Clean indoor air and lower environmental impacts: Heat recovery ventilation in cold climates

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Abstract

Over half of Alaska homes are at risk of poor indoor air quality, which increases the risk of respiratory and other illnesses for people and animals. Heat recovery ventilators (HRVs) provide warm, fresh air to a building interior while minimizing energy use. They can be programmed to provide varying amounts of fresh air to ensure adequate ventilation for occupants and can be configured to filter air during wildfires or other events. In addition to improving the safety of indoor air and extending the life of a building, HRVs can improve surrounding outdoor air because they reduce the amount of fossil fuels needed to heat a building. Recent research by CCHRC has focused on lowering barriers to using HRVs in cold climates through laboratory evaluations and homeowner education. This poster will cover data on indoor air quality in Alaska, results of CCHRC research, and future research questions.

Houses need to breathe too.

Americans spend nearly 90% of every day indoors (Klepeis, et. al. 2001). Inside airtight buildings, where there is little air exchange between indoors and outdoors, pollutants can build up. These might include radon coming from the soils beneath a home, volatile organic compounds that off-gas from paints, furniture, or cleaners, particulate matter from wood stove smoke, dust tracked in on someone's clothes, acrolein from cooking, and more. Even excess humidity from cooking or showers can lead to mold growth that then pollutes the air with spores.

A human adult will take 12 to 18 breaths per minute, and children up to 30 breaths. To avoid an excess of contaminants in the air we breathe, it's important that our houses breathe too. Some do this naturally, because they have openings around doors and windows that allow for enough air exchange to keep the air inside fresh. The problem with a leaky home in a cold climate though is that these homes also lose their hard-earned and expensive heat. Tighter homes conserve energy use, but will require mechanical ventilation to provide fresh air.

In Alaska, many homes are at risk for poor indoor air quality, leading to issues such as mold and illness.

There is an often-quoted saying in building science – "Build it tight, ventilate right." In Alaska, builders are working to make sure they stay true to both, equally important halves of this advice. The 2018 Alaska Housing Needs Assessment (Wiltse & Madden, 2018) highlighted the challenges that Alaska is currently facing in our housing stock. Glaringly, almost 80,000 homes are housing cost-burdened, meaning that occupants spend over 30% of their monthly income on housing-related costs. At least 14,600 homes are rated 1-star, the lowest energy rating in Alaska, which means that houses are extremely inefficient. In these case, building tight – or air-sealing a building envelope against the cold – can save on energy costs and make houses comfortable to live in. And indeed, in other cases this has happened. However, it is important that air-tight houses have corresponding mechanical ventilation as well and unfortunately in Alaska 55% of air-tight homes do not have the necessary ventilation, putting them at risk for moisture and indoor air quality issues.

78,959
households in Alaska are housing cost-burdened

14,600
homes are rated 1-star, burdening households with high energy costs

55%
of homes in Alaska are at higher risk for moisture and indoor air quality issues

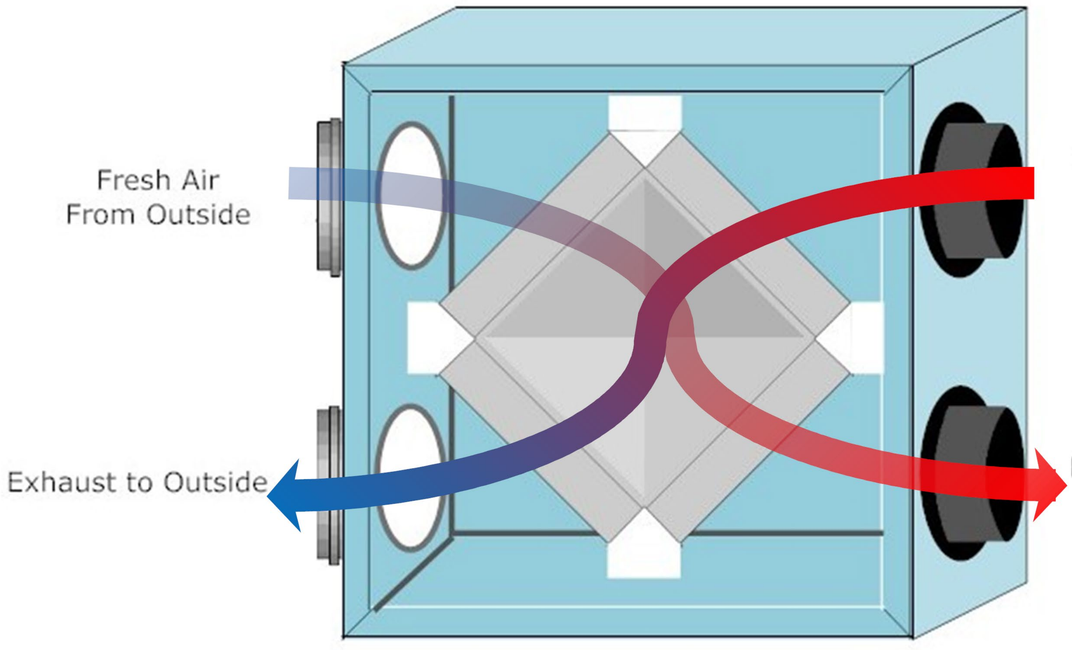
Fortunately, a heat recovery ventilator, or HRV, can help in these situations. HRVs provide a building with balanced ventilation, meaning the devices both supply and exhaust air at equal rates. Furthermore, outgoing stale air transfers heat to incoming fresh air via a core inside the HRV. The air streams do not mix, but this heat exchange means that building owners can retain the heat they paid for inside their buildings.

HRVs typically pull exhaust air from near the kitchen and bathroom, and have supply ports to the bedrooms and living space. In this way, they are able to provide airflow throughout a house. Current HRV models can be programmed to provide varying amounts of ventilation depending on occupancy, and have boost modes for times when more exhaust is needed. Extra filtration is an option depending on outdoor air conditions as well.

In cold climates, HRVs do occasionally build up ice in their core, and require a defrost cycle – either electrical heat or recirculating exhaust air through the core to warm it up – occasionally in temperatures below freezing. While this does come at an energy penalty, the energy savings and healthy air the devices can provide are well worth consideration.

The photo to the left shows a typical HRV. In this picture, the front cover of the device has been removed, and the heat exchanger core pulled out. The core contains lots of channels – some for outgoing air, some for incoming air – and the channels allow heat to pass from one air stream to another.

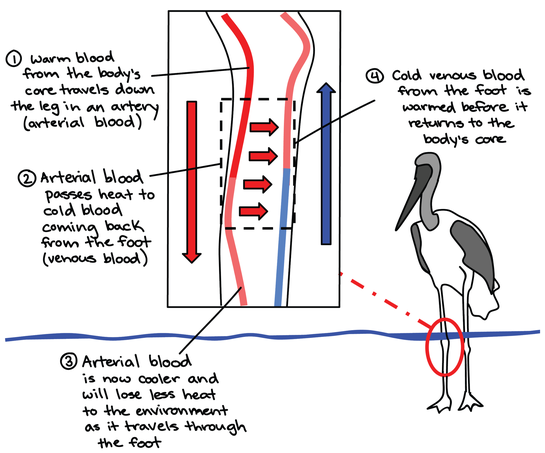
HRVs have filters around the core to stop bugs and other large contaminants from clogging the device. The maintenance for HRVs largely consists of periodically cleaning both these filters and the core itself.



Heat recovery ventilators (HRVs) provide warm, fresh air to homes in cold climates.

How does an HRV work? Similar to heat transfer in some animals, actually.

Did you know that nature has its own HRVs? Several animal species, including the sled dogs commonly found in Alaska, have their own version of an HRV in the blood vessels of their extremities. In these cases, heat passes from blood coming from the heart to blood returning to the core, meaning that less heat is lost to the environment. The figure below shows how this happens in a bird. *Image credit is listed under works cited.*



Alaska research – energy recovery ventilators

Energy recovery ventilators are very similar to heat recovery ventilators, as their name suggests. However, energy recovery ventilators, or ERVs, use the core to exchange both moisture and heat. This can be a big advantage for some homes in cold climates that struggle to maintain healthy indoor relative humidity levels. CCHRC's research has shown that ERVs can be effective in cold climates and work just as well as HRVs. They can also improve indoor relative humidity levels, especially at levels above 25% (Garber-Slaght & Stevens, 2016). Given that optimal interior relative humidity is 30 – 50% in cold climates, using an ERV can be helpful for households that are struggling to maintain that range.

Alaska research – through wall ventilation

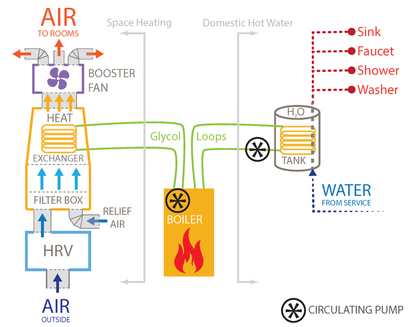
Currently, there are limited HRV models on the market for the small homes and cabins. Most models are sized for larger homes, and over-ventilating a smaller home would come at an energy penalty even with the heat recovery. Furthermore, HRVs can be difficult to retrofit into existing homes if options for running ducting are limited. Through wall ventilators are an emerging solution for smaller homes. They do not require ductwork, and instead exchange indoor and outdoor air through a heat recovery core that passes straight through a wall (see photo below, left). Unfortunately, currently available models did not perform well when tested in Fairbanks at high moisture loads and cold outside temperatures (Sosebee, et. al., 2019). Ice that built up on the supply and exhaust ports blocked air flow (see photo below, right). Currently available through wall ventilators are not as efficient at heat exchange as an HRV, but are slightly more efficient than open air vent holes.

Alaska research – insulated ducting

Heat loss from ventilation occurs not just from air exchange but also from the intake and exhaust ducts that connect the appliance to the outdoors. CCHRC researchers created a mathematical model, described in (Marsik et. al., 2021) to calculate the overall heat recovery efficiency of HRV systems. The model was tested against data from an installed HRV and translated into a calculator that provides homeowners a way to estimate the total efficiency of their ventilation system. The resulting calculator is available here: http://hrvcalc.cchrc.org/

Alaska research – combined heating and ventilation

HRVs warm incoming cold, fresh air – but in the coldest winter temperatures incoming air can still be quite cool. CCHRC has pioneered a combined heating and ventilation system, called BrHEAThe, for air-tight, small, energy efficient homes in Alaska. By combining heat with ventilation, BrHEAThe ensures that fresh air is always warm, increasing comfort and ensuring ventilation systems remain on. First installed in a home in Anaktuvuk Pass in 2011, the system has been and continues to be refined in homes throughout Alaska. The diagram below shows the current iteration of BrHEAThe, which uses a boiler to provide space heating and domestic hot water while the HRV provides ventilation.



Future research topics

CCHRC's building science research program continues to research ventilation in cold climates to find inexpensive, healthy options for builders and occupants of Alaska's residences. Current and future plans include:

- Assessing the feasibility of replacing some mechanical ventilation with filtration in cold climate homes, in the hopes that energy savings can be achieved without a loss in air quality;
- Exploring how different plants and growing systems can contribute to healthy indoor air quality and food security in an arctic home;
- Evaluating different designs for dual hoods that allow the intake and exhaust ports on a house to be combined, lessening the number of penetrations through the wall; and
- Quantifying the number of homes in a thermalize program in Juneau, Alaska, that could benefit from heat recovery ventilation, as well as tracking the number of homes that choose to pursue that type of retrofit.

Works cited

Image credit: Modified by Khan Academy from Counter current exchange in birds by Ekann, CC BY-SA 4.0; Modified image is licensed under a CC BY-SA 4.0 license as well. Original image link: https://commons.wikimedia.org/wiki/File:Counter_current_exchange_in_birds.svg Modified image link at Khan Academy here: https://www.khanacademy.org/science/biology/principles-of-physiology/metabolism-and-thermoregulation/a/animal-temperature-regulation-strategies

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