

A Deep Dive into Air Sealing Best Practices and Market Potential

Brigid O'Connor, Summerhill, Sooria Narsiah, Summerhill

ABSTRACT

The fundamental approach to whole-building retrofits includes a comprehensive plan for improving energy efficiency across the building envelope and major equipment and appliances; with the goal of maintaining good air quality and home comfort. Inspecting a building envelope for air leaks and sealing them is a natural starting point in holistic home retrofits. HVAC systems can only function effectively within a tight building envelope and they require reliable air sealing and insulation to maximize the benefits of upgrades to heating and cooling systems.

Thus, this paper is exploring air sealing in detail to explain the benefits and the market potential to achieving significant energy savings and carbon reductions for communities.

A research study was conducted to identify best practices in air sealing, and to explore models for scaling home air sealing in the City of Vancouver. Our paper shares the lessons learned and provides recommendations covering several topics. It starts with setting up the context for meeting Canada's 2030 carbon emissions reductions target and explains the methodology applied in conducting this market research. Air infiltration is explained, and the benefits of air sealing are highlighted. To demonstrate the limited availability of rebate programs addressing air sealing in Canada, a market scan depicting the existing programs is presented. Best practices for fixing air leaks in various locations in a house, the types of materials used and an approach to developing cost effective rebate programs which can also create opportunities for training and capacity building are discussed.

The paper ends with the presentation of a calculator which was specifically designed for quantifying energy losses through infiltration and how it evolved into a smart phone application which contractors can use on site to estimate energy savings from air sealing with instant results. It is a very effective tool which utilities can utilize to deploy a performance-based air sealing program.

Introduction

For Canada to reach its 2030 target to reduce emissions by 40-45% from 2005 levels, we need to improve the energy efficiency of our building stock and air sealing can play an important role. According to Natural Resources Canada (2021), making improvements to reduce the draftiness of a home is the single most important retrofit you can make to improve energy efficiency, and it should be considered first in any retrofit strategy.

Air sealing (also known as weatherization or draft proofing) is considered a low hanging fruit to tighten leaky homes with minimal intrusion to residents. Industry experts recognize air sealing as an integral part of whole-home retrofits, but it is under researched compared to other retrofit options like insulation, and window and furnace upgrades that are more common in energy conservation programming.

While challenges exist, industry experts believe that by finding the best balance of incentives, training for contractors, and consumer education, air sealing will become more popular in residential energy efficiency retrofits.

Methodology

Our team's research included a scan of existing literature and interviews with regional and national subject matter experts to uncover best practices and the potential for scaling air sealing in retrofit programming. Phone interviews were conducted with representatives of air sealing and residential energy efficiency design, installation, and construction, including Andy Cockburn of NAIMA Canada, Ryan Coleman of Ecolighten Energy Services, Peter Sundberg of City Green Solutions, Gail Lawlor of Energy Matters, and Gord Cooke of Building Knowledge Canada. These experts have several decades of experience in air sealing techniques and technologies. Topics covered included: historic uptake in air sealing programs, current opportunities and incentives, work force readiness, the interactive effects of air sealing with other home retrofits and barriers and opportunities for scaling air sealing efforts. Interviews were supplemented with online research including reviewing reports from Natural Resources Canada, Building Knowledge Canada, City Green Solutions and the BC Housing Research Centre, as well as scanning utility and government websites for details on existing air sealing programs and incentives.

An in-home pilot case study is currently underway in a sample of thirty homes in the City of Vancouver. Through the in-home pilot we are testing the feasibility and energy savings potential of different air sealing program models from shallow to deep.

What is Air Infiltration and why is Air Sealing Beneficial?

Air infiltration is the movement of air into a building through cracks, holes, and crevices across the building envelope. While air leakage is part of construction and can never be eliminated, it should be managed and controlled within acceptable limits per building codes.

Air sealing is the process of sealing these cracks and gaps in homes to create an air barrier preventing the flow of air between the inside and outside of a house. Air sealing experts interviewed indicated that reducing air leakage in a home has many benefits including improving home comfort, improving energy efficiency and reducing GHG emissions. The key benefits of air sealing are summarized below:

- **Reduced heat loss/heat gain:** Air leakage increases heat loss in the winter and heat gain in the summer, resulting in an increased use of the mechanical systems for heating and cooling.
- **Increase thermal comfort:** Air leakage can create noticeable drafts, and significantly impact occupant comfort. Air sealing can reduce or eliminate drafts and allow for a more consistent temperature in the home.
- **Lower energy bills:** A leaky home requires more energy to regulate temperatures in a home. Conducting well-planned air sealing work can help reduce energy consumption, and lower energy bills.
- **Shrinks the carbon footprint:** The more energy that is used in the home, the higher the carbon footprint. Air sealing, particularly in homes heated with greenhouse gas intensive sources of energy (such as natural gas, oil, or propane heating), can significantly reduce the environmental footprint of a home.

- **Improved indoor air quality:** Air sealing reduces the number of potential pollutants, and microbes that infiltrate a building from the outdoors such as vehicle exhaust or wood smoke. Air sealing also reduces the potential for pollutants within the building envelope (walls, attics, or crawlspaces), such as mould, asbestos, insulation fibers, to enter the living space of the home. A home with indoor air quality issues can negatively impact the health, wellbeing, and comfort of occupants.
- **Fewer insects and rodents:** Cracks, gaps and other openings in a home provide a pathway for insects and rodents to enter homes. Insects can enter a home through the smallest cracks or gaps. Small rats can enter a home through a hole the size of a quarter, and mice can enter through any opening larger than a pen. Insects and rodents can cause a wide range of damage to a home and can be costly to exterminate.
- **Acoustic comfort:** Air leaks in a home will also allow exterior noise (vehicle noise, construction noise, etc.) to enter the home more easily. Air sealing can reduce the amount of noise that enters a home and provide a quieter living space.

Common Leakage Areas and Prioritizing Air Sealing

The diagram below outlines the most common air leakage areas in a residential building.

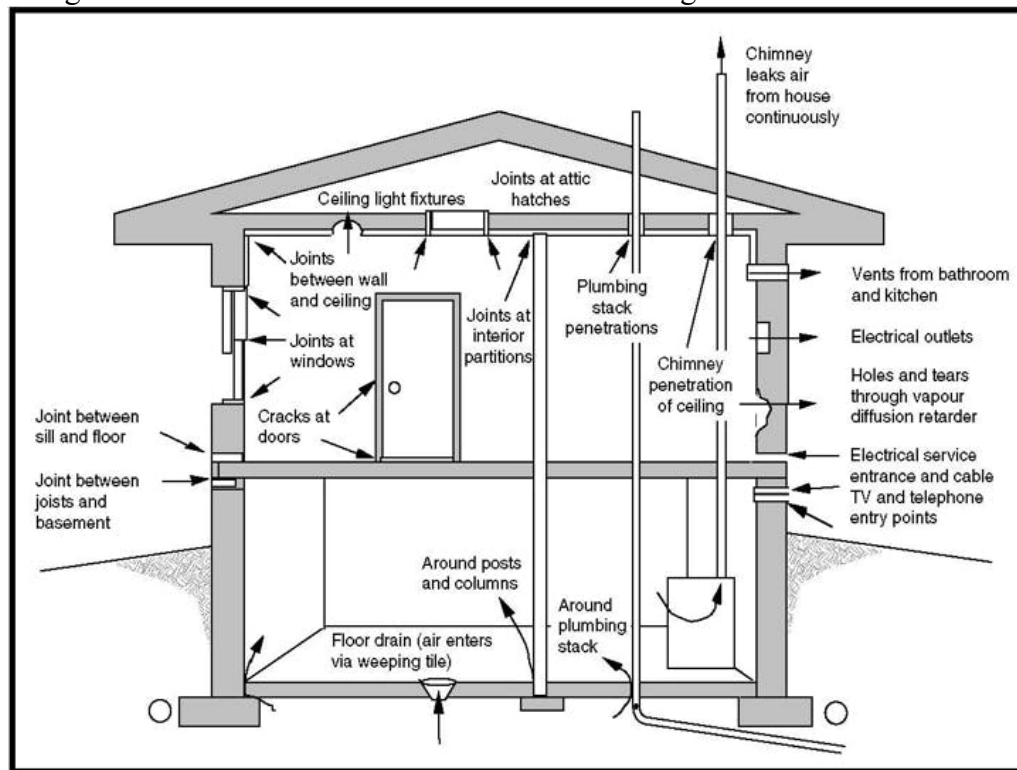


Figure 1. Common leakage areas in home. *Source:* Canadian Home Builders' Association Builders Manual, 2020.

Air sealing priority areas vary based on housing type but the general priority areas for air sealing are outlined below (Sundberg, 2022).

1. **Areas requiring insulation, before insulating.** Before any insulation is added to a wall or roof, air sealing should be performed within the insulated area. Failure to do so may

result in reduced insulation effectiveness, as well as moisture accumulation, and potential health and durability issues. Air sealing before insulating is a top priority.

2. **Large holes, regardless of location** including plumbing or electrical penetrations, ductwork through unconditioned spaces, large gaps under doors, masonry chimney chase ways. Large holes are a significant air leakage pathway. They are easier to identify and fix; making them more cost-effective than other air leakage areas. Large holes present quick air sealing wins for the homeowner.
3. **Smaller holes on top floor ceiling/attic** including pot lights, ceiling penetrations around fixtures, attic hatch, attic knee walls, service shafts, etc. While a homeowner may report feeling drafts and seeing air leakage areas around windows and doors on the main floor, the most significant air leaks are frequently found in the attic/top floor and basement floor. This is due to the stack effect: in a heated home, less dense warm air rises and expands, creating a higher-pressure area near the top of the house that pushes warm moist air out through air leakage points. Air sealing at the top of the home reduces the ability of moist warm air being pushed through the ceilings and roof, thereby minimizing the stack effect (which also pulls cold air into the lower levels in a home).
4. **Smaller holes on the bottom floor** including hose bib penetrations, cracks on exterior and foundation walls, basement doors, electrical boxes, gas lines or oil fill pipes that go through exterior walls, etc. Air sealing efforts on the bottom floor further reduce the ability of the stack effect to pull cold air into the lower portions of the home.
5. **Smaller holes on the main floor** including windows, doors, top and bottom of baseboards, fireplace dampers, electrical outlets, switches. While air sealing on the main floor can reduce air leakage and assist in improving comfort on windy days, if air sealing is undertaken on the main floor without first addressing air leakage issues on the top and bottom floors, the work on the main floor will not reduce air leakage caused by the stack effect. Instead, the main floor air leakage may result in a home that is a better funnel for air leakage from bottom to top (caused by the stack effect).

Standard Products and Services

The basic tools and materials used for air sealing have remained fairly consistent over the past few decades. The tape and caulking used to seal the house should be durable and houses built in the early 1990s are as airtight today as they were when they were built.

Standard guides to DIY air sealing are widely available and cover current procedures and products in detail. One of the most comprehensive guides was published in 2020 by the BC Housing Research Centre – [Best Practice Guide for Air Sealing and Insulation Retrofits for Single Family Homes](#). Common materials used include spray foams, sealants, adhesives, gaskets, window, and door weatherstripping. The table below summarizes the common materials and tools by area.

Table 1. Common Air Sealing Materials and Tools

Area	Common Materials and Tools
Recessed Pot/Can Lights	• Gypsum board/ sheeting • Polyurethane sealant • Sheeting tape

Attic Hatch	• Extruded polystyrene and/ or batt insulation Self-adhered weather stripping • Sheathing and framing lumber • Screws or nails • Adhesive
Bathroom Exhaust Fan and Duct	• Spray foam (spray can or two-part) and/or polyurethane sealant • Extruded polystyrene (or gypsum board) • Sheathing or foil tape
Kitchen Range, Dryer or Other Exhaust Duct	• Spray foam (spray can or two-part) and/or polyurethane sealant • Foil tape • Insulated duct sleeve (2" glass fibre insulation) with foil or plastic cover, or insulated flex duct sleeve
Fireplace or Other Combustion Appliance Vent	• Fire-resistant silicone sealant • Sheet metal • Circular metal duct (approx. 6" larger diameter than vent to be sealed)
Wall Top Plate and Plumbing/ Electrical Penetrations	• Spray foam (spray can or two-part) and/or polyurethane sealant • 10 mil polyethylene sheet or flexible gasket or tape • Acoustic sealant
Large Openings, Shafts or Drop Ceilings	• Spray foam (spray can or two-part) and/or polyurethane sealant • Wood, OSB or gypsum board • Fasteners
Attic Knee Walls	• Spray foam (spray can or two-part) and/or polyurethane sealant • Fibre batt insulation or foam board insulation (for between joists) • Rigid fibre insulation boards • Gasket
Ceiling Perimeter and Gable End Walls	• Spray foam (spray can or two-part) and/or polyurethane sealant
Masonry Chimney	• Fire-resistant silicone sealant • Sheet metal • Gypsum board and wood framing or noncombustible rigid insulation • Fasteners
Above-grade Exterior Walls (electrical receptacles, light fixtures)	• Sealant • Foam Gaskets
Exterior doors	• Weatherstripping

	• Gaskets
Window frames	• Polyurethane sealant • Weatherstripping • Gaskets
Exhaust Vents Through Walls and Soffits	• Spray foam • Polyurethane sealant • New ducts and foil tape (if required)
Porches over Living Space	• Spray foam (spray can or two-part) and/or polyurethane sealant • Fibreglass or mineral wool batt insulation • Extruded polystyrene • Materials needed for gypsum board finish • Vapour-retarding interior paint

Source: BC Housing Research Centre Best Practices Guide for Air Sealing and Insulation Retrofits, 2020.

Historical Context

Until 10 years ago, air sealing in British Columbia was commonly incented by utility companies through programs such as LiveSmart BC, and ecoENERGY (BC Government, 2013). When these programs were wound down, air sealing dropped off the list of common retrofits outside of basic DIY efforts. Without outside incentives and programs, there has been limited effort across British Columbia to build air sealing as a trade until recently.

Outside of BC, air sealing has also not been a key component of most utility and government energy efficiency programs. Rebates for DIY products such as foam sealant, weather stripping, and caulking have been incentivized, but have not been positioned within the market as important drivers of GHG reductions. Air sealing experts that have led DIY training programs for homeowners over the years concluded that this type of rebate program had minor impact without a way to quantify the improvements in air tightness.

When most air sealing incentives were provided through DIY workshops with free materials including foam sealant and weatherstripping, there was a sense that people were going to the workshops for the free materials. In those programs there was little to no follow-up to verify materials were installed or to measure the energy savings (Cooke and Lawlor, 2021).

In recent years, new programs that include incentives for air sealing have been launched and are ramping up. There is significant potential for further growth in the space. Requirements around measurement techniques, such as energy assessments and blower door testing have made new federal and provincial rebate and efficiency programs more robust than the programs that have been popular in the past. These programs have trained contractors who identify the primary sources of leakage and quantify the value of more comprehensive air sealing efforts which has been a gap in previous DIY models.

Current Air Sealing Rebate Programs

Natural Resources Canada Greener Homes Program

The Greener Homes Program offers an initial \$550 for air sealing work that reaches the airtightness target outlined in an initial Renovation Upgrade Report. If a house achieves 10% above the target, homeowners can apply for an \$810 rebate. For performance at 20% higher than target, they can apply for \$1,000. These grants are one of several eligible incentives from the Greener Homes Program which provides up to \$5,000 in incentives for a variety of retrofits paired with EnerGuide pre and post renovation evaluations (Natural Resources Canada, 2022).

CleanBC Better Homes and Home Renovation Rebate Program

The CleanBC Better Homes Rebate Program administered by BC Hydro, FortisBC and the Province of BC does not currently include air sealing upgrades, though it does address building envelope issues with rebates for retrofits in insulation (up to \$5,500), and new windows and doors (up to \$2,000). The program also provides up to \$300 in rebates for pre and post retrofit energy evaluation from a list of qualified energy evaluators.

In addition, they offer a Home Energy Improvement Bonus of \$750 to \$2,000 for improving the overall efficiency of your homes. Draft proofing can contribute towards the bonus depending on how drafty a home is (CleanBC Better Homes, 2022).

A sample of rebate and loan programs that offer air sealing as a measure from across Canada and the Pacific Northwest is provided in the following table.

Table 2. Air sealing rebate and loan programs

Region / Municipality	Description	Incentive
Saskatoon	Home Energy Loan Program covers insulation, HRV, air sealing (weather stripping and/or caulking), window / exterior door replacement	Low-interest loan program min \$1K to max \$60K
Newfoundland (Newfoundland Power / Newfoundland Labrador Hydro)	TakeCharge! Program provides periodic rebate programs for DIY weather stripping and tips on air sealing	Rebate up to \$5 per unit on energy efficiency products
Regional District of Central Kootenay	Regional Energy Efficiency Program is piloting “See the Heat” loaner thermal imaging cameras with DIY draft proofing materials	No cost loaner program
Alberta municipalities	Clean Energy Improvement Program finances multiple home upgrades including air sealing	Unspecified max amount for weather stripping, caulking, spray foam
Gray’s Harbor (Washington State)	Residential Energy Saving Program rebates contracted work on air sealing retrofits for existing duct work	Rebate \$250 per home

Ontario municipalities / Enbridge	Home Efficiency Rebate includes air sealing among other upgrades	Rebate up to \$150 (without bonus rebates) plus \$600 for an energy advisor
Nova Scotia municipalities / Efficiency Nova Scotia	Residential rebate programs include draft proofing among other upgrades, including insulation (but requires Greener Homes EnerGuide assessment)	Rebate up to \$200

Air Sealing in the Context of Whole-Building Retrofits

HVAC Systems

HVAC systems operate more effectively within a tight building envelope, and they do not have to work as hard to keep a home at a comfortable temperature. Consequently, there could be opportunities to replace old furnaces or air conditioners by more efficient, smaller units (less capacity) to meet the reduced heating and cooling loads of a tighter home. This is especially true with newer technologies in condensing furnaces, boilers, and heat pumps. As building envelopes become more airtight, heating, and cooling loads are reduced, and HVAC systems can be downsized for reduced loads.

Indoor Air Quality and Moisture

An important consideration for air sealing is the impact on indoor air quality, and avoiding issues with elevated levels of humidity, moisture accumulation in walls, and potential mould growth. Air sealing requires sealing openings in building enclosures that may have previously been relied on for passive ventilation in the home. Natural infiltration and exfiltration, whether through windows or unintended air leaks, could be expected to dilute potential pollutants in houses, however, there are challenges with relying on this approach for air quality control. Natural infiltration rates are highly variable, and are dependent on factors such as:

- Pressures induced by wind and temperature differences
- Height and size of houses
- Location of leaks in the enclosure

Any energy efficiency plan that includes air sealing should assess ventilation needs to avoid indoor air quality issues. The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) recommends that homes receive at least 0.35 air changes per hour to minimize adverse health effects. Additionally, they provide a ventilation table for air leakage to determine the required mechanical ventilation capacity needed for each home and based on the number of bedrooms and square footage of the home.

Incorporating a heat recovery ventilator (HRV) or energy recovery ventilator (ERV) into a home's ventilation system is an effective means of meeting code ventilation requirements and achieving a healthy indoor environment.

Combustion Spillage

The risks of combustion spillage are another important consideration when air sealing homes that have combustion appliances such as:

- gas-fired furnace, boiler, or water heater
- oil-fired furnace, boiler, or water heater
- wood stove or fireplace
- portable propane, natural gas or kerosene heaters
- other fuel-burning devices (e.g., gas range)

These appliances produce combustion gases as fuel burns. They are normally vented to the outdoors, but if a house is made significantly more airtight it could contribute to back drafting where carbon monoxide, and other dangerous combustion gases, spill into the home when the space becomes negatively pressurized. Negative pressure could result in:

- Risk of combustion products from fuel burning appliances spilling into the house
- Soil gas entry through foundation leakage points
- Entry of pollutants from attached garages

This can cause health concerns ranging from headaches to carbon monoxide (CO) poisoning. CO detectors should always be present in homes that have combustion appliances. Homeowners can also be instructed to avoid operating several powerful exhaust devices simultaneously, such as a high-capacity kitchen range hood and a clothes dryer. They should also avoid operating combinations of appliances that are likely to create depressurization like a fireplace and range-top fan to avoid back drafting.

Depressurization tests should be performed on homes with combustion spillage susceptible appliances. This test determines the level of house depressurization that can occur when all of the home's exhaust appliances and ventilation devices are running at the same time to avoid back drafting. If the test indicates there is a risk, and there is a naturally aspirated gas, or oil-fired combustion appliances, it is recommended that homeowners have the naturally aspirated water or space heaters replaced with a direct vent or sealed combustion appliance that is more efficient and lowers the risk of combustion spillage.

Bundling Air Sealing with Other Retrofits

The common perception amongst experts interviewed is that with new federal and provincial incentives, air sealing can be bundled effectively with other retrofits, through general renovation contracting, insulation upgrades, window, and door replacements, and even house painting (Sundberg, 2022). Exterior cladding, as an extension of air sealing activities has been identified as a large opportunity to improve energy efficiency, especially in older homes. Air sealing seems to stack quite well with other retrofit work, and this is something we are testing in the in-home pilot that is currently underway.

Trade representatives interviewed as part of this research mentioned that a potential co-benefit could be delivered if trades, including general contractors and renovators, HVAC specialists, window and door replacement specialists, siding and cladding contractors and house painters were incentivized to expand into air sealing work. Additional opportunities exist for

engaging contractors to start reciprocal referral networks to refer other contractors such as the HVAC contractor referring insulators and air sealers and vice versa (Sundberg, 2022).

Opportunities for Training and Capacity Building

Air sealing done by licensed and trained contractors has not been prioritized since the early 2010s, which has made it challenging to find skilled air sealing contractors. If program incentives and training were boosted, this could help develop capacity, especially because air sealing has low overhead and start-up costs. Three recent developments in training promise to rebuild expertise in air sealing including:

- The North American Insulation Manufacturers Association (NAIMA) in Canada recently launched online training modules that cover current best practices in air sealing, as well as insulation retrofits.
- In Vancouver, the Home Performance Stakeholder Council (HPSC) enhanced its training to standardize best practices in energy-efficient retrofits and upgrades, including installation of heat pumps, efficient windows, and conducting energy audits using House-as-a-System approach. They define “House-as-a-System” as a building science concept that defines the house as an energy system made up of interdependent components that impact the performance of each other and the entire system. It considers the intended and unintended effects that changing one component can have on others in terms of energy performance, moisture, air quality, occupant safety, comfort, and home durability. They recently launched an online training course which is an introduction to the fundamentals of air sealing for single family detached and attached residential building retrofit contractors. HPSC has a contractor network where individuals can sign up under various sectors including insulation and air sealing.
- Natural Resource Canada’s Greener Homes initiative funds training for energy advisors who will build awareness about energy efficiency retrofits and create opportunities to introduce air sealing as an important driver of energy savings.

Approach to Costing for Air Sealing Programs

The cost of air sealing has a lot of variability depending on factors such as the air tightness of the home, age, and square footage. Costing can be broken into three broad categories:

- At the low end of the rebate spectrum \$500 to \$1,000 will cover basic DIY air sealing costs.
- At the mid-level \$1,000 - \$5,000 will cover the services of an energy advisor and some air sealing work done by a contractor.
- At the higher end, rebates for a deep energy retrofit (including for example insulation and / or HVAC retrofits) can cost many tens of thousands of dollars and would cover the work of certified trades.

An important consideration in any decision about air sealing rebates is whether financial incentives should be applied towards DIY air sealing efforts. The consensus amongst experts in the space is that it is preferable to use rebates for programs that require energy advisors who can

encourage customers to consider whole home improvements, such as upgrades to windows and doors and the installation of a heat recovery ventilator where recommended, and who can quantify the improvement in air tightness.

Since air sealing improves building performance and reduces ongoing operating costs, education on these savings is essential to factor into any program design because it can help homeowners see the return on their investment to justify any upfront costs.

Summary of Best Practices in Air Sealing

The following is a compilation of best practices in air sealing program design and implementation based on interviews with industry leaders and a scan of best practice literature:

- Begin by offering customers access to energy advisory services, potentially ones that are rebated. Go beyond identifying leakage areas to embrace a “whole home” approach to energy efficiency – insulation, plus air sealing, plus improvements to the building envelope. Air sealing should be done on air leakage pathways into walls and attics before air sealing to maximize the efficiency of the insulation and to prevent moisture from entering the insulated area and either damaging the insulation or creating mould (Home Performance Stakeholder Council, 2022).
- Consider packaging energy evaluation/energy concierge services to give prospective participants a better understanding of the value of a whole home approach. Any energy evaluations/inspections should be done by someone who understands mechanical systems and energy modelling such as trained Energy Advisors.
- Blower door testing is increasingly seen as essential in any air sealing program because it sets a baseline and creates a target around which an energy efficiency retrofit plan can be designed. This is particularly important in programs where there is a need to track reduction in GHGs/ energy savings associated with any air sealing activities. A testing aspect in program design also helps if there’s an interest in third-party certification – LEED, Passive House, Net-Zero which have requirements for minimum air changes per hour (ACH) levels.
- For non-DIY programs, paying contractors based on a pay for performance model can help incentivize them to go beyond the low hanging fruit and achieve deeper savings.
- In program and rebate design, a key issue is determining a reasonable and achievable goal for air leakage reductions. ACH reduction potential varies by home with older homes having the greatest reduction potential. A 25% ACH reduction is achievable, and a 20 to 30% reduction is considered typical. One method, Aerobarrier, delivers about 60% - 80% reductions, though it is not practical to deploy in an occupied house. (Cooke, 2021)
- Three potential levels of air sealing programs/packages would include the following:
 - o Basic sealing, led by blower-door testing, reduces air leakage by approximately 25%.
 - o An incentivized plan to perform basic air sealing led by blower-door testing and re-insulating the attic floor.
 - o Aerobarrier, but preferably when a house is changing hands and has been completely emptied as it can be disruptive.
- Additional incentives should be provided for any proven reduction levels of 40% or more.
- Tie incentives to other common retrofits, such as window replacement or recladding.

- Target the largest leaks first – the most common large air leaks are found in plumbing penetrations; around tub, toilet and sink drains; and where plumbing supply lines come into cabinets in kitchens and bathrooms. Electrical penetrations to target include where wires run through top plates, bottom plates, or other wood materials. Air leaks should also be targeted around chimneys and flues (be sure to use non-combustible sealing materials in these areas), and around bathroom fans and kitchen range exhaust fans. Doors (and sometimes windows), spaces between an attic access hatch and drywall, and space behind attic knee walls and trim can also be targeted, although these are often hard to access in existing homes.
- Use the right sealing material for the size of the leak; for gaps smaller than 3/8” use caulk; for 3/8” to 1” use 1-part expanding foam; and for leaks larger than 1”, begin by adding a solid backing like foam board insulation or plywood before sealing with caulk or expanding foam. Seek out low VOC and low-emitting products to reduce off-gassing of vapors while working and when products dry/cure. Ensure the sealant you use is compatible with what you’re sealing.

Air Sealing Savings Calculator for Performance-based Air Sealing Programs

Quantification of air infiltration involves complex algorithms and significant uncertainties which can result in unrealistic estimates if the relevant factors are not assessed adequately. In most cases, Energy Advisors will use established industry software such as HOT2000 to quantify air infiltration. However, this requires a full home EnerGuide audit to be able to populate the software with all required data points and it is a tedious and costly process.

Summerhill has designed a tool specifically for quantifying air infiltration to calculate energy savings from air sealing retrofit activities. This calculator is based on a well-known model called the Alberta Air Infiltration model (AIM-2) and is described in greater detail below.

The Alberta Air Infiltration Model

The AIM-2 model was developed to provide a more accurate approach to air infiltration calculations from user inputs collected from site observations and measurements as well as blower door test results. The model is designed for single-zone applications, essential single-family homes.

Building on the work of Wilson and Walker (Wilson and Walker, 1990), Sherman et al. and other building scientists, Summerhill has developed a tool to calculate energy savings in both heating and cooling modes based on the AIM-2 model. The tool is available as an app designed for contractors and energy auditors to use on site and obtain instant results and it is an especially useful tool for performance-based air sealing incentive programs.

The calculator focuses on calculating stack and wind effects based on the following parameters:

- Wind speed
- Inside and outside temperatures
- Height and diameter of flue
- House type
- Shielding effect
- Terrain condition

Hourly weather data is applied to calculate infiltration rates variations throughout the year and the corresponding energy losses. As air sealing improvements are implemented, a second set of blower door tests is performed, and the energy losses post retrofit are calculated. The difference between pre and post blower door tests provide the savings.

Empirical Data Sets

Contractors and Energy auditors visiting the site are required to collect the following parameters which are then used to calculate stack and wind effects before computing natural infiltration rates and eventually energy losses.

Blower Door Tests

The AIM-2 model focuses on calculating stack and wind factors first separately and then their individual infiltration rates before being superimposed to calculate total infiltration rates of the combined effect of wind and temperature differential between indoor and outdoor conditions.

Multi-point blower door tests are to be conducted on site at two different times, one prior and one post air sealing. The calculator is designed to log a set of 6 tests ranging from approximately 25 to 50 Pa with different settings of the fan speeds at approximately 5 Pa intervals. Due to the fluctuations of the readings, it is recommended to log time averaged values (say over 10 secs). These values are then used to calculate the flow coefficient, “C” and flow exponent “n” which are then applied, along with the other variables described below, to calculate wind and stack effects and natural infiltration rates and eventually the annual heat loss associated with air leaks.

The calculations are repeated after contractors conduct the second set of blower door tests post air sealing implementation. The difference between the two values of heat losses provides energy savings from air sealing.

Presenting an example of a typical calculation for infiltration losses and savings from air sealing, Fig. 2 below demonstrates the first step of collecting differential pressure and flow data from blower door tests conducted pre and post air sealing.

Data Set 1

BLOWER DOOR TEST RESULTS

BEFORE AIR SEALING		AFTER AIR SEALING	
Contractor Inputs		Contractor Inputs	
Pressure Differential, ΔP , (Pa)	Air Flow Rate, Q, CFM	Pressure Differential, ΔP , (Pa)	Air Flow Rate, Q, CFM
25	1,785	25	1,563
30	2,070	30	1,856
35	2,304	35	2,150
40	2,704	40	2,501
45	2,877	45	2,635
50	3,179	50	2,890

Figure 2. Sample blower door tests before and after air sealing retrofit activities

These data sets are used in the calculator to determine the leakage characteristics and eventually calculate the energy losses due to infiltration caused by temperature and wind effects.

Weather Location

CWEC (Canadian Weather year for Energy Calculation) datasets are used in the tool. CWEC datasets are created by combining 12 “Typical Meteorological Months” for various locations across Canada, selected from a database of usually 30 years. The user will select the weather location closest to the audited site and the software will pull hourly ambient temperatures, wind speeds and humidity.

House Parameters

- House type. There are a few parameters related to different house configurations which are applied to calculate the wind and stack effects accurately. Thus, the tool provides a list of options to choose from where the user can select a configuration based on, say, number of storeys, with or without basement etc. The selection is made from a drop-down menu. The height of the eaves, height of flue from ground level as well diameter of flue and house volume are also collected.

Shielding & Terrain Coefficients

There are two main factors that affect wind speed at the building site, namely, local shielding by obstacles around the house and terrain conditions. They are quantified by:

- Shielding (or Shelter) Coefficient
- And Terrain Classification Coefficient

The AIM-2 models and the work of Wilson and Parker have proposed values for both shielding and terrain coefficients which were produced by lab tests and theoretical modeling exercises. These same values are used in the calculator.

Air Leakage Distribution

Infiltration rates depend on the size and location of air leakage points on the building envelope and the pressure difference across each point which in turn depend on the wind speed, temperature differences between indoor and outdoor air and operation of appliances.

Predicting air infiltration rates requires an understanding of the interaction between different driving mechanisms. However, this is a complex process, and the level of uncertainties involved in quantifying wind shelter and distribution of leakage sites makes it even more challenging to develop an accurate model which applies to all house types and different leakage characteristics. In this regard, the AIM-2 model uses algebraic equations to approximate numerical solutions to the mass balance equations due to wind and stack effects (Wang, et al.), A detailed description of the AIM-2 model can be found at

<https://www.sciencedirect.com/science/article/abs/pii/S0360132308000449>

Thus, this calculator has applied the leakage distribution parameters as suggested by the AIM-2 model. They are assumptions for leakage fractions between floor, ceiling, and walls.

Results

The tool returns the energy savings achieved because of air sealing. Figure 3 below shows an example of the output from the calculator for the heating season. The first line shows

the total annual energy loss as an equivalent to natural gas prior to any air sealing activity and the second line shows the losses post retrofit. And the difference between the two values represents the potential savings.

FINAL RESULTS		
Variables	Values	Units
Annual Natural Gas loss due to infiltration, before air sealing	266.49	m ³
Annual Natural Gas loss due to infiltration, after air sealing	202.08	m ³
Annual Natural Gas Savings	64.41	
Total Potential Incentive, \$	\$173.91	

Figure 3. Energy losses before and after air sealing and potential incentives

Utilities then apply their set incentive value per unit of energy saved to calculate the rebate amount. In this example, a gas utility was paying \$2.70/m³ of natural gas saved, thus achieving a total incentive of \$173.91 for the program delivery agent.

This air sealing savings calculator is a very convenient tool for air sealing contractors which they can use on their mobile devices to obtain instant savings values as work progresses on site. To maximize savings potential and thus incentives, a contractor may want to perform a blower door test after each major air sealing task and check the results right away and continue to do so until the allowable air tightness level is reached.

Conclusion

The global climate impacts over the past year, including persistent effects of wildfire, and extreme rainfall have highlighted the immediate need to curb GHG emissions. Buildings account for over 15% of total greenhouse gas emissions in Canada and we need to improve the energy efficiency of existing building stock to make our buildings more resilient and mitigate the impacts of climate change.

Research has shown that there is potential for air sealing as a key component of residential energy efficiency retrofits that can deliver energy savings and improved home comfort. With the right incentives, education for homeowners and contractor training, air sealing has the potential to become more common in energy retrofit programming. To scale air sealing and maximize the energy and GHG reductions homeowners will need to be motivated through program incentives and education and contractor capacity will need to be boosted including ensuring a systematic process that prioritizes air leaks and considers indoor air quality. Our in-home pilot will provide additional insights to quantify the air sealing potential and feasibility of different air sealing packages from shallow to deep including innovative technologies such as Aerobarrier and AeroSeal.

References

Cockburn, A. (2021). [Interview].

Coleman, R. (2021). [Interview].

- Cooke, G. (2021). [Interview].
- Lawlor, G. (2021). [Interview].
- Sundberg, P. (2022). [Interview].
- Cooke, C. 2021. *Building Knowledge Canada White Paper on Depressurization Limits vs. Air Tightness*.
- Sundberg P. 2021. *City Green Solutions: General Guidelines for Prioritizing Air Sealing Recommendations*.
- Walker, I.S., and D.J. Wilson. 1990. *The Alberta Air Infiltration Model*
www.aivc.org/sites/default/files/airbase_3705.pdf.
- Walker, I.S., and D.J. Wilson. 1993. Evaluating Models For Superposition Of Wind And Stack Effect In Air Infiltration". *Building And Environment* 28 (2): 201-210. doi:10.1016/0360-1323(93)90053-6.
- Wang, W, I. Beausoleil-Morrison, and J. Reardon. 2009. "Evaluation of The Alberta Air Infiltration Model Using Measurements And Inter-Model Comparisons". *Building And Environment* 44 (2): 309-318. doi:10.1016/j.buildenv.2008.03.005.
2013. *BC Gov News: LiveSmart BC program extended for one year*.
<https://news.gov.bc.ca/releases/2013EMNG0069-000810>
2020. *Canadian Home Builders' Association Builders Manual*.
2020. *BC Housing: Best Practice Guide Air Sealing & Insulation Retrofits for Single Family Homes*. <https://www.bchousing.org/research-centre/library/residential-design-construction/best-practices-air-sealing-insulation-retrofits>.
2021. *Natural Resources Canada: Keeping The Heat In*. <https://www.nrcan.gc.ca/energy-efficiency/homes/make-your-home-more-energy-efficient/keeping-the-heat/15768>.
2022. *Natural Resources Canada: Greener Homes Initiative*. <https://www.nrcan.gc.ca/energy-efficiency/homes/canada-greener-homes-grant/start-your-energy-efficient-retrofits/all-about-the-canada-greener-homes-initiative/23476>
2022. *Home Performance Stakeholder Council: Home Energy Retrofits: Why Use The House-as-a-System (HAAS) Approach?* <https://guides.co/g/home-energy-retrofits-why-use-the-house-as-a-system-haas-approach/194789>
2022. *Implementation of the AIM-2 Infiltration Model in HOT2000*.
s3.amazonaws.com/greenbuildingadvisor.s3.tauntoncloud.com/app/uploads/2019/03/01100254/AIM2_Implementation_20111.pdf.

2022. *CleanBC Better Homes Rebate Factsheet*. https://betterhomesbc.ca/wp-content/uploads/2022/05/Better-Homes-Rebate-Factsheet_053122.pdf