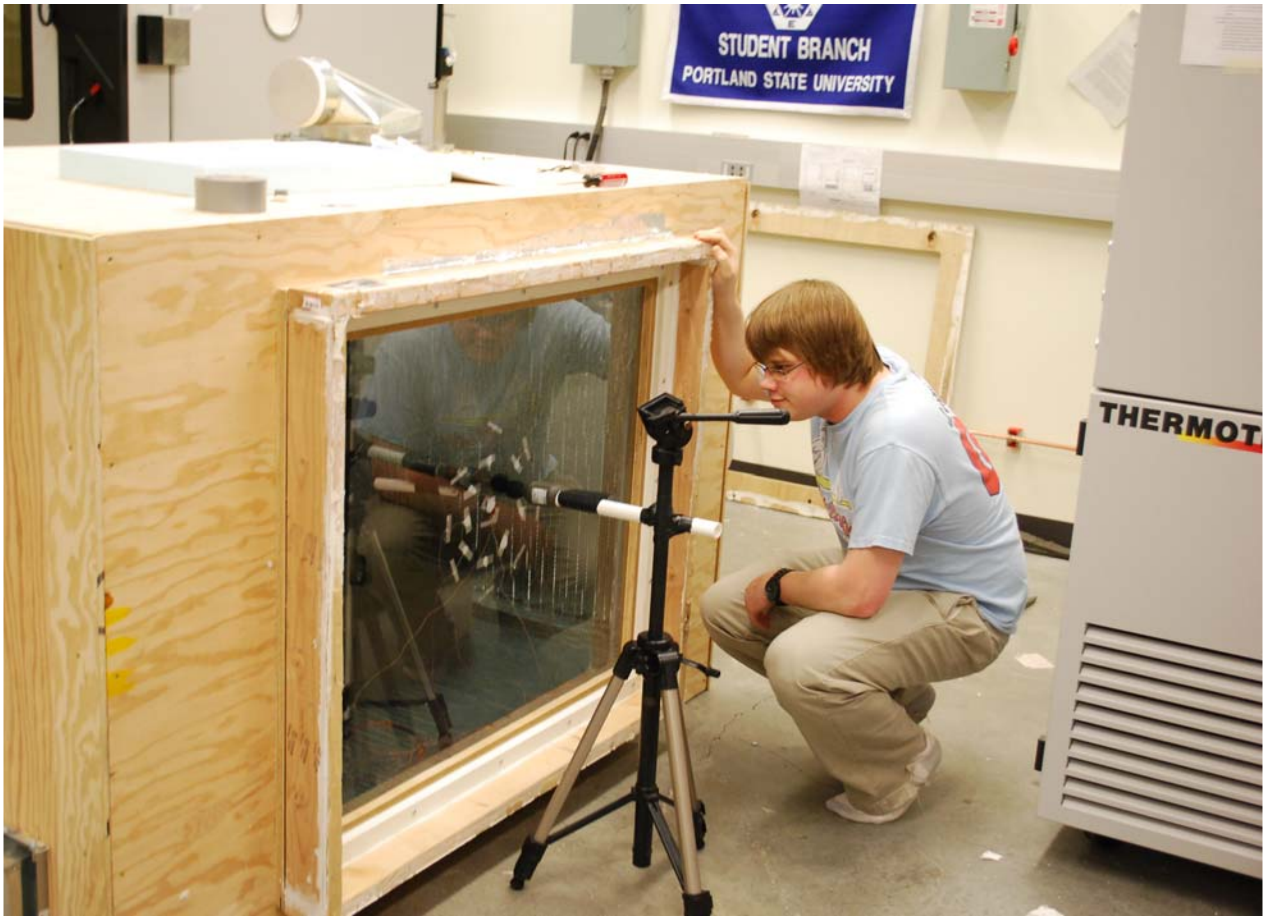

Figure 3. Noise abatement testing. Sound source is located at a specified location interior to the test fixture (outside environment) while noise levels are measured by the tripod-mounted microphone located outside the test fixture (inside environment).

Summary of Lab Test Results:

The results of these laboratory measurements are summarized in **Table 1**. This table provides a description of the Indow product dimensions, the Solar Heat Gain Coefficient (SHGC), the fraction of transmitted Visible, UV, and Infrared radiation (through the Indow product prior to installation over the glass window), the Center of Glass (COG) U-factor of the combined system, and the noise reduction performance (OILR). Sample 0 is the single pane of 1/8 inch thick glass by itself. Samples 1-3 were older samples provided to the GBRL from

Indow in late 2010. Samples 4-8 were newer samples provided by Indow in the spring of 2011, with samples 7 and 8 being experimental double pane (dp) versions of the Indow product.

Table 1. Summary of the thermal and noise performance for Indow window products.

	Thickness (in)				Light Transmittance						
Sample #	Glass	Indow Pane 1	Indow Air Gap	Indow Pane 2	SHGC	Visible	UV	Infrared	COG U-Value (Btu/h ft2 F)	% U-Value Reduction	OILR (dBA)
0	0.13	N/A	N/A	N/A	---	---	---	---	1.005	N/A	---
1	0.13	0.125	N/A	N/A	0.9	0.74	0.86	0.9	0.559	44.42	9.0
2	0.13	0.125	N/A	N/A	0.92	0.76	0.88	0.92	0.545	45.73	8.5
3	0.13	0.125	N/A	N/A	0.92	0.77	0.9	0.92	0.552	45.09	14.1
4	0.13	0.25	N/A	N/A	0.92	0.05	0.93	0.94	0.538	46.43	18.9
5	0.13	0.125	N/A	N/A	0.9	0.17	0.89	0.91	0.562	44.07	6.8
6	0.13	0.15625	N/A	N/A	0.91	0.19	0.91	0.92	0.552	45.11	9.5
7	0.13	---	---	---	0.86	0.12	0.82	0.86	0.503	49.98	3.9
8	0.13	0.125	0.459	0.125	0.85	0.06	0.82	0.85	0.405	59.72	9.5

* Note: SHGC and transmittance values are indicated for the Indow product in the absence of the single pane of glazing.

Table 2 provides representative performance data (SHGC, visible transmittance, and center-of-glazing U-factor) from the American Society of Heating, Refrigeration, and Air-Conditioning Engineering (ASHRAE) for traditional single, double, and triple pane (sp, dp, and tp) window products. These data provide a useful reference for comparing the performance of the Indow Window products.

Table 2. Summary of the thermal performance for traditional glazing products (source: ASHRAE).

Sample	Pane 1	Air Gap	Pane 2	SHGC	Visible	COG U-Value (Btu/h ft^2 F)
ASHRAE SP	0.125	NA	NA	0.78	0.9	1.04
ASHRAE DP	0.125	0.25	0.125	0.66	0.81	0.55
ASHRAE DP	0.125	0.5	0.125	0.66	0.81	0.48
ASHRAE TP	0.125	0.25	0.125	0.57	0.74	0.38
ASHRAE TP	0.125	0.5	0.125	0.57	0.74	0.31

PILOT HOME TESTING AND ANALYSIS

During the course of this project, 4 pilot houses were recruited by Indow with assistance from local utilities to participate in a small scale pilot study. Several criteria were used in the selection of the houses. First, the buildings had to be representative of the target market—older homes with single pane windows. In order to appropriately evaluate the effects of the Indow retrofit it was also important that no major energy renovations or occupancy changes occurred in the year leading up to the retrofit or during the evaluation period.

Pilot houses are named in this report based on their nominal location: North Portland, OR; McMinnville, OR; Milwaukie, OR and Vancouver, WA. The site locations are indicated in the map shown in **Figure 4**.

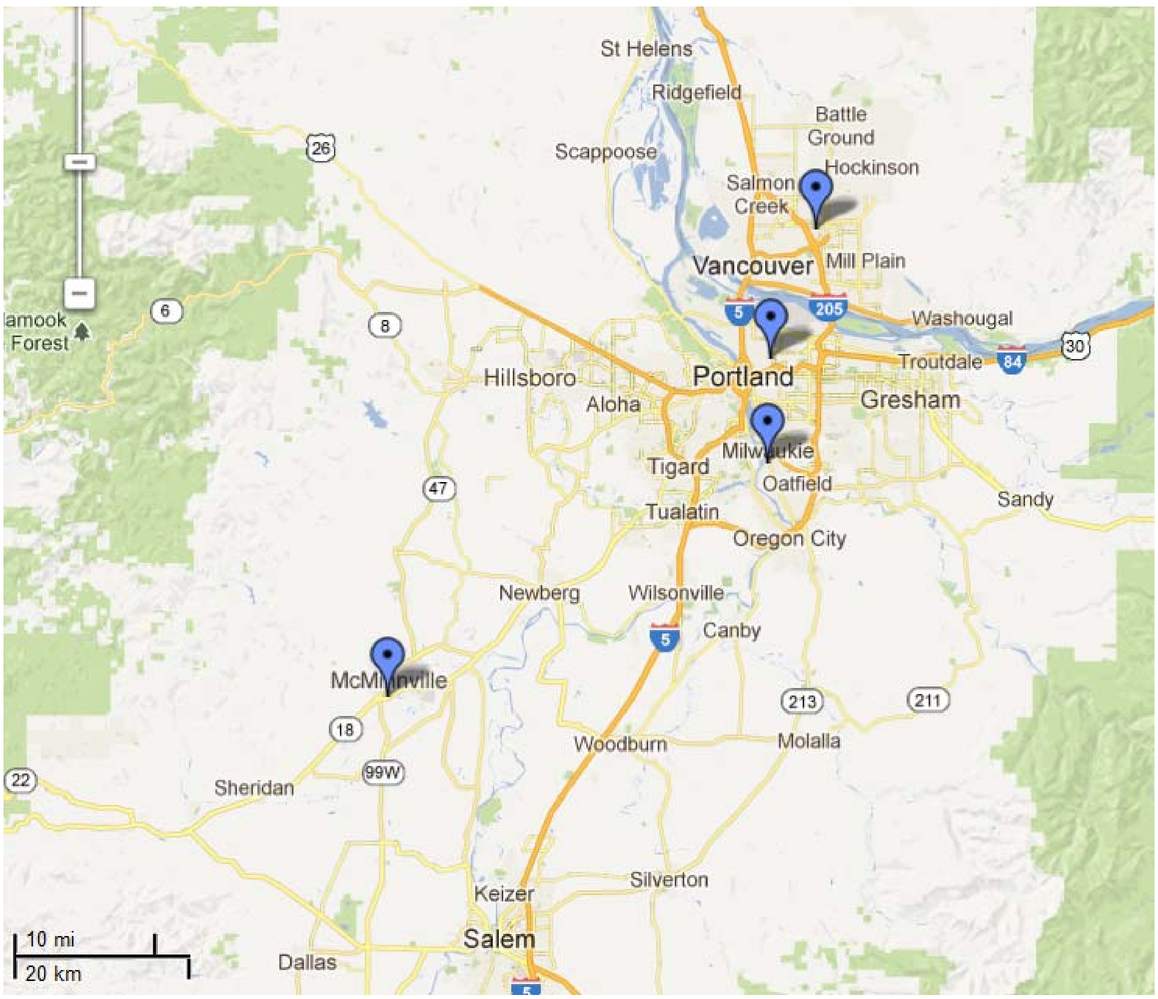

Figure 4. Nominal locations of the four pilot homes participating in the pilot home test study of Indow Windows (source: Google Maps). From North to South, the pilots are Vancouver, N. Portland, Milwaukie, and McMinnville.

Two site visits were required for each pilot in order to gather sufficient data for modeling. With the help of checklists, the first visit informed our team on house dimensions (useful for the creation of AutoCAD floor plans implemented in the energy modeling software) and windows and HVAC system specifics. This first visit was coordinated with the Indow Window team, who performed the custom window measurements while the GBRL team performed other measurements in support of the modeling effort.

The second set of visits was coordinated with the installation phase of the Indow product. During these visits, blower door tests (**Figure 5**) were completed for each house before and after the installation of the IndowWindow inserts. Consequently, air infiltration rates were calculated for each house. Infrared imaging was used to track the progress of each installation with images, in some cases, revealing insulation and leakage issues.

Figure 5. Blower door tests being conducted at McMinnville pilot home site.

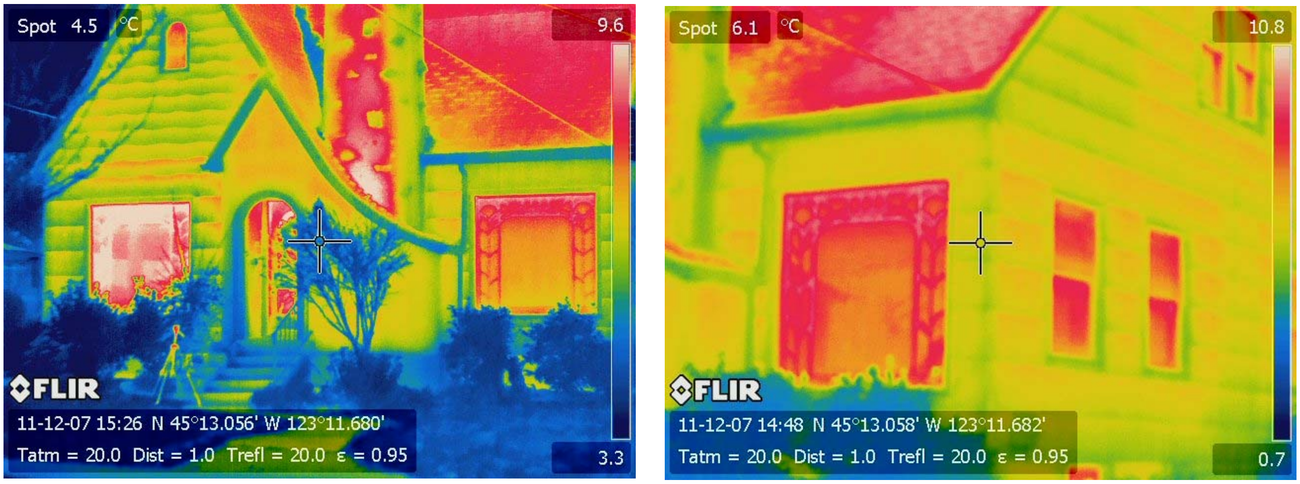

Figure 6. Sample infrared images from the McMinnville pilot home site.

Based on the field measurements there was significant variation in the "bare-window area" (*i.e. area not covered by Indow Windows*) across the pilot homes (see **Table 3**). For example, the bare window area of the Milwaukie house was of 117.2 square feet, almost 12 times more bare-window area than the North Portland house, 4 times more than the McMinnville house and 3 times more than the Vancouver house. The extent of this area is explained by the fact that the largest glazing areas found in the Milwaukie house is sliding glass-doors; which cannot be covered by Indow Window inserts.

Table 3. Bare-window area for various pilot houses

Pilot Home	Year of Construction	Floor Area (ft^2)	*IndowWindow* Area (ft^2)	Actual Window Area (ft^2) + Glass door area (ft^2)	Bare-window area (*Window Area not covered by IndowWindows*) (ft^2)
North Portland	1927	2571	218.3	228 + 13.4*= 228.4	10.1
McMinnville	1937	2438	174.2	174.2 + 26.7 = 200.9	26.7
Vancouver	1901	1600	201.5	236.1 *(No glass doors)*	34.6
Milwaukie	1978	1645	137.1	154.3+100= 254.3	117.2

The blower door tests measured the airflow in cubic feet per minute (CFM) at an applied indoor-outdoor pressure differential of 50 Pascals (Pa). As shown in **Table 4** these tests demonstrated that the Indow Window product had the most significant influence on infiltration in the North Portland house where it reduced air infiltration by 7.7%. On the other hand, the product had the least influence on the infiltration of the McMinnville house where the reduction was 3.7%.

Table 4. Blower door test results for various pilot houses

Pilot Home	Airflow @50 Pa (CFM)		% Reduction
	Without *IndowWindows*	With *IndowWindows*	
N. Portland	3100	2860	7.74%
McMinnville	3900	3756	3.69%
Vancouver	4850	4650	4.12%
Milwaukie	2593	2436	6.05%

Building Energy Modeling of Pilot Homes

During the modeling phase, geometry was extracted from AutoCAD floor plans (c.f., **Figure 7**), shading was modeled with the help of photographs taken on site (e.g., **Figure 8**), and all data gathered from checklists was implemented in the building performance software: DesignBuilder v3.0.

Figure 7. Building geometry being extruded from AutoCAD floor plans.

This version of the software uses EnergyPlus (v7.0) - *the industry standard for building energy simulation* - at its core to calculate several parameters. Of the available output parameters from this model, heating energy consumption was the primary focus of this study. Windows were modeled from measurements done on site given by both the *Window Energy Profiler* WP4500 and the *Glass-Check Pro* GC3000 devices. This data includes Ultraviolet (UV) radiation, visible light, Infrared (IR) light through glass, Solar Heat Gain Coefficients (SHGC), thicknesses of the various glass layers, and their thermal performance (U-factor). Modeled heating energy consumption was compared to utility bills for natural gas (all houses used gas as their heating fuel). If the difference between utility bills (for at least one of the years of observations when several were available) and simulation results were less than 5%, the baseline simulation was considered satisfactory. Otherwise, model assumptions were revisited and revised until such a threshold was met.

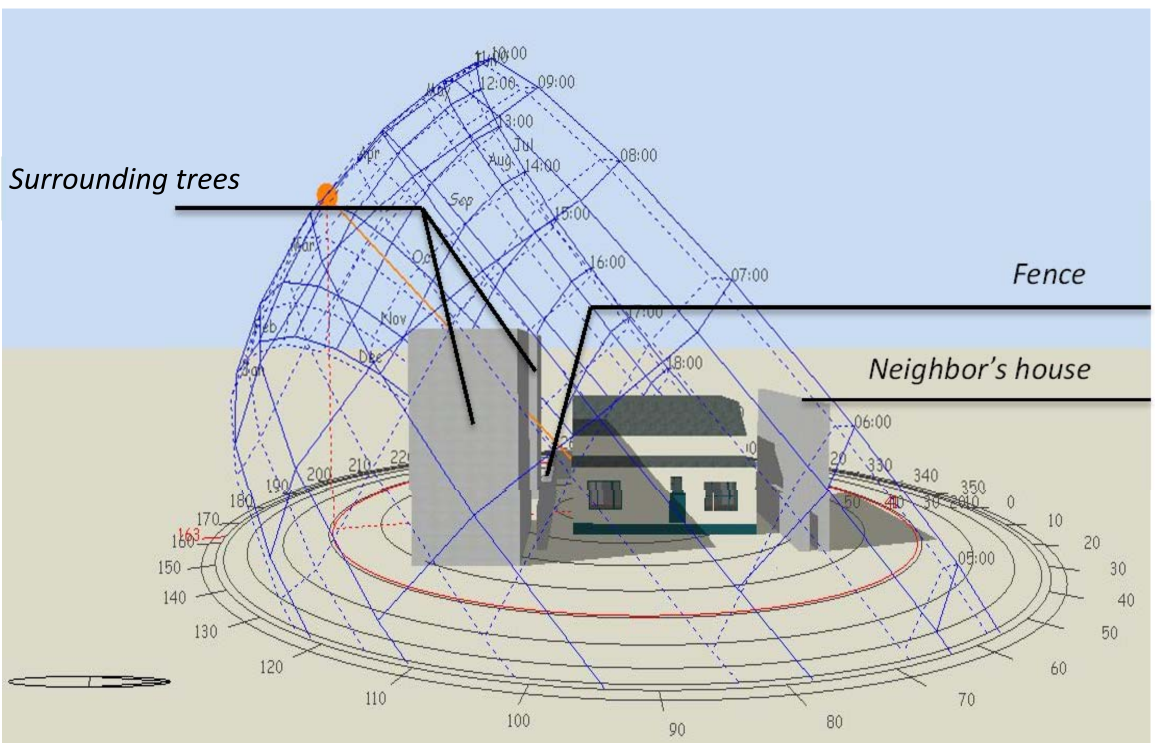

Figure 8. Shading of the North Portland house in DesignBuilder (add legend and photo of real shading)

The representation of each pilot house in DesignBuilder was intended to balance the level of detail with the required accuracy for modeling whole house energy performance. While each model provides for a reasonably detailed level of accuracy regarding geometry, construction characteristics, occupancy, and indoor electrical and natural gas equipment, the models have limited accuracy related to shading by nearby trees and structures, which are simply represented by opaque shade surfaces in the model. **Figure 9** provides a direct comparison between the DesignBuilder model and the actual building for the North Portland home. Shading inaccuracies will be particularly evident in estimations of thermal comfort (or energy use for air conditioning) in summer. The models also make fairly standard assumptions related to occupant schedules. The front views of all pilot homes are illustrated in **Figure 10,** which also shows the approximation of shading through use of simple opaque shade surfaces in the models.

Additional modeling assumptions were made related to unknown insulation levels and occupant behavior. The envelope insulation assumptions were based upon age of construction, photographs and thickness of outer wall measured at the entry door. Occupant behavior assumptions were based on and calibrated with the utility bills.

Figure 9. All façades (from top to bottom: N, S, E, W) of the North Portland house in pictures (left) and as rendered in DesignBuilder (right). Shading surfaces not shown.

Figure 10. Qualitative comparison of actual pilot homes (pictures) with their corresponding DesignBuilder models.

Building Energy Model Results

DesignBuilder models were simulated using the integrated EnergyPlus whole-building energy simulation capability. Each simulation used the typical meteorological year (TMY) data from the closest major airport location (e.g., location of 1st order National Weather Service weather station). This was Portland International Airport (PDX) for all simulations. It must be noted that lack of site-specific TMY data introduces uncertainty in the model results, but as all sites are within approximately 50 miles of PDX it is believed that the error introduced is small relative to errors associated with other modeling assumptions. This error, however, is likely to correlate with the direction and speed of the prevailing wind (e.g., PDX is located adjacent to the Columbia River gorge).

The projected energy use savings of the four pilot homes is given in **Table 5**. This table gives monthly and annual heating energy savings (kWh) for each home in direct comparison with and without the use of Indow

Windows as installed. The percent savings relative to the total heating energy use is given in parentheses and the corresponding cost savings estimate is also given.

Table 5. Monthly and annual heating energy and heating cost savings associated with Indow Windows. Note the extent of window area not covered by the Indow product varies from ~10 ft^2 in the N. Portland home to nearly 120 ft^2 in the Milwaukie home.

	North Portland, OR		McMinnville, OR		Vancouver, WA		Milwaukie, OR	
	kWh (%)	Cost	kWh (%)	Cost	kWh (%)	Cost	kWh (%)	Cost
Jan	538.75 (20.1%)	$17.70	321.92 (10.1%)	$ 10.50	201.65 (7.6%)	$ 6.60	191.87 (6.5%)	$ 6.30
Feb	456.39 (22.8%)	$15.00	260.17 (10.6%)	$ 8.50	162.25 (7.7%)	$ 5.30	154.72 (6.8%)	$ 5.10
Mar	307.04 (22.6%)	$10.10	207.12 (12.0%)	$ 6.80	133.43 (9.3%)	$ 4.40	115.71 (7.4%)	$ 3.80
Apr	194.05 (30.7%)	$ 6.40	125.33 (13.9%)	$ 4.10	78.40 (10.1%)	$ 2.60	70.75 (7.4%)	$ 2.30
May	90.85 (43.8%)	$ 3.00	64.14 (16.8%)	$ 2.10	47.38 (14.2%)	$ 1.60	35.40 (8.5%)	$ 1.20
Jun	10.66 (64.1%)	$ 0.30	4.01 (6.4%)	$ 0.10	11.59 (23.4%)	$ 0.40	5.81 (7.7%)	$ 0.20
Jul	2.98 (57.6%)	$ 0.10	2.41 (7.2%)	$ 0.10	2.48 (23.9%)	$ 0.10	1.64 (5.7%)	$ 0.10
Aug	.44 (56.4%)	$ -	.71 (3.1%)	$ -	.22 (21.2%)	$ -	1.42 (7.6%)	$ -
Sep	20.23 (50.6%)	$ 0.70	12.52 (13.3%)	$ 0.40	15.56 (25.1%)	$ 0.50	8.95 (8.4%)	$ 0.30
Oct	133.54 (28.4%)	$ 4.40	95.43 (15.2%)	$ 3.10	63.50 (12.4%)	$ 2.10	48.26 (9.2%)	$ 1.60
Nov	319.67 (20.5%)	$10.50	222.48 (11.7%)	$ 7.30	136.94 (8.8%)	$ 4.50	139.24 (8.1%)	$ 4.60
Dec	530.21 (17.9%)	$17.40	346.32 (10.2%)	$ 11.30	220.26 (7.8%)	$ 7.20	202.08 (6.7%)	$ 6.60
Annual	2604.81 (21.8%)	$85.30	1662.56 (11.3%)	$ 54.50	1073.66 (8.7%)	$ 35.20	975.85 (7.1%)	$ 32.00

**Cost of gas assumed to be $0.0327645 per kWh (Source: www.eia.doe.gov). The conversion from kWh to Therms is 1 Therm = 29.3 kWh.*

Actual vs. Modeled Weather During Pilot Study

The modeled building energy performance is based on the concept of a Typical Meteorological Year (TMY). Using a TMY weather file for all simulations provides a common basis for evaluating performance under what is considered to be typical conditions. Of course, during the course of any actual field experiment the actual weather differs from the TMY weather. Comparing the actual and TMY weather is important prior to comparing the actual energy performance with the modeled energy performance.

Across the four pilot homes we established two local weather stations which reported hourly temperature and relative humidity data. The two stations were located at the McMinnville and Milwaukie sites. Unfortunately, a late monitoring start and an undetected battery failure at the Milwaukie site lead to an incomplete picture of the weather conditions at that site (missing January, and September through December data). An air temperature comparison is presented in **Figure 11**.

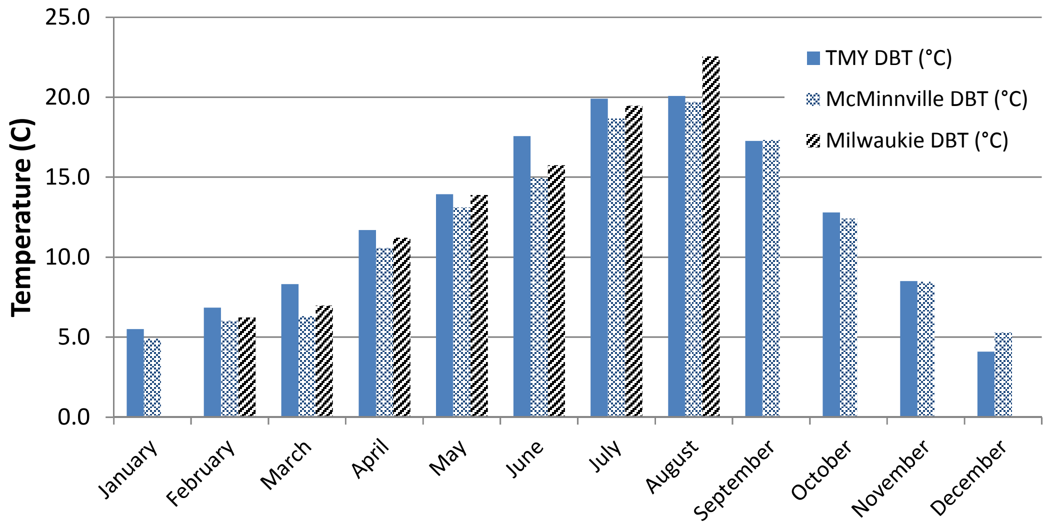

Figure 11. Monthly average temperature data from the Typical Meteorological Year (TMY) data file used in building energy simulations and the corresponding temperature data from the two pilot home weather stations.

This figure clearly demonstrates that the actual weather in the region was generally consistent with that of the TMY, although a bit cooler, particularly in the month of June. The observations from August are inconsistent, with the McMinnville site having nearly identical average temperature as the TMY, but the Milwaukie site being several degrees warmer on average. This effect could easily be the result of micro and regional climate variability. Since microclimate was not uniformly measured at all sites, no correction can be made to the TMY data. Nevertheless, qualitative differences between TMY and regional observations during the period of the study can help to explain differences between modeled and actual energy performance.

With respect to the relative humidity data shown in **Figure 12**, the relative humidity at the pilot homes is, with few exceptions, consistently higher than in the TMY. This, however, is consistent with the observation that site temperatures (at least for the winter/spring months) is lower than TMY (for a fixed level of absolute moisture content in the air, the relative humidity is higher when the temperature is lower).

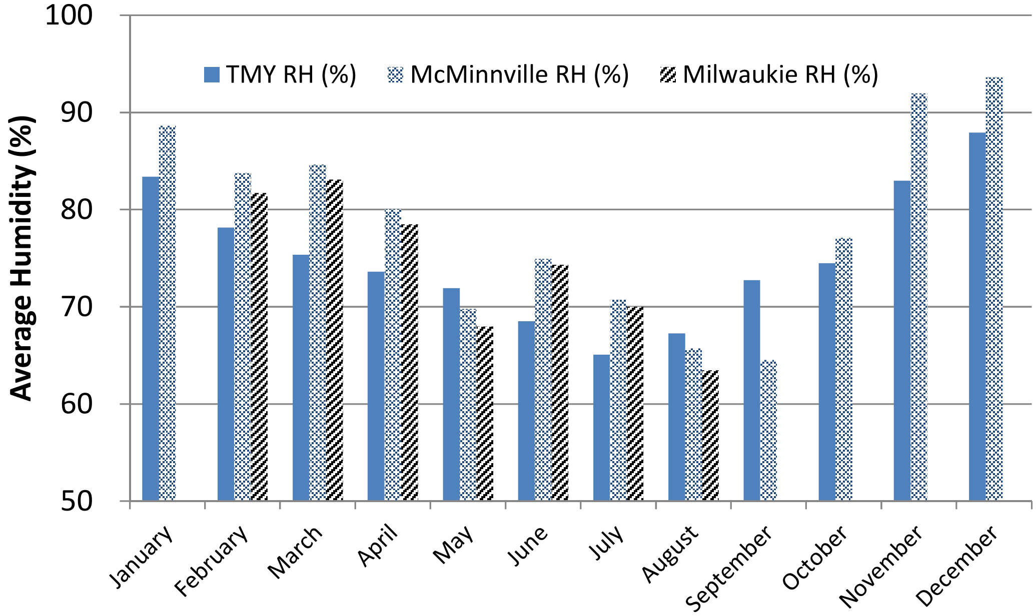

Figure 12. Monthly average humidity data from the Typical Meteorological Year (TMY) data file used in building energy simulations and the corresponding humidity data from the two pilot home weather stations.

Actual vs. Modeled Energy Performance

Natural gas consumption is the energy performance metric of most interest in the evaluation of the performance of Indow Windows. So, as part of the pilot home study we gathered natural gas consumption data from a 12 month period prior to and post installation of Indow Windows. Annual natural gas consumption in all four homes was lower after the installation of Indow Windows. Table 6 presents both the modeled and measured natural gas use before and after the installation of Indow Windows. As would be expected, the modeled consumption, while generally of the right order of magnitude, does not capture specific behavior patterns of this small sample of homeowners. As a result, the modeled natural gas use of the baseline homes (prior to installing Indow Windows) is roughly 10% lower than actual measured usage. The modeled energy savings of installing Indow Windows ranges from 7 to 22%. The measured savings ranged from 11 to 27%. It should be noted, however, that measured and modeled savings patterns did not mirror each other. For example, the modeled results anticipated the largest savings in the North Portland home (22%) while the measured usage demonstrates that the North Portland home actually experienced the least savings (11%). These contrasts between the model and measurements are consistent with the recognized importance of occupant behavior and energy use patterns, which may vary substantially from home to home and across years. The important result from this table is that, in the aggregate, the homes are anticipated by the model to save roughly 10% on their natural gas bills. The fact that the average measured savings was nearly double this (at 19%) might be a direct result of the thermal comfort benefits of the Indow Windows. Specifically, since the interior window surface of the Indow product is much warmer than would be the inner surface of the single pane of glass, the occupant within the building will feel warmer standing next to the Indow Window, than standing next to a single pane of glass even if the room air temperature is the same in both cases. As a result, the occupant is more likely to operate their home heating system at a lower thermostat setting after the Indow Windows are installed. This likely contributes to the greater than modeled energy savings that were recorded across the pilot homes.

Table 6. Modeled and measured annual natural gas usage before and after the installation of Indow Windows.

Pilot Home	Natural Gas Usage **Before** Indow Windows (Therms)		Natural Gas Usage **After** Indow Windows (Therms)		**Savings** (%)	
	Modeled	**Measured**	**Modeled**	**Measured**	**Modeled**	**Measured**
N. Portland	408	511	318	453	22%	11%
McMinnville	502	531	445	385	11%	27%
Vancouver	421	452	384	349	9%	23%
Milwaukie	469	510	436	438	7%	14%
AVERAGE	450	501	396	406	9.8%	19.0%

Figure 13 illustrates the seasonal variation in natural gas consumption over the course of a typical year both before the installation of the Indow Window product, and after. As is clear from this figure, the majority of natural gas consumption is for heating purposes in the months from December through March. The relatively small amount of natural gas used in summer (~ 5 Therms) corresponds to the base load associated with gas used for water heating and cooking. So, in the winter, up to 95% of the natural gas consumption is used by gas furnaces for heating the homes. The installation of Indow Windows results in a natural gas consumption reduction of 15 to 20 Therms in winter.

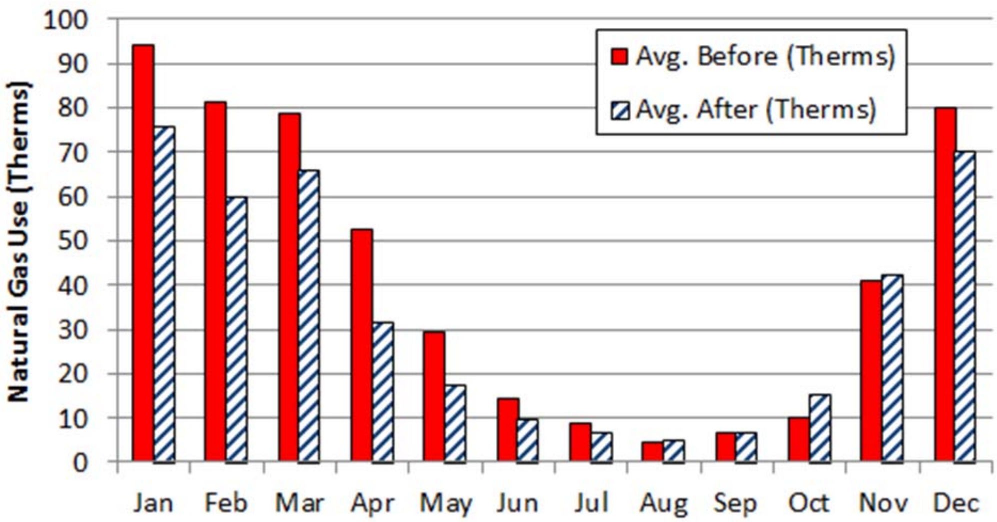

Figure 13. Monthly breakdown of measured natural gas consumption (averaged over the 4 pilot homes) before and after the installation of Indow Windows.

Pilot Study Homeowner/Occupant Observations and Comments

During the process of removing the sensors from the pilots several homeowners offered information and observations regarding the experiment.

McMinnville:

1. The homeowners had a baby in September 2012. As a result they turned up the thermostat "a bit" to keep the house more comfortable. They noted that it was much easier to maintain the increased setpoint temperature with the Indow Windows and that they had difficulty in the past maintaining that temperature.
2. Their bill from the gas company is normalized so that they pay the same amount each month for the entire year. They started receiving rebates over the summer due to the decreased consumption compared to years past.

Milwaukie:

1. The homeowners are very pleased with their Indow Windows. They have recommended them to several friends.
2. They removed one Indow Window in the kitchen because they like to open it while cooking.
3. They said the only downside to them was that they couldn't open and close the windows as easily.

Both the North Portland and Vancouver homeowners said they were pleased with their Indow Windows but they didn't give any specific details.

Conclusions

Laboratory tests demonstrate that the Indow Window product can reduce noise penetration into a space by 10 to 20 db. Adding Indow Windows to a standard single pane window can also result in an improvement of the thermal performance of the window approaching that of a standard double pane window.

Modeling of the performance of Indow Windows in typical older vintage homes with single pane windows suggested the potential to save on the order of 10% in natural gas consumption. Actual measured performance averaged across 4 pilot homes indicated a savings of 19%. This discrepancy is likely due to the additional thermal benefits resulting from the warmer interior surface of the Indow product which would result in improved thermal comfort at lower room air temperatures.