



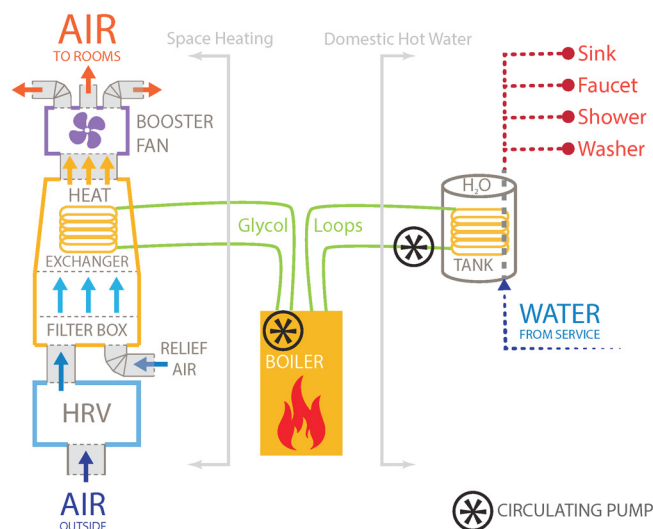
BrHEAThe System Evaluation

Inefficient buildings are both uncomfortable to live in and costly to heat, especially in a place like Alaska. The 2018 Alaska Housing Assessment reported nearly 15,000 residences in the state with a 1-star energy rating, burdening occupants with steep energy costs (Wiltse & Madden, 2018). However, as builders add insulation and tighten homes to lower energy costs, another issue can arise: airtight homes without mechanical ventilation are at risk of high moisture levels and poor indoor air quality. According to the 2018 report, 55% of homes in the state fall into this category. Even homes that have ventilation systems can face similar issues, as occupants might block vents that are bringing in fresh air from outside in order to eliminate cold drafts and save energy. This allows moisture and pollutants to build up inside the house, and in some cases can put the house at a negative pressure relative to the outdoors, potentially causing combustion heating appliances to backdraft poisonous exhaust gases. In addition to these challenges, rural Alaskans also face high shipping costs and have few skilled contractors that can install and maintain heating and ventilation systems.

Development of the BrHEAThe System

In 2011, CCHRC created the BrHEAThe system to address these challenges in small, energy efficient, airtight homes. BrHEAThe is a combined heating and ventilation system that uses a heat exchanger to tie the heating appliance into the heat recovery ventilator (HRV) ducting. BrHEAThe not only provides space heating, but also ensures that incoming fresh air is warm so residents can ventilate their homes year-round without experiencing cold drafts.

The first BrHEAThe system was installed in an energy efficient home in Anaktuvuk Pass, and consisted of a small diesel-fired heater paired with an HRV. Since then, BrHEAThe has been installed in nine additional communities throughout Alaska and has become more user-friendly. In today's version, an HRV provides continuous ventilation and a boiler supplies heat for



The BrHEAThe system ties heat and ventilation into a single system to ensure healthy indoor air quality in small, airtight, and energy efficient homes.

both domestic hot water and space heating needs. If the fresh air stream from the HRV is too cold, the boiler provides heated liquid to the heat exchanger to bring the air temperature up to a more comfortable level. The boiler also activates when the thermostat calls for heat, and in this case a booster fan also comes on to increase airflow to rooms so they warm up more quickly.

One big advantage of BrHEAThe is that it is modular, unlike other combined heating and ventilation systems on the market. Both the HRV and boiler can be tailored to the installation, allowing local installers to use appliances they are familiar with and know how to repair. BrHEAThe also incorporates a filter box with the heat exchanger assembly, giving homeowners the ability to purify outdoor air that might have smoke from wood stove exhaust or wildfire.

Evaluating BrHEAThe

In 2017, CCHRC began the first formal evaluation of past BrHEAThe installations to identify key features and further improve the system. Researchers spoke with individuals who had worked with or used BrHEAThe and monitored the installation of BrHEAThe in the Birch house at the University of Alaska Fairbanks (UAF) Sustainable Village.

BrHEAThe system resources

Visit CCHRC's website at cchrc.org/brheathe-evaluation for:

- background on the development of BrHEAThe
- an instructional manual and video for homeowners



Contractor and Resident Feedback

CCHRC spoke with 14 individuals about their BrHEAThe system experience, including four occupants from three different homes, five installers, one manufacturer, three architectural designers, and one researcher. Interviews centered on BrHEAThe installations from 2011 - 2017.

Homeowner satisfaction

Overall, home occupants reported understanding the need for ventilation and said the BrHEAThe system kept the air feeling “fresh.” However all four occupants interviewed reported issues with uneven heating, resulting in areas of the home that were consistently either too hot or too cold.

Installer satisfaction

In general, installers and designers reported no major issues with BrHEAThe installations. Many commented that the main advantage was that the system is an affordable, efficient option for airtight homes and promotes healthy indoor air. A second advantage, mentioned by four interviewees, was the system’s flexibility in accommodating a variety of HRVs and boilers, allowing contractors to use appliances that are familiar to homeowners and local installers.

The main drawback was that BrHEAThe is only compatible with a small, efficient building envelope. While CCHRC designed BrHEAThe specifically for homes with small heat loads, designers still need to plan the house with BrHEAThe in mind: maximizing airflow and an open floor plan, ensuring easy access for maintenance tasks such as changing filters, and placing ducting to optimize both ventilation and space heating. Another disadvantage was the system’s dependence on the heat exchanger, a custom-made part that can be costly to fabricate and ship.

Potential improvements

Suggested improvements fell into three main categories. First, the current BrHEAThe systems are meant for small, airtight, energy efficient homes, meaning in effect that the home should be sized and designed to the heating system. Should BrHEAThe’s intended installations expand to include homes with larger footprints, installers had several ideas on how to do so, including zoning, larger booster fans, and additional ductwork.

The second grouping of suggestions addressed the issue of uneven heating in BrHEAThe homes. Ideas ranged from installing downstream airflow and temperature sensors in ducting to better regulate heating to adjusting the boiler temperature and central control system to eliminate excessively hot temperatures at the source.

Finally, interviewees suggested improving the education



The Birch house at the University of Alaska Fairbanks Sustainable Village is 1,500 ft² and houses four students in separate bedrooms downstairs. The upstairs is an open kitchen and living space.

materials for BrHEAThe as occupant understanding of the system is key to its success. Currently, there is a handbook and video for homeowners on maintaining BrHEAThe. Interviewees suggested also creating an installation manual and video to provide a clear set of objectives and procedures. Homeowners could also benefit from a streamlined appearance of the system in the mechanical room with labeled appliances so maintenance tasks are easy to fulfill.

In-situ monitoring

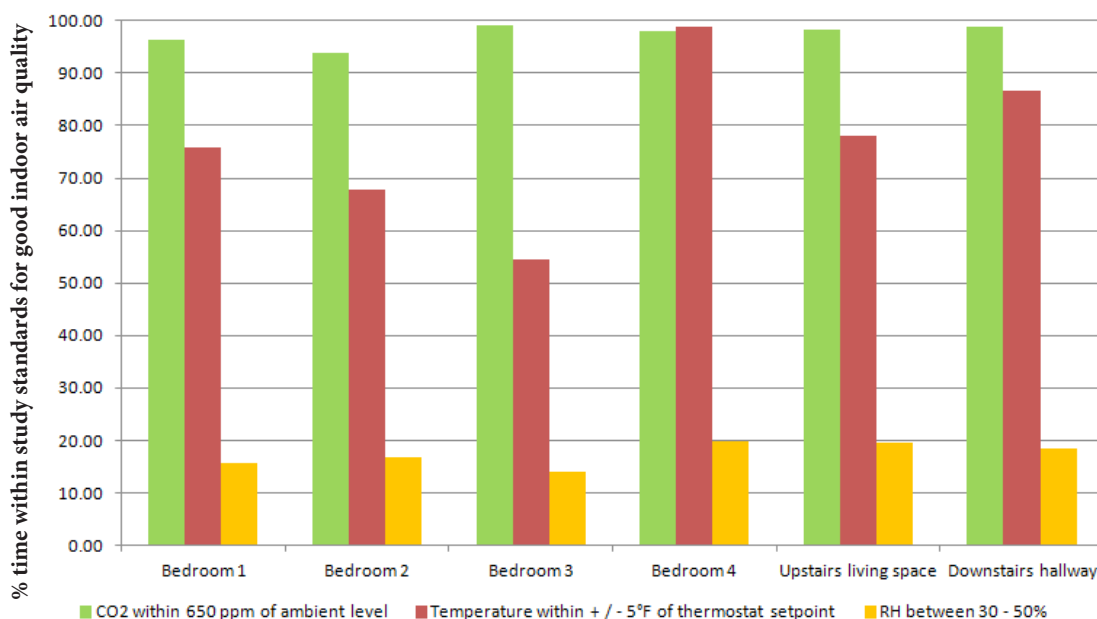
CCHRC monitored the 2013 installation of the BrHEAThe system in the Birch house at the University of Alaska Fairbanks Sustainable Village over the 2017-2018 academic year. Four students live in the two-story home, and the questions that guided the analysis considered both general features of BrHEAThe and the performance of the specific installation.

Did the BrHEAThe system maintain adequate indoor air quality in the Birch house?

Researchers balanced the HRV at the onset of the study, setting the minimum ventilation level at Alaska’s Building Energy Efficiency Standard (BEES) recommendation, and then monitored temperature, relative humidity (RH), and carbon dioxide levels at six locations in the home. BrHEAThe provided adequate ventilation to the house, keeping carbon dioxide levels within 650 parts per million (ppm) of ambient levels nearly 99% of the time, the body odor acceptability level mentioned in the ASTM D6245 - 12 Standard Guide. However, monitoring showed issues with both relative humidity (RH) and temperature. RH samples fell within the 30-50% range recommended



RIGHT: The bar chart shows the percentage of time that the six indoor air quality monitoring stations in the Birch house recorded values within the study's standards.



for cold climate homes (Deer, et. al., 2007) less than 20% of the time in all six monitoring locations. This was overwhelmingly due to low RH levels, with minimum values dropping below 10% and average RH around 20%. The Birch house also experienced uneven temperatures. Monitoring showed that three bedrooms were overheated more than 20% of the time, and residents complained of cold temperatures in the fourth bedroom and upstairs living area.

What is the seasonal energy use of the BrHEAThe system in providing space heating and domestic hot water to the Birch house?

During the winter of 2017-2018, the BrHEAThe system used 48.1 MMBTU, or the equivalent of 365 gallons of fuel oil #1, to provide space heating and domestic hot water to the Birch house. This total fuel use falls close to the AkWarm prediction for the residence of 358 gallons of fuel oil #1 during the study period. The oil-fired boiler was responsible for the majority of this energy use. The remainder is attributed to the electric resistance defrost element of the HRV, activated at cold temperatures to prevent the core from freezing. It used 6.1 MMBTU, or the equivalent of 46 gallons of fuel.

The BrHEAThe system uses a heat exchanger and booster fan to distribute heat via ventilation ducting. What is the effect of this distribution system on the overall mechanical system of the home?

CCHRC conducted tests in three areas to explore this question. First, researchers compared the seasonal energy use of the inline booster fan in the BrHEAThe system to that of the distribution pump for heated water to the radiant floor in a neighboring house with a similar layout and heat load.

There was no energy penalty to using the booster fan, which consumed less electrical energy than the pump over the course of the heating season.

Second, researchers conducted a test of supply air temperatures in a high heat load scenario in January 2018 to explore whether there might be safety concerns from distribution air that is too hot. During the test, researchers raised the boiler temperature to the maximum setting and raised the thermostat to 90°F. Supply temperatures rose above 120°F, with a maximum of 143°F occurring in one of the upstairs supply vents. These temperatures fell within the typical range of 120-150°F for heated air in a ducted distribution system, meaning that the particular BrHEAThe system does not pose a safety issue from supply air temperatures.

Finally, CCHRC explored the effect of the inline booster fan on the pressurization of the Birch house. The activation of the inline booster fan puts the house at positive pressure relative to the outdoors. A short-term test showed that pressure rose by 3 pascals (PA) when the fan came on. Monitoring over the heating season showed that the building was pressurized within + / - 5 PA of neutral pressure 94% of the time, but that positive pressure occurred more often than negative, with a heating season average of 1.2 PA.

Conclusion

The BrHEAThe system in the Birch house meets the goal of delivering energy efficient heating and adequate ventilation. However, a residence of this size and layout is at the limit of BrHEAThe's capability to provide comfortable heating to every room, as evidenced by the uneven temperatures experienced throughout the home.



The latest BrHEAThe system is heating and ventilating a home in Oscarville, Alaska after its installation in 2017. It is similar to the BrHEAThe system in the Birch house but features more advanced controls.

Considerations for future installations

Through this project, CCHRC identified best practice guidelines to ensure that future BrHEAThe installations meet the following goals:

Affordable, energy efficient heat

BrHEAThe's ability to provide affordable heating to the Birch house was dependent on an energy efficient, airtight building envelope. Appliances, including the boiler, HRV, and booster fan, should be properly sized, efficient, and maintained. The HRV needs a defrost mode to prevent freezing in the winter, and installers should be aware that appliances with electric resistance elements such as the one in the Birch house may result in high energy bills in some communities.

Adequate ventilation

Each HRV should be commissioned and balanced with air exchange rates that reflect the intended use and occupancy of the home, as occurred in the Birch house. Homeowners should be educated on the need for ventilation, how to use system controls, and required maintenance tasks.

Healthy relative humidity level

In homes with low relative humidity (RH), such as the Birch house, installers should ensure the HRV is commissioned properly and is not over-ventilating the house. The HRV could also be replaced with an energy recovery ventilator (ERV) as ERVs can improve RH levels in a cold climate (Garber-Slaght & Stevens, 2016) (Aubin, et. al., 2013). However, this decision should be made with future occupants in mind, and an HRV should remain the default appliance in homes where future use and occupancy are unknown, as high RH levels are the more common scenario for rural Alaskan homes.

Comfortable temperatures

Designers need to be aware that BrHEAThe is meant for homes that are small, energy efficient, single-story, and

single-zone. It's important to consider BrHEAThe from the onset, emphasizing an open floor plan and even airflow throughout the house. Many homes built after 2013 have new strategies to address uneven temperatures, including the use of jumper ducts to facilitate airflow through rooms with closed doors and control systems that better regulate boiler temperature.

Neutral pressure

The Birch house study found that BrHEAThe in normal operation can cause homes to be at positive pressure relative to the outdoors the majority of the time. Installers should ensure the HRV is balanced with the booster fan off. The house should have a good vapor barrier to mitigate the risk of moisture entering the walls and roof, and a passive make-up air vent to relieve any instances of high positive or negative pressure.

CCHRC is continually striving to improve BrHEAThe and welcomes feedback and suggestions for potential upgrades to the system so that each iteration is better able to provide healthy air and affordable heat to Alaska homes.

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