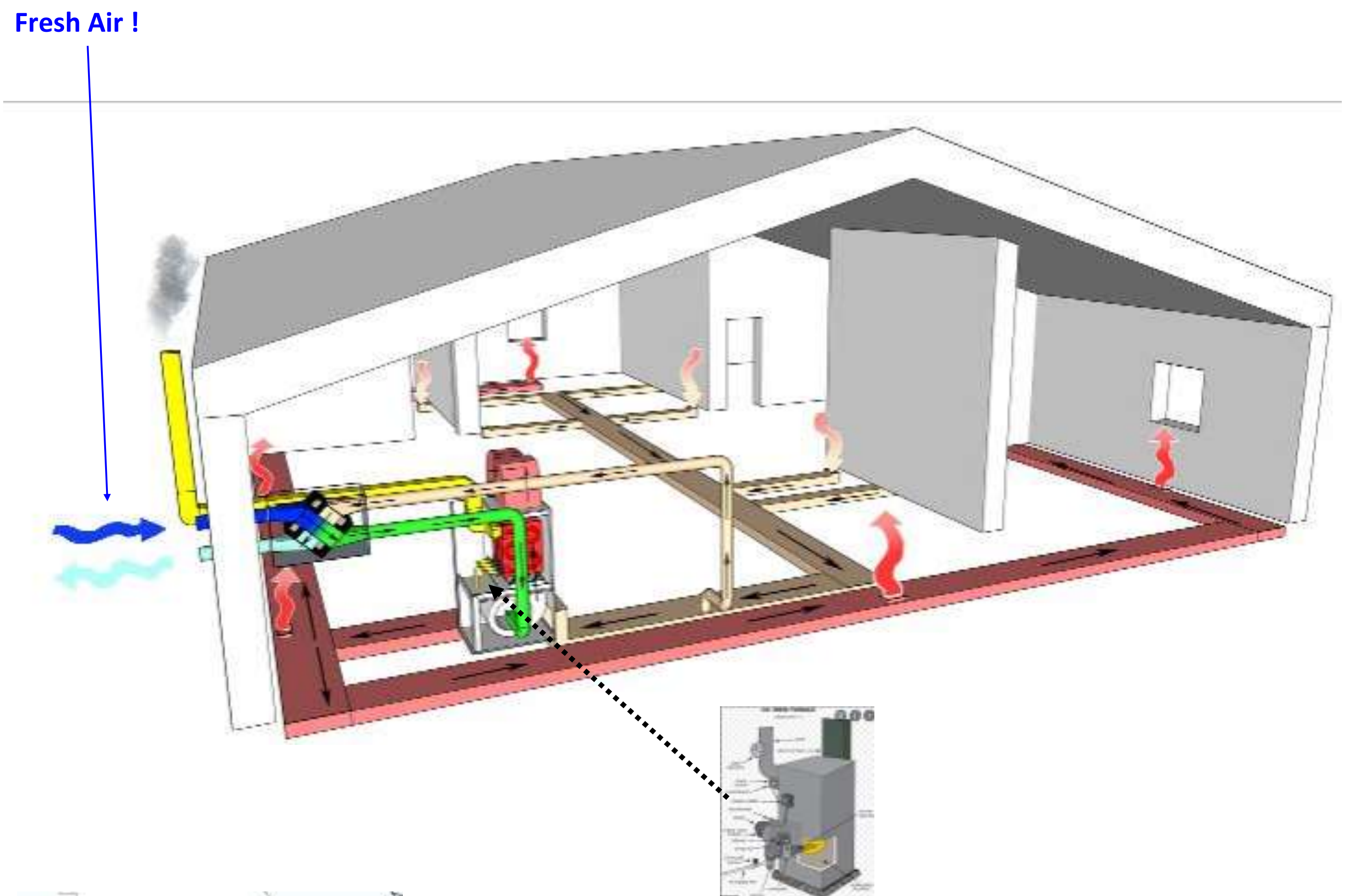
BOOKLET 2: VENTILATION

TECHNICAL GUIDE FOR NORTHERN HOUSING



TAILORED FOR REMOTE NORTHERN ONTARIO COMMUNITIES

First Nations National Building Officers Association
Association nationale des agents du bâtiment des premières nations

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The story of ventilation in the north

Residential ventilation is the exchange of indoor air with fresh outdoor air. Ventilation is one of the most important technical topics covered in this guide's series of booklets.

Air exchange is essential to life. All animals need to breathe. Air exchange is also critical for plant respiration.

Ventilation is essential for indoor air quality (IAQ) and occupant health. For example, very high rates of tuberculosis have been directly linked to northern homes with inadequate ventilation. Inadequate ventilation is also one of the main causes of moisture issues that lead to mould growth in homes, which damages and significantly reduces the life-span of homes.

A common complaint from the general public is that modern stick-built and insulated houses that are airtight don't appear to work in the north, and traditional log cabins with wood-burning stoves have generally performed well without moisture and mould issues. The fundamental reason for this is that in the past, many stick-built and insulated houses constructed to be airtight had very weak ventilation systems and did not perform well, or failed. Some people still believe that houses can be too airtight. However, this is only the case if proper ventilation is neglected, not properly included in the design of the house, not used (i.e. turned off), or not maintained.

Historically, houses were not built to be airtight, and ventilation was neglected to various degrees. These old-style "leaky" houses can have major issues, including costly heating demands. Hence, airtight houses with specified ventilation systems are now generally considered the proper approach to housing in cold climates. Today, a common saying is "build tight, ventilate right!"

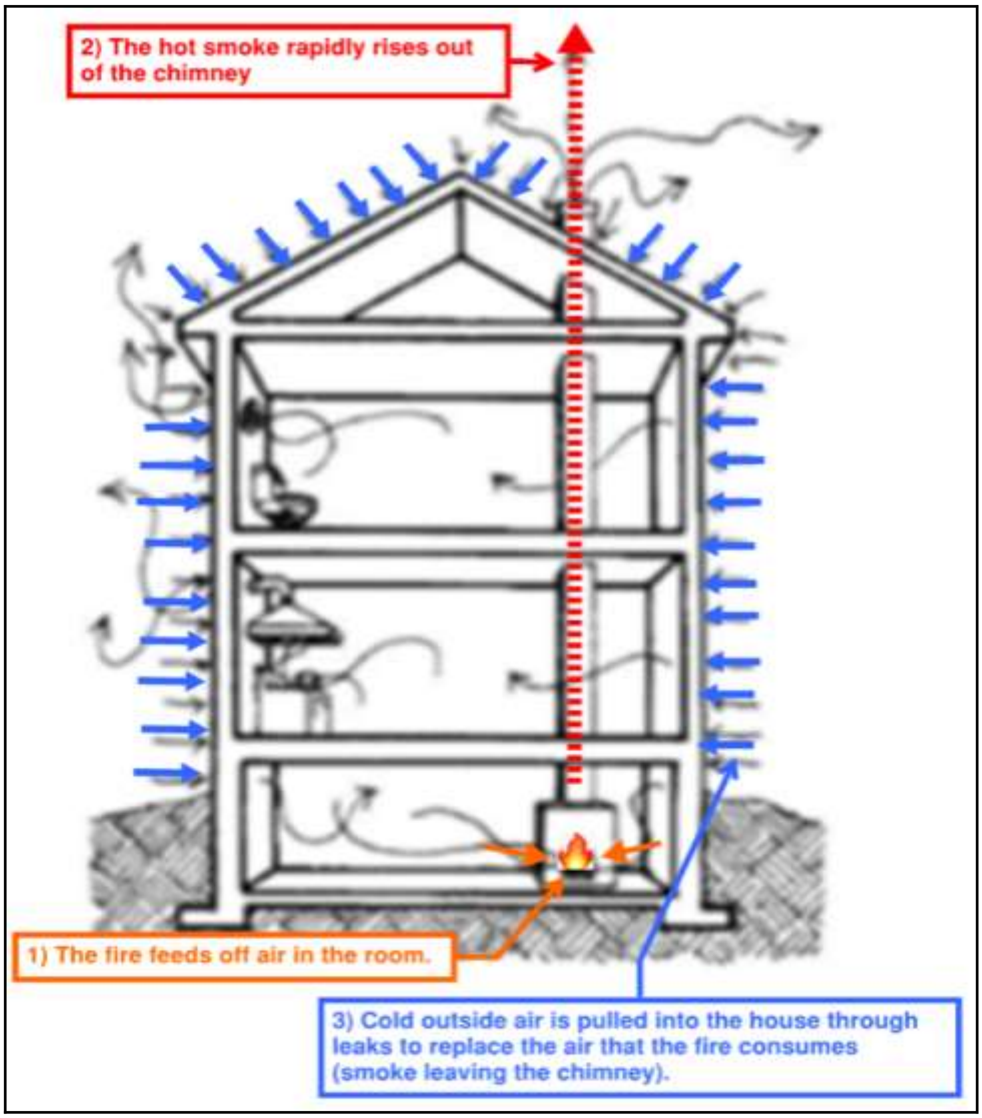
The key to making a modern airtight house perform well is to have a reliable well-thought-out ventilation system included and maintained–this is critical.

Ventilating a house can be very simple and work very well from an air-exchange-only perspective. For example, a basic log cabin with a traditional wood-burning stove generally provides abundant ventilation. There are two main reasons for this.

First, the walls of a basic log cabin are relatively drafty/leaky (not airtight), outdoor air is able to flow through cracks and gaps between the logs as the chinking between logs generally does not create a perfect airtight seal. Air leakage also occurs around windows and doors, and where the walls meet the floor and roof.

The story of ventilation in the north—continued

The second reason is that a wood-burning stove creates a relatively strong negative air pressure (partial depressurization) within the house that draws outdoor air through cracks and gaps generally situated in low parts of the house shell. Combustion gases in the wood stove are very hot and buoyant, and naturally rise rapidly up the chimney and outwards to the sky, creating a strong negative draft in the chimney. This draft causes indoor air to get drawn into the wood stove, where it supports the combustion process. In addition, warm buoyant air in the cabin will rise towards the ceiling and leak out any cracks or gaps in the upper parts of the house shell. This is called stack effect, and stack effect will also cause more outdoor air to enter the cabin along with the fireplace draft.



Cold outside air is pulled into a house, through leaks in the walls and roof, by the draft created by fire in the wood stove.

The story of ventilation in the north—continued

For a small single-room log cabin, the air exchange (ventilation) driven by a wood-burning stove easily provides lots of fresh air that continuously flows into the cabin. As a result, moisture from occupants breathing does not build up in the air, and the air does not get stale with odours from the occupants. The air in a log cabin with a wood-burning stove is generally very dry, due to the high rate of cold, dry, outdoor air flowing in. The coldness of the inflowing outdoor air is often not an issue, as wood stoves radiate large amounts of heat that can overheat the room where the stove is located. Air quality is generally good, except for smoke that leaks into the room when the stove door is opened (which can also trigger smoke alarms and be an annoyance).

Prior to modern heating technologies, houses were heated by a fireplace or stove that pulled air from inside the house. These historic homes generally did not have insulation, other than the thickness of the wood in the walls and roof, and were very drafty, which helped maintain a steady flow of air to feed the fire. However, these leaky houses also required large amounts of fuel to stay warm, and rapidly lost heat, often requiring the fire to be stoked multiple times in the middle of the night during cold weather. As well, it was common that multiple fireplaces or stoves were needed in different rooms or parts of the house. These houses were so drafty with air leaks that people did not need to think about ventilation. Their attention was on staying warm.

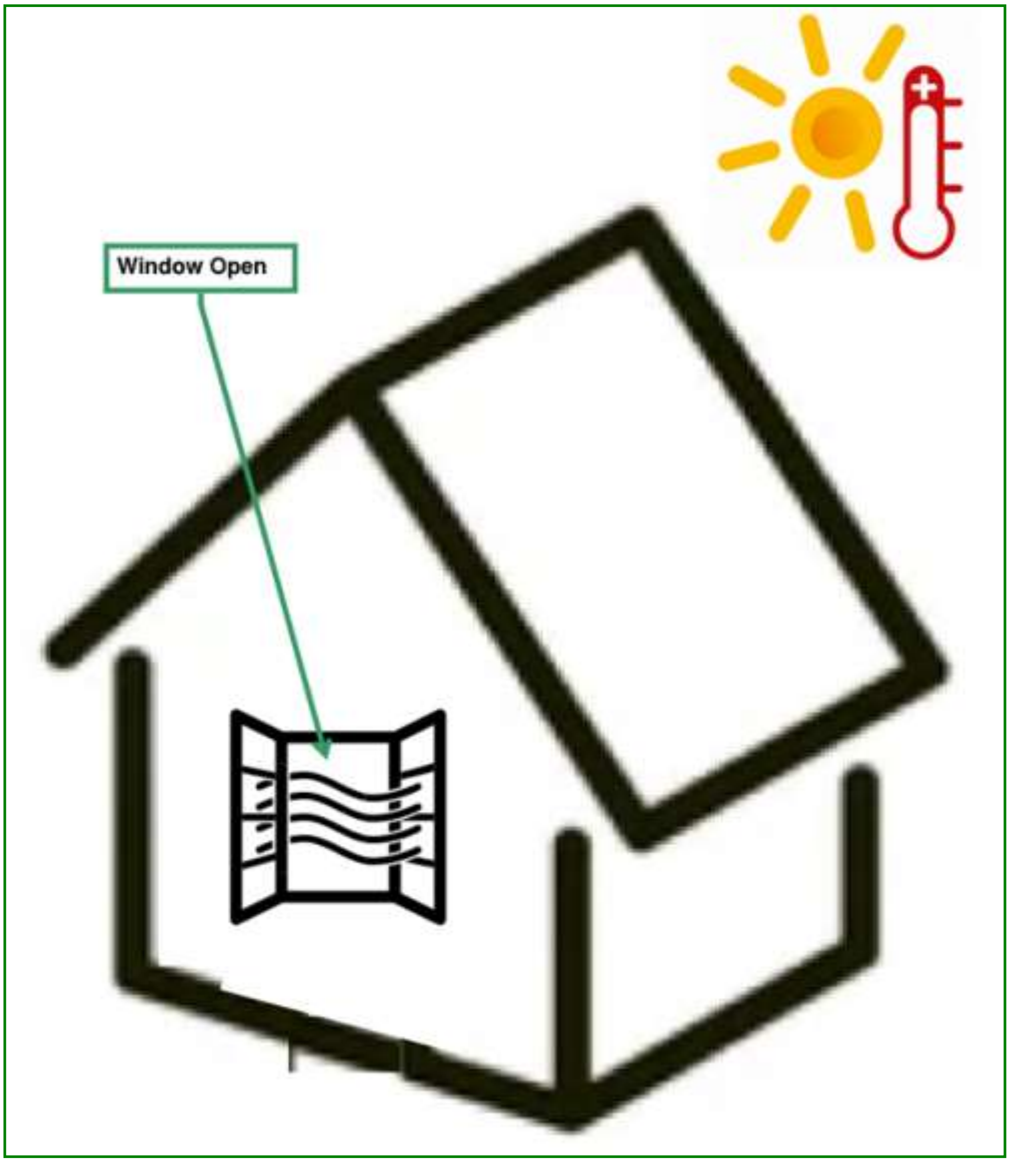
With modern construction materials and heating technologies, houses can be kept warmer using less energy (firewood, fuel, and electricity). Modern insulated and airtight houses hold the heat for much longer. This avoids the need to stoke a fire in the middle of the night. These modern houses save lots of money in fuel and electricity costs. They can also significantly reduce the amount of firewood burned in a season. **The catch is that these modern houses must have a proper ventilation system to ensure acceptable indoor air quality (IAQ), keep the occupants healthy, and protect the building.**

READ THIS BOOKLET IF YOU NEED TO:

1. **Learn about approaches to house ventilation to help maintain healthy indoor conditions and prevent mould growth.**
2. **Decide which type of ventilation approach and system to use for a new* *healthy* house in northern Ontario.**
3. **Know more about the critical elements that make up a proper ventilation system.**
4. **Learn more about suitable housing designs in northern Ontario.**

* Although this booklet is for new housing, the concepts can also apply to the retrofit of existing homes.

Healthy—The ultimate goal is to advise on housing approaches most likely to result in healthy living conditions and community well-being (i.e. avoid moisture problems, last a long time, and minimize heating costs). **Addressing ventilation in houses will significantly reduce the risk of mould growth, which adversely impacts the health of community members, causing higher rates of respiratory-tract infections and the spread of communicable diseases, such as tuberculosis.**



Natural ventilation: Open windows during warm, sunny weather

Natural ventilation by "stack effect" pressure

If ventilation is neglected in a house, any air exchange will be through natural ventilation, such as random leaks/drafts (infiltration/exfiltration), and open doors and windows. Two things are needed for natural ventilation to occur:

* The presence of holes or gaps in the walls, roof and/or floor where air can pass through

* A natural air-pressure difference **(stack-effect pressures & wind pressures)**.

During cold weather, when the house is heated, there is always some air pressure, due to the difference in temperature between inside and outside. As hotter air rises and colder air sinks, the warm air in the house "wants" to leak out the top of the house, and cold air "wants" to leak in at the bottom of the house. This airflow pattern, caused by the difference in air pressure related to the temperature in the house being warmer than outside, is called stack effect, and is shown in the image below. Stack-effect pressure is the reason smoke rises out of a chimney. The larger the temperature difference, the greater the stack-effect pressure. Also, the more floors a house has, the more stack-effect pressure there will be (a single-level house has relatively small stack-effect pressures, except during very cold weather).

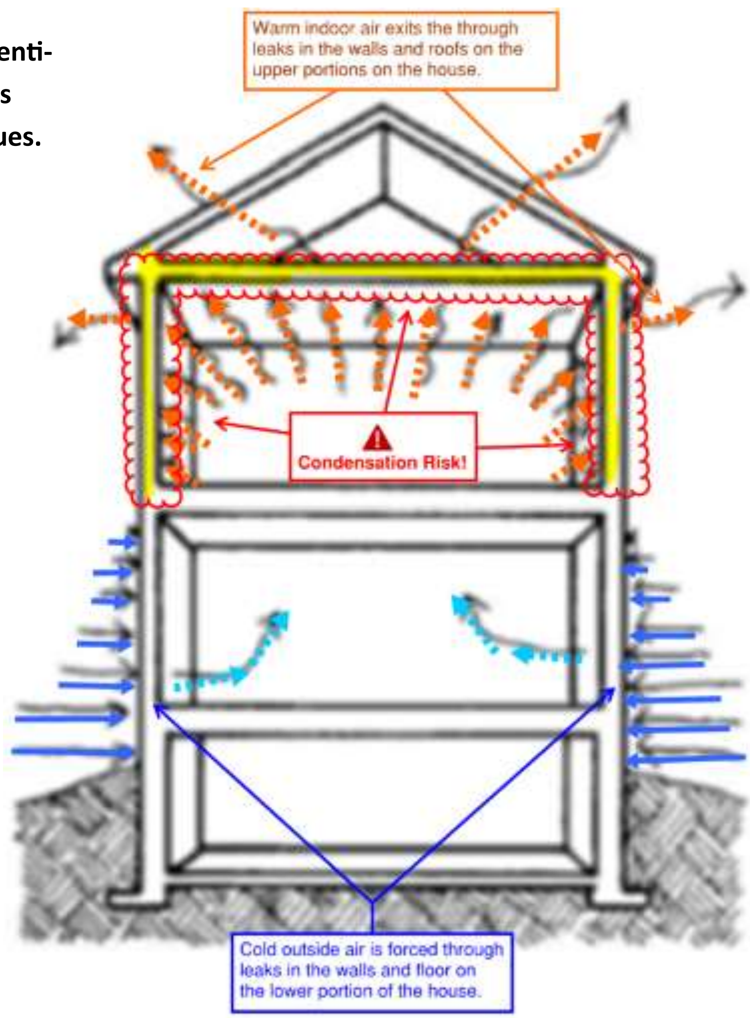
Note: Stack effect does not reliably provide enough ventilation to maintain healthy indoor-air conditions, but is significant enough to cause moisture and comfort issues.

A warning about natural ventilation through leaks: The warm air in a house picks up moisture from people breathing, cooking, showering, etc. The longer the air is in the house (i.e. under-ventilation of the house), the more moisture the air picks up.

When this warm, moist air cools as it leaks through the building shell, there is a high risk that it will condense and deposit moisture in the walls and ceiling/roof.

This is a major cause of mould and moisture problems in old leaky homes, especially ones without wood-burning stoves or a mechanical ventilation system.

Airtight house construction with mechanical ventilation significantly reduces the risk of condensation from air leakage.



Natural ventilation by stack-effect pressure

Natural ventilation by Wind pressure

Wind is the other main natural pressure other than stack effect that drives natural ventilation.

Wind pressures force outdoor air into the house through holes in the walls and roof on the side exposed to the incoming wind. Additionally, air is sucked out of the house through holes in the walls/roof on the downwind side, due to the suction pressure of the wind. Strong winds can create a lot of natural ventilation in leaky homes. However, wind is generally erratic and cannot be relied upon to provide consistent natural ventilation. If the wind is consistent, it can cause condensation issues, as highlighted in yellow in the image below.

A warning about natural ventilation through leaks: Warm air in a house picks up moisture from people breathing, cooking, showering, etc. The longer the air is in the house (i.e. not enough ventilation), the more moisture the air picks up.

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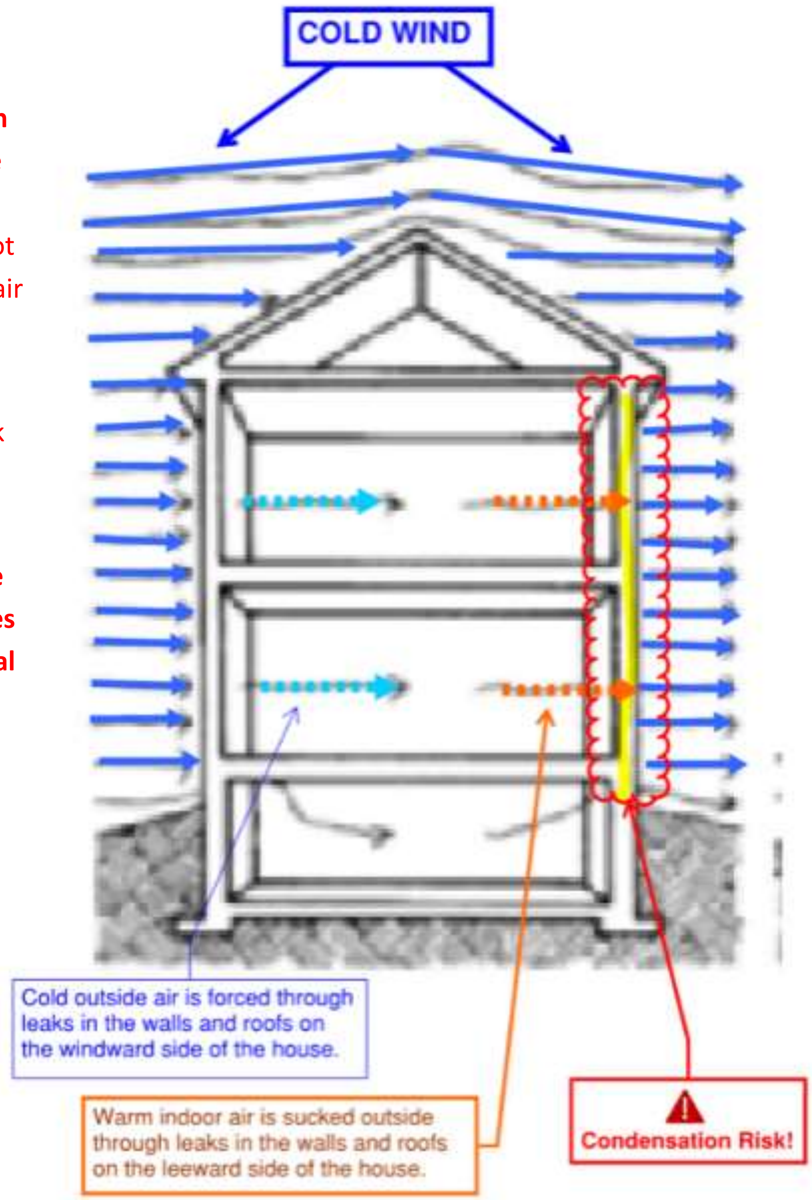


Natural ventilation by open windows

Having numerous large openings in the house will provide excellent ventilation, even if there is minimal wind and/or stack effect. This is the primary form of ventilation in warm/hot climate regions. The most common way this occurs is by opening multiple windows in different rooms and different sides of a house. In addition to the windows, leaving doors open is a simple way of significantly increasing natural ventilation.

Natural ventilation through an open window

During hot weather in the summer months, opening windows is a great natural way to ventilate your house. Even if your house has excellent mechanical ventilation, turning off the mechanical system and opening windows when it is hot outside is recommended to save energy.

Opening windows during cold weather results in a large amount of heat loss. It wastes firewood, heating oil, and electric heating energy. It also exposes the occupants to cold drafts. Open windows could freeze, which could cause damage to hardware and frames if they are forced closed.

It is common for wood-burning stoves to overheat small cabins even if they are not insulated or airtight, even during very cold weather. Wood-burning stoves radiate large amounts of heat which is difficult to control. As a result, people typically leave windows open, to various degrees, to control the house temperature.

There can be issues with ventilation if the open window is near the stove. Fresh air from the window travels directly to the stove and does not provide fresh air to the other rooms in the house. If the window is far away from the stove, the room with the open window will be very cold, while the room with the stove is too hot. Large temperature differences between different rooms/areas of a house becomes a significant issue.

Other types of heating, such as furnaces or electric baseboard heaters, are much easier to control, so opening windows is not typically needed.

Much better approaches exist that provide steady temperatures throughout the house, improve occupant comfort, use much less energy/firewood, and provide excellent ventilation. These approaches are presented in the following pages of this booklet.

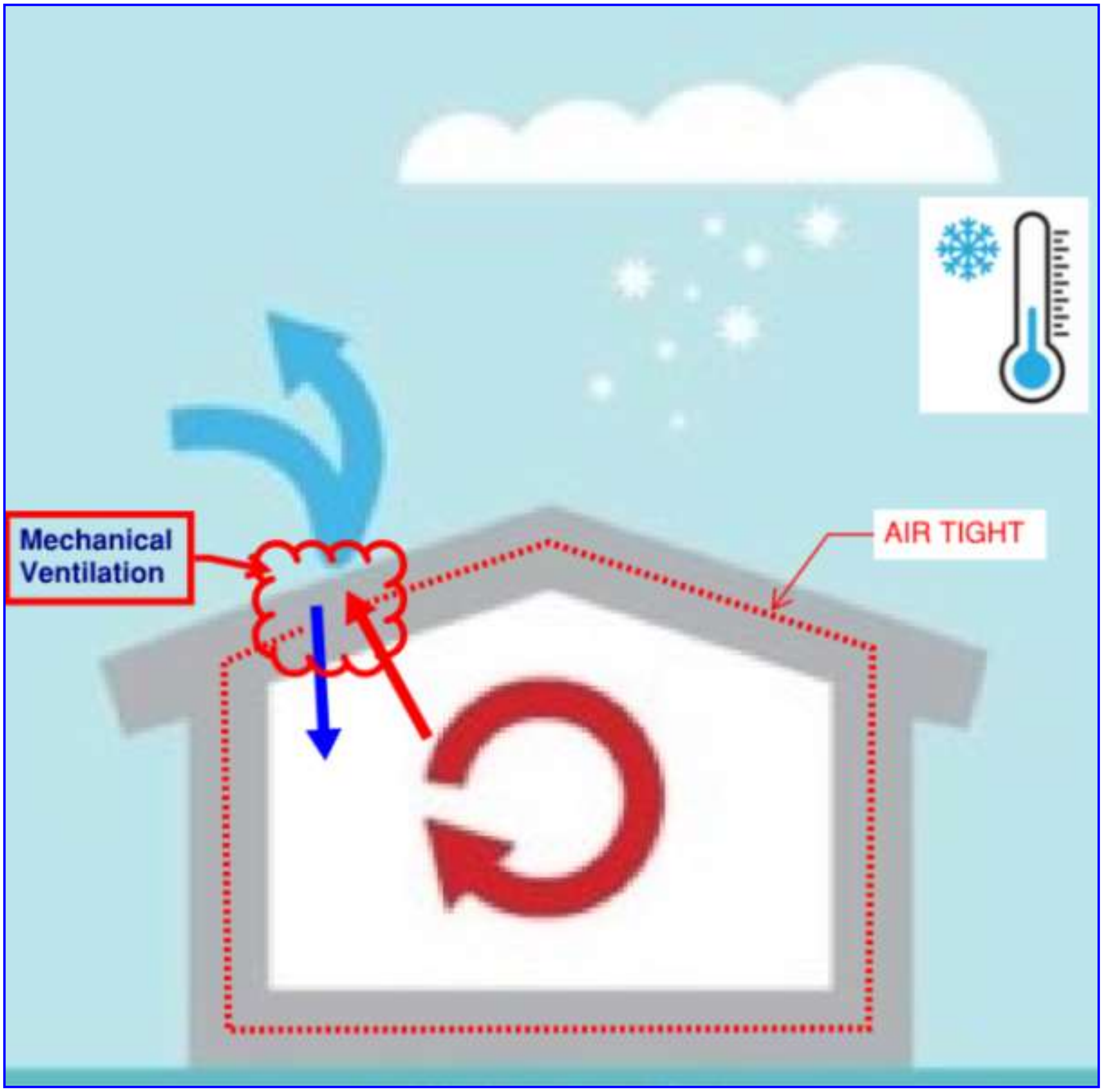
Natural ventilation by passive air-inlet ports

An alternative to open windows and doors for natural ventilation are passive air-inlet ports. These ports are holes intentionally included in the construction of a house's walls to allow air to flow into the house. They provide a clear path for air to flow either into or out of a house. They provide natural ventilation the same way an open window does. However, they are smaller than operable windows and provide less air flow than a typical open window.

Passive air inlet (pipe through a wall)

Caution: Passive air-inlet ports are not recommended for houses in the north. They will result in too much heat loss during cold weather, especially in the winter months, leading to more costs in firewood, heating oil, and electric-heating energy.

Operable windows are recommended over passive air inlets.



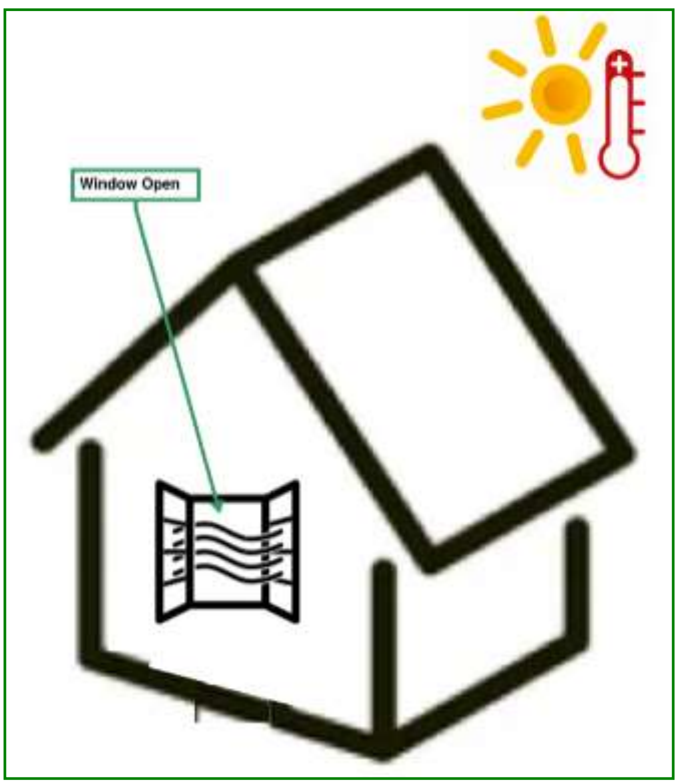
House with mechanical ventilation operating in cold snowy weather (windows closed)

Natural and mechanical ventilation—in an airtight house

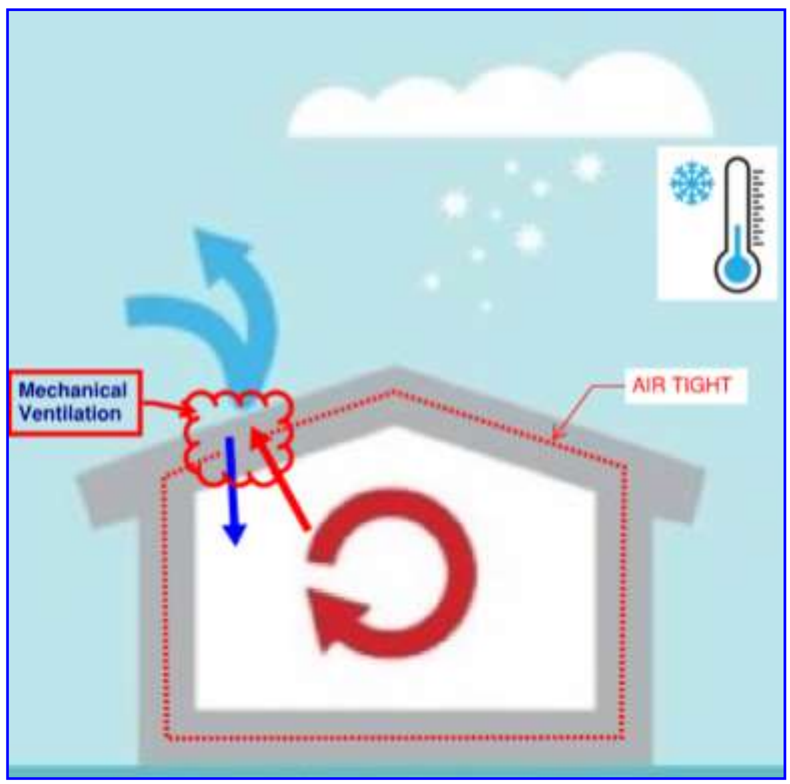
The modern approach to house construction in cold climates is to build airtight*. The goal is to reduce air leakage as much as reasonably possible, save energy, avoid condensation issues, and maintain occupant comfort by avoiding cold drafts. This means that natural ventilation through leaks in the house does not occur, or is so minimal (minimum required ventilation is not met) that it has no noticeable effect on inside air quality.

Open Windows: The only recommended form of **natural ventilation** in an airtight house; leaving windows open is recommended only during warm weather in the summer months.

Mechanical Ventilation: During colder weather, the windows should be closed to keep heat inside. Mechanical ventilation is needed to ensure proper ventilation and maintain healthy air conditions when the windows need to be closed. If properly installed, controlled and maintained, it can work year round.



House with open window in warm sunny weather



House with mechanical ventilation operating in cold snowy weather (windows closed)

**For information about airtight construction refer to Booklet 7 on walls, roofs and floors.*

EXHAUST FANS

Exhaust fans are the simplest and most common type of mechanical ventilation. They pull air from the room they are in and push it outside through a duct with a hood, typically installed on an exterior wall. The duct should have a backdraft damper to prevent air flowing into the house when the fan is turned off.

A basic exhaust fan

Backdraft damper in a duct

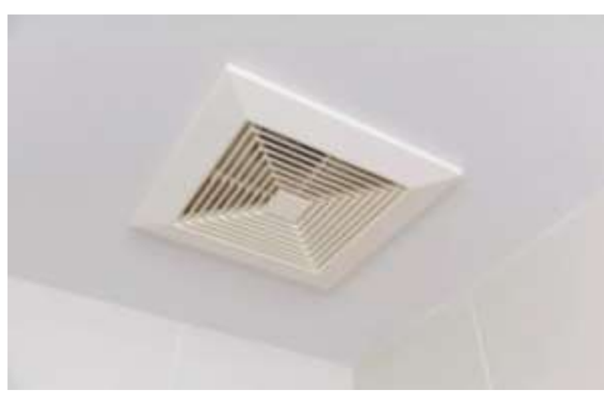
Exterior exhaust hood

Exhaust fans are required in rooms where lots of moisture or odours are produced, to avoid air in the house from becoming too humid or contaminated with odours. For example, they are placed above stovetops, to exhaust odours during cooking, and moisture from boiling kettles, etc. Exhaust fans are very important in air-tight houses, but should also be installed in older-style, non-airtight, leaky homes. The following locations require exhaust fans:

- **Kitchen** (ideally, above stovetop burners)
- **Bathrooms** (ideally, in the ceiling directly over the shower)
- **Laundry dryers** have a built-in fan to exhaust the moist air from wet clothing.

Exhaust fans in kitchens and bathrooms rely on occupant behaviour. They have to be switched on by occupants, who often neglect to do so. Education of the homeowner is needed.

A basic exhaust fan over a stove



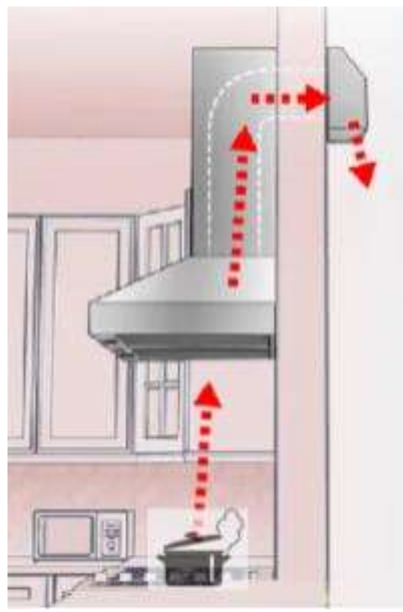
A basic exhaust fan above a shower

EXHAUST FANS—continued

Exhaust fans also protect Heat Recovery Ventilators (HRV) and/or Energy Recovery Ventilators (ERVs) from becoming clogged with grease from cooking, or lint from a laundry dryer.

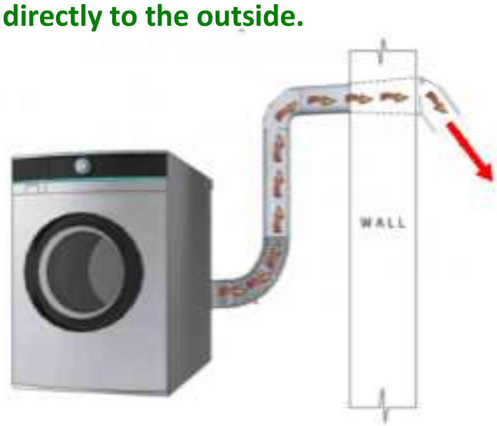
Cooking puts grease into the air that can accumulate in ventilation systems, especially HRV heat-exchanger cores. This becomes a maintenance issue. Exhaust air from laundry dryers contains lint that would clog an HRV heat-exchanger core. Avoid drawing air from near the kitchen stove when using an HRV/ERV, and never from a clothes dryer.

Cooking gases need to be exhausted directly from the kitchen to the outside with a fan in the range hood.



Cooking gases being exhausted directly outside with a fan above the stove

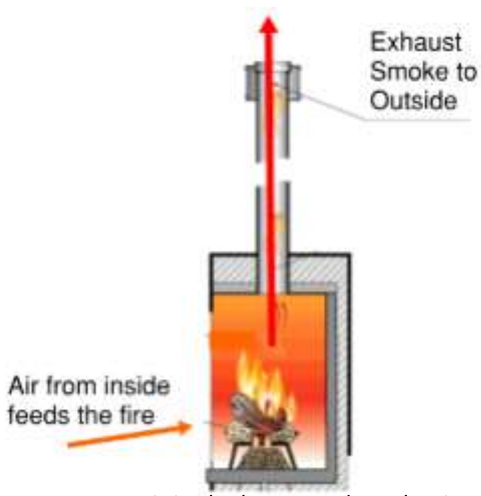
Laundry dryers also need to exhaust directly to the outside.



A laundry dryer exhausting directly through a wall to the outside

Direct Venting of Combustion Appliances

Traditionally, combustion appliances (fireplaces, wood stoves, furnaces, hot-water tanks, etc.) have burners that consume air in the room. Combustion appliances that consume air are considered "open-combustion" appliances. For example, a traditional fireplace has open combustion, as shown in the image below. Open-combustion appliances can work well if there is enough combustion air from natural ventilation, such as when lots of windows are open. However, open-combustion appliances are risky in airtight houses. The chimney of the open-combustion appliance can become the only air-supply hole where outdoor air can flow in to replace the air expelled by any exhaust fans. This can cause the chimney to reverse flow, and is especially dangerous when a wood fire is dying out and low temperatures and lots of carbon monoxide are being produced.



Open combustion where the fire consumes air in the house and smoke rises up the chimney

When exhaust fans are turned on in an airtight house, smoke tends to get pulled from open-combustion appliances into the house instead of rising up the chimney. If the laundry dryer and bathroom and kitchen fans are all running, lots of smoke can easily get pulled into the house from open-combustion appliances and negatively impact air quality. This can create dangerous conditions where poisonous carbon-monoxide gas (which is invisible and odourless) accumulates in the house, instead of exiting through the chimney.

It is strongly recommended that carbon-monoxide detectors are installed in every home with fuel-burning equipment.

Smoke getting pulled into a house from a wood stove when an exhaust fan is turned on

Direct Venting of Combustion Appliances—continued

To prevent smoke from getting pulled into the house, combustion appliances need to be direct vented. This means that the fire burner in the appliance or combustion chamber in a wood stove is connected with a pipe to the outdoors so that the fire can directly consume outdoor air. The images below show wood stoves that are direct-vented to the outside.

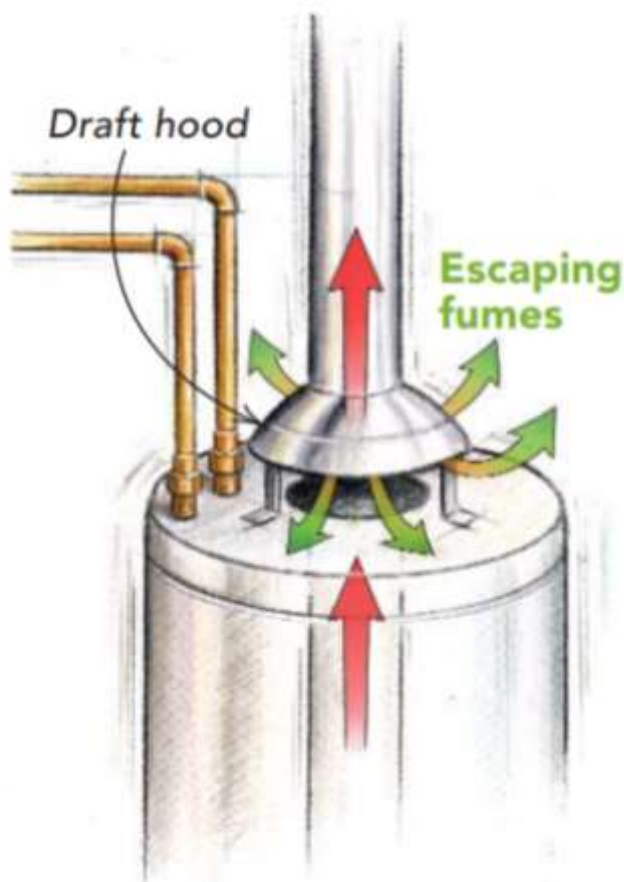
Follow all manufacturer instructions with regard to safety precautions, Ensure that air-supply ducts are non-combustible and sized correctly, and venting is not touching any combustible materials. No combustible sealants or tapes should be used.

Direct venting of a wood stove with a pipe through the wall

Direct venting of a wood stove with a pipe through the floor and a valve

Similar to the wood-stove example, many fuel-burning hot-water tanks and furnaces have open-combustion configurations. When exhaust fans are turned on in an airtight house, combustion gases, including poisonous carbon monoxide, are prone to getting pulled from these appliances into the house, instead of rising up the chimney. This can create dangerous conditions where poisonous carbon monoxide gas (which is invisible and odorless) accumulates in the house, instead of exiting through the chimney. The images below show the top of a common fuel-burning hot-water tank with an open draft hood. Do not block the openings of the draft hood. Follow all installation instructions.

An open draft hood at the top of a hot-water tank circled in red

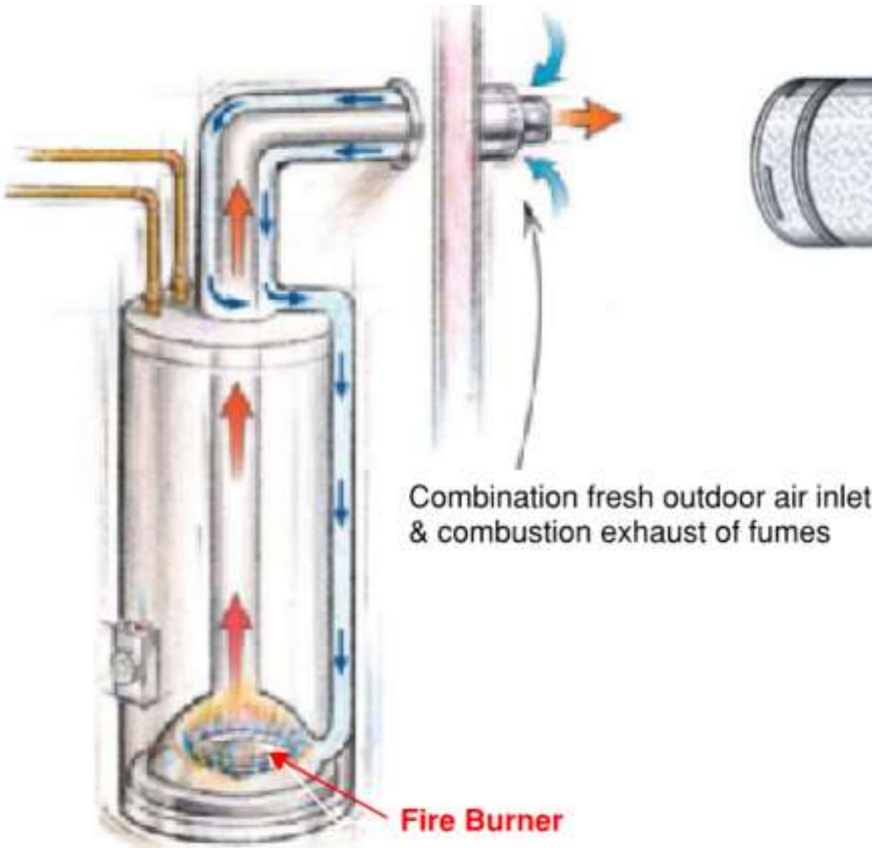


Escaping combustion gases from the open draft hood at the top of a hot-water tank

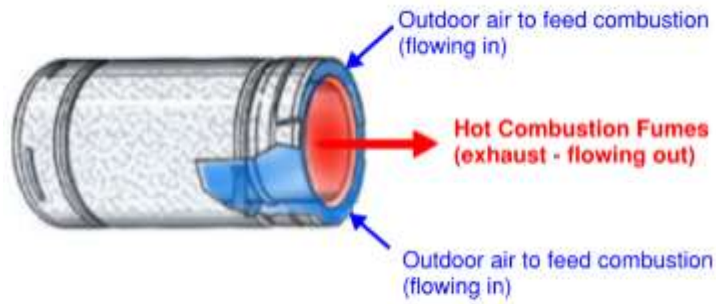
Direct Venting of Combustion Appliances—continued

To prevent combustion gases from getting pulled into the house, combustion appliances should be direct-vented whenever possible. This means that the burner in the appliance or combustion chamber of a wood-fired stove is connected with a pipe to the outdoors, so the fire can consume outdoor air. The images below show a fuel-burning hot-water tank designed to be direct-vented to the outside with a co-axial pipe.

It is strongly recommended that carbon-monoxide detectors be installed in every home with fuel-burning equipment.



A fuel-burning hot-water tank direct-vented with a combination air-supply/exhaust vent (co-axial)



Nested pipes of a combination air-supply/exhaust vent (co-axial)

A benefit of the combination air-supply/exhaust vent is that the outdoor air is pre-heated by the combustion exhaust pipe (centre), due to close contact with the surrounding air-intake pipe. The burner chamber is not cooled as much by the warmed outdoor air. This results in greater energy efficiency.

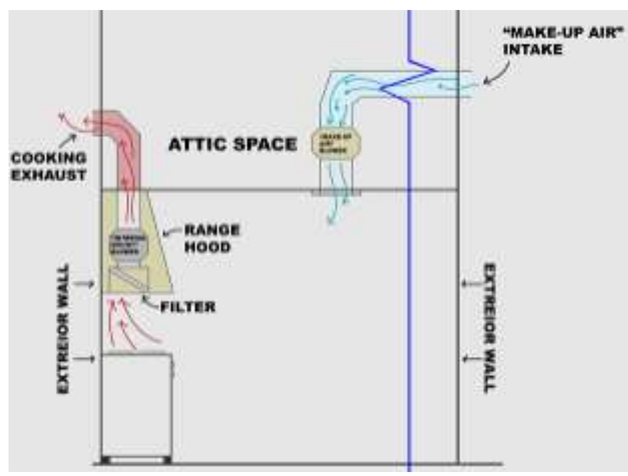
Make-up air for exhaust fans

All air exhausted out of the house by fans in the kitchen and bathroom, and by the laundry dryer, needs to be replaced. For airtight houses, this replacement air (called make-up air) must be brought in from outdoors. When the windows are open in the summer, the outdoor make-up air will simply flow into the room to replace indoor air being expelled by the exhaust fan (as shown below).

Air flowing into a bathroom with a steamy shower and the exhaust fan running

In winter, windows are usually kept closed to keep heat in the house. Therefore, the make-up air needs to come from somewhere else (not the windows). In warmer southern climates, simple make-up air ducts and fans are provided in the same room as the exhaust fan (as shown below).

However, these simple make-up air ducts supply cold outside air directly into the room. They act like an open window, and make the house cold in the winter, which is not suitable for northern climates.



A simple make-up air duct (blue) to replace the exhaust fan air (red), for a kitchen stove exhaust

It's important to make sure that make-up air gets heated, otherwise people will feel a cold draft and block the offending opening. Ideally, air should come into a forced-air furnace so the furnace will heat it up before distributing it through the house. Additionally, a Heat Recovery Ventilator (HRV) should be used to pre-heat the outdoor air intake by recovering waste heat from the warm exhaust air (sensible heat is transferred from warm exhaust air to cold supply air through the core), to save energy.

HEAT RECOVERY VENTILATORS AND ENERGY RECOVERY VENTILATORS (HRVs & ERVs): More than just exhaust fans

In an airtight house, the intermittent use of exhaust fans generally does not provide enough air exchange to ensure healthy indoor conditions. Exhaust fans typically run for only short periods of time when the bathroom and/or kitchen are in use, or when the laundry dryer is running. Additional ventilation (air exchange) is required.

The concentration of carbon dioxide (CO_2) in a house is the standard indicator of indoor air quality. Outside air typically has a CO_2 concentration of about 400 parts per million (ppm), depending on outdoor pollution. Indoor air will have higher CO_2 concentrations, mostly due to the presence of occupants (breathing). Ventilation standards and guidelines recommend that the indoor CO_2 concentration be kept below 1,000 ppm. When the CO_2 concentration rises above 1,000 ppm, the air in the house is getting stale and not renewed enough, and people in the house are re-breathing the same air over again. The risk for respiratory illnesses and spread of communicable diseases, such as tuberculosis, increases significantly in these poor indoor air quality conditions.

The National Research Council of Canada has performed CO_2 testing in houses in the north both with and without proper mechanical ventilation, and observed that homes with proper mechanical ventilation systems had CO_2 concentrations lower than 1,000 ppm the majority of the time. However, houses without proper mechanical ventilation had CO_2 concentrations much higher than 1,000 ppm the majority of the time (see the image below). All the houses generally had exhaust fans; the houses with proper mechanical ventilation had additional systems to provide ventilation (such as an HRV or ERV).

As a result of poor indoor air quality in houses without proper ventilation systems, people in remote northern communities have had rates of tuberculosis infection more than 100 times the rate in the rest of Canada. Under-ventilation and overcrowding lead to buildup of excess moisture in homes and the development of mould, which adversely impacts the health of occupants who have higher rates of respiratory-tract infections. Children (around 5 years old and younger) are particularly vulnerable.

The good news is that mechanical ventilation systems are very good at improving indoor air quality. Better indoor air quality significantly reduces the risk of illness and spread of communicable diseases. The amount of required ventilation can easily be determined based on the size of the house and the number of people living in the house.

HEAT RECOVERY VENTILATORS AND ENERGY RECOVERY VENTILATORS (HRVs AND ERVs): How much continuous ventilation is needed?

The amount of ventilation a house needs depends on its size (livable surface area) and number of occupants. For every person that lives in the house, 7.5 cubic feet per minute (cfm) of ventilation should be provided plus 0.03 cfm per square foot of floor space in the house.

$$\text{Required Ventilation (in cfm)} = 0.03 \times (total\ floor\ area) + 7.5 \times (number\ of\ occupants)$$

Therefore, if you have a house with 2,000 square feet of floor area and six people living in it, a minimum continuous ventilation rate of 105 cfm should be provided.

$$0.03 \frac{cfm}{sq.ft.} \times (2{,}000\ sq.ft.) + 7.5 \frac{cfm}{occupant} \times (6\ occupants) = 105\text{ cfm}$$

To put the 105 cfm ventilation rate into perspective, typical bathroom exhaust fans are rated 50 cfm to 110 cfm. The bathroom fan in the image below is rated for 80 cfm. Therefore, to meet the 105 cfm minimum ventilation rate, two fans would be needed.

Typical bathroom fan (this one rated to 80 cfm)

Leaving exhaust fans running does not work in an airtight house, as it leads to house depressurization, unless there is a path for fresh outdoor air to enter the house, such as an open window. In the winter, leaving two bathroom exhaust fans continuously running with windows partially open would waste a lot of heat and make the house very difficult to keep warm.

HRVs and ERVs are the best equipment/technique to address issues listed above. They provide a path for both the exhaust air and the incoming fresh outdoor air (balanced ventilation), and transfer heat or energy from the exhaust air to the incoming outdoor air to conserve energy. An HRV or ERV should typically provide this 105 cfm of continuous ventilation (not the exhaust fans on their own).

HEAT RECOVERY VENTILATORS AND ENERGY RECOVERY VENTILATORS (HRVs AND ERVs):
Past history of use in the north

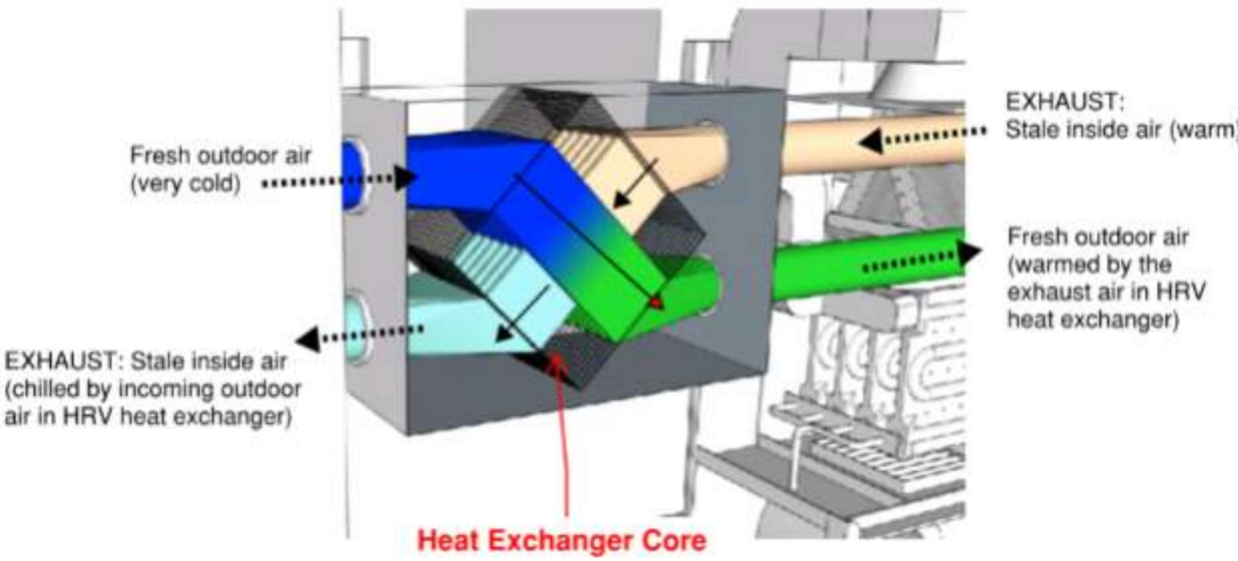
The use of Heat Recovery Ventilators (HRVs) and Energy Recovery Ventilators (ERVs) in remote northern communities has been challenging. Successful operation and performance without issues has been limited to a minority of homes. Of all the different products, materials, and technologies used in housing in the north, HRVs and ERVs have received a lot of negative attention (HRVs/ERVs installed in the north are plagued with problems; freezing core, failure, noisy). HRV problems are near the top of the list for most common complaint from occupants. **However, HRVs/ERVs are essential to provide required ventilation and maintain healthy indoor conditions, while at the same time conserving heat and energy.***

Photo of a typical HRV installed in the mechanical room of a house with insulated air ducts connected to it; the different air streams in the HRV

**Healthy indoor conditions can be maintained in a house without an HRV or ERV, but a lot more heat will be lost to the outdoors. To reduce high heating-fuel and energy costs while also reducing the impact on the environment, install an HRV or ERV for proper ventilation.*

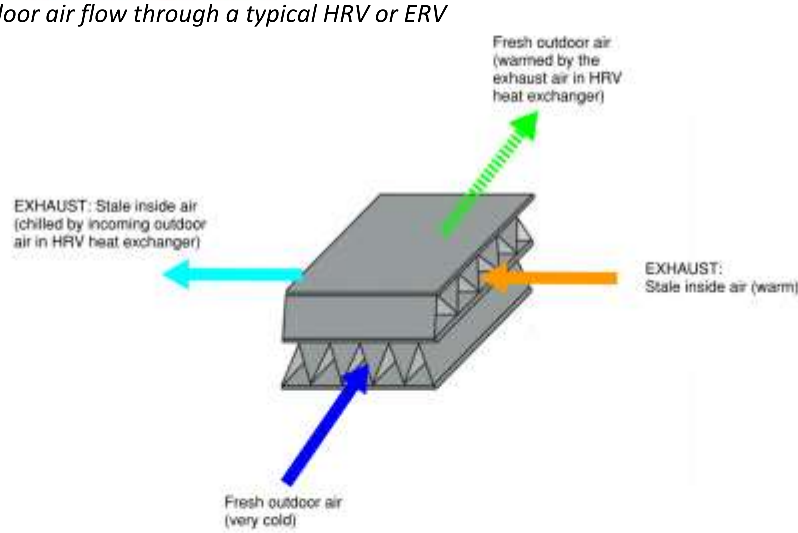
HEAT RECOVERY VENTILATORS AND ENERGY RECOVERY VENTILATORS (HRVs AND ERVs): How do they work

HRVs and ERVs used in dwellings typically have a single core (heat exchanger) that consists of channeled plates. The channels in the plates are rotated 90 degrees between each layer so that exhaust air and incoming fresh air flow across each other at 90 degrees (right angle), but separated by the plate as shown in the images below. The channeled plates separate the exhaust air from mixing with the fresh incoming air. The core is made of thin material that has the property to transfer sensible heat in the case of an HRV, or energy (sensible and latent heat) in the case of an ERV from the warm exhaust air to the incoming fresh outdoor air. Dual-core units with sensible core and enthalpy core in series are also available.



Exhaust air and incoming fresh outdoor air flow through a typical HRV or ERV

Heat exchanger core of an HRV



Typical offset channeled plates in the heat-exchanger core

HEAT RECOVERY VENTILATORS AND ENERGY RECOVERY VENTILATORS (HRVs AND ERVs):

What's the difference between the "H" and the "E"?

An HRV only transfers sensible heat from the exhaust air to the incoming outdoor air. An ERV transfers not only sensible heat but also latent heat (moisture) from the more humid airstream into the other airstream. Both HRV and ERV cores are designed with multiple channels physically separated to prevent cross-contamination between incoming and outgoing airstreams.

The HRV core is made of metal (usually aluminum) and called sensible core. The ERV core is made of a synthetic porous material that functions as a semi-permeable membrane that moisture can migrate through. It is called an enthalpy core. HRVs are recommended for cold climates, but can contribute to indoor dryness in extreme cold climates (very dry fresh outdoor supply air). ERVs are being installed in cold climates and present the advantage of maintaining more acceptable indoor relative humidity (RH) than an HRV. An ERV transfers some moisture back to the indoors through its core, which recovers moisture from exhaust air to the intake outdoor air (in winter, indoor RH could be higher than intake air RH, due to indoor activities).

Heat exchanger core of an HRV, made of aluminum

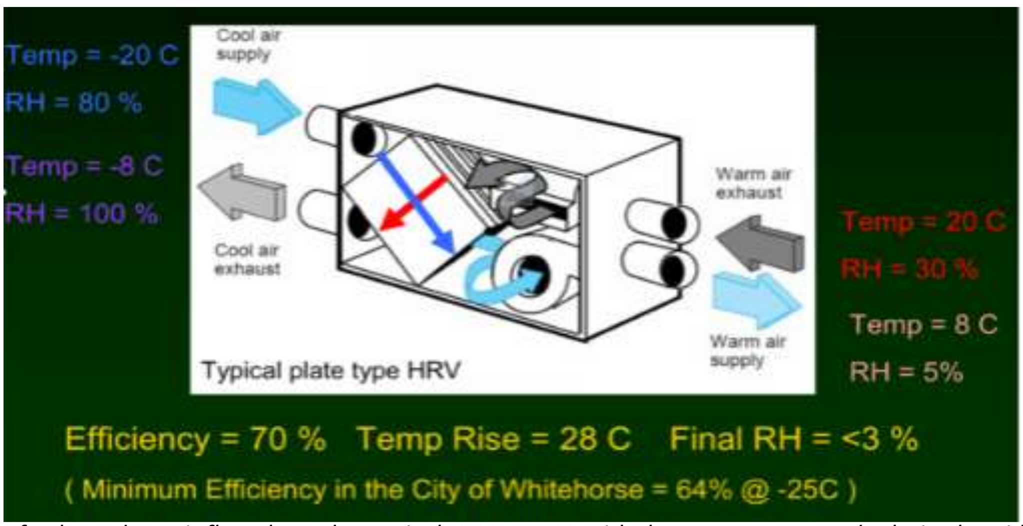
Heat exchanger core of an ERV, made with synthetic materials that allow moisture transfer

Field studies completed by the NRC Construction Research Centre IAQ team show the impact of installing an HRV or an ERV as a retrofit to improve the ventilation of homes.

HEAT RECOVERY VENTILATORS AND ENERGY RECOVERY VENTILATORS (HRVs AND ERVs): How well do they work in the north?

HRVs and ERVs work very well at recovering heat from the warm exhaust air to the incoming fresh outdoor air. ERVs work well in recovering moisture from the exhaust air to the intake fresh outdoor air. The image below shows an HRV exchanging indoor air at a temperature of 20°C and a relative humidity (RH) of 30 per cent; with outdoor air, that is at a temperature of -20°C, and a relative humidity (RH) of 80 per cent.

The result is that the HRV is able to warm the outdoor air by +28°C, to reach a temperature of +8°C, with a relative humidity of five per cent. The reason the air does not simply warm to the mid-way temperature of 0°C is that there is a lot of energy (sensible + latent) stored in the moisture of the inside air. Wet warm air contains more heat than dry warm air at the same temperature. Similarly, cold dry air increases temperature with less heat than cold wet air.



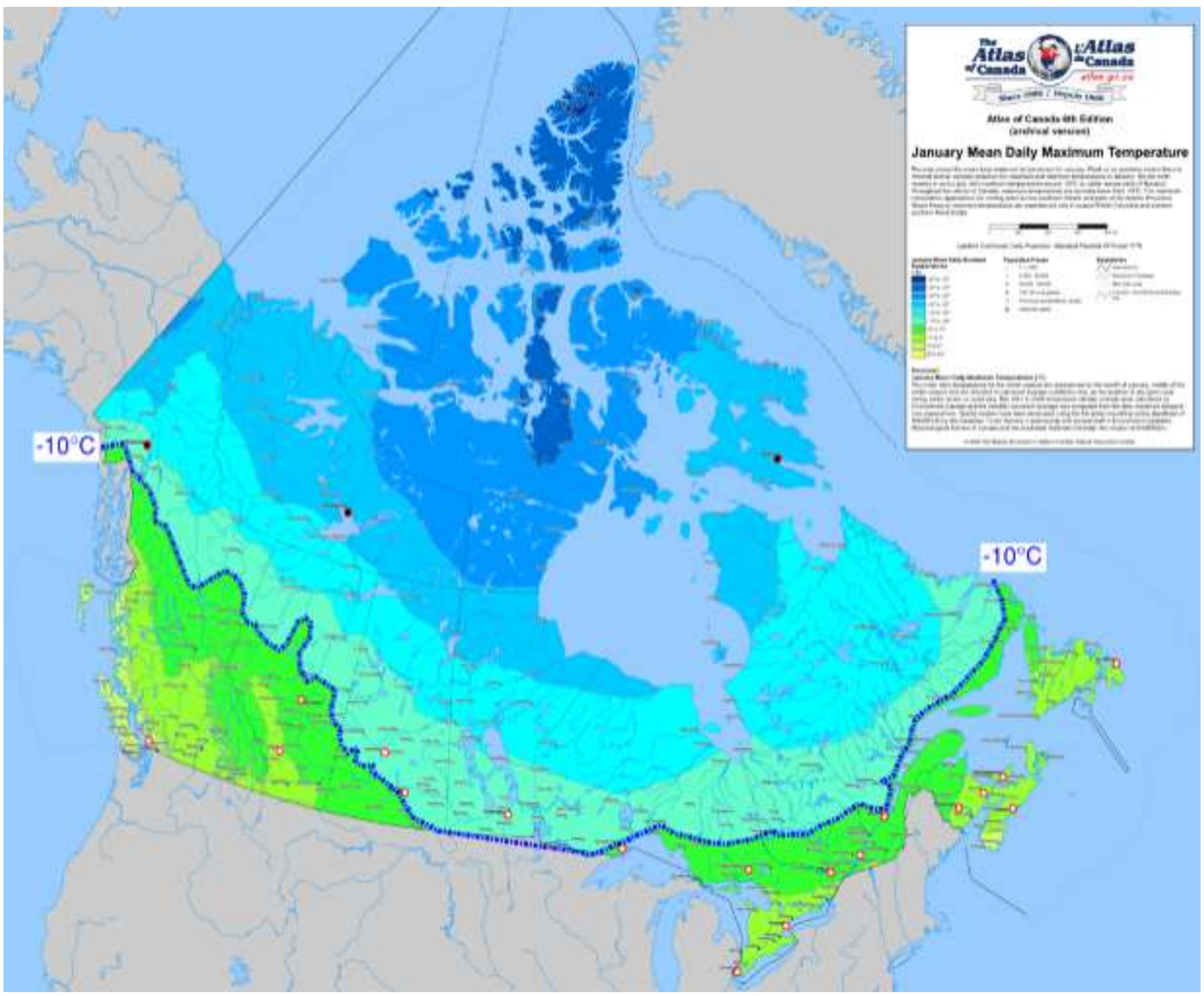
Exhaust air and incoming fresh outdoor air flow through a typical HRV or ERV, with the temperature and relative humidity of the different air streams listed

Unfortunately, this is only part of the picture. HRVs/ERVs installed in the north are plagued with problems. The reality is that single-core HRVs/ERVs are prone to icing up, especially if not properly matched initially for the house, installed correctly, balanced and maintained. They may work well for a short period of time, even when the defrost cycle is working. However, as the warm humid air passes through the HRV, moisture condenses inside the heat-exchanger core as the outdoor air temperature is colder than the dew point of the inside air. This moisture accumulates and freezes quicker than the defrost cycle can handle, until the heat-exchanger core is blocked with frost/ice. The long defrost cycle reduces the ventilation rate, and when frozen solid, prevents further ventilation. During the defrost cycle, there is no provision of fresh outdoor air to indoors. These are some of the major reasons many people in the north are skeptical about HRVs.

HEAT RECOVERY VENTILATORS AND ENERGY RECOVERY VENTILATORS (HRVs AND ERVs):

Iced-up single-core HRVs—where is it a problem?

Icing up of an HRV's core (frost formation in the heat exchanger) generally becomes problematic in regions where the temperature is below –10°C for extended periods of time. On the map below, the regions above the blue line are consistently colder than –10°C in January. Note: Saskatoon, Regina, and Winnipeg are the only major Canadian cities within this colder region.

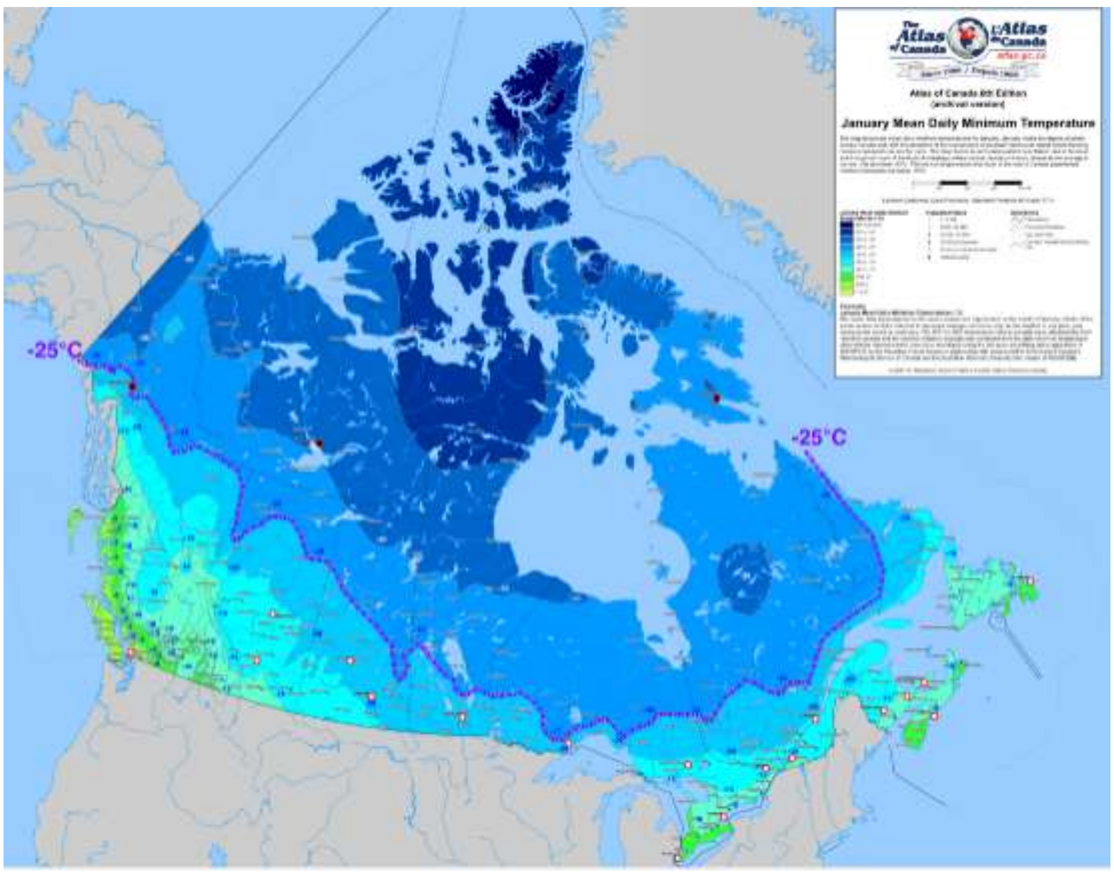


Map of Canada with blue line indicating the region to the north consistently colder than –10°C in January

Icing up of an HRV's core also occurs to various degrees in the regions south of the blue line (such as in Ottawa, which is well south of the blue line), but the icing up in these warmer regions is limited to shorter-duration cold snaps and is generally manageable with defrost cycles and less inconvenience, such as reduced ventilation rates.

HEAT RECOVERY VENTILATORS AND ENERGY RECOVERY VENTILATORS (HRVs AND ERVs):
Iced-up single core HRVs where is it a problem?– continued

In regions where the temperature drops below –25°C on a daily basis, such as in Canada's far north and the Arctic, single-core HRVs face many challenges and are not resilient to the extreme harsh climate. They perform badly and are not suitable for homes with relatively high occupancy and overcrowding. They ice up too much and too quickly, which means the defrost cycle runs so long it reduces the energy saving expected from an HRV, and undermines the ventilation critical for a healthy dwelling. On the map below, regions above the purple line experience temperatures of –25°C or colder on a daily basis in winter. Interestingly, this boundary is very close to the remote and northern boundary covered in the Introduction booklet (A). Note: All major Canadian cities, including in the prairies, are south of the –25°C line.



Map of Canada with purple line indicating the region to the north consistently colder than –25°C in January

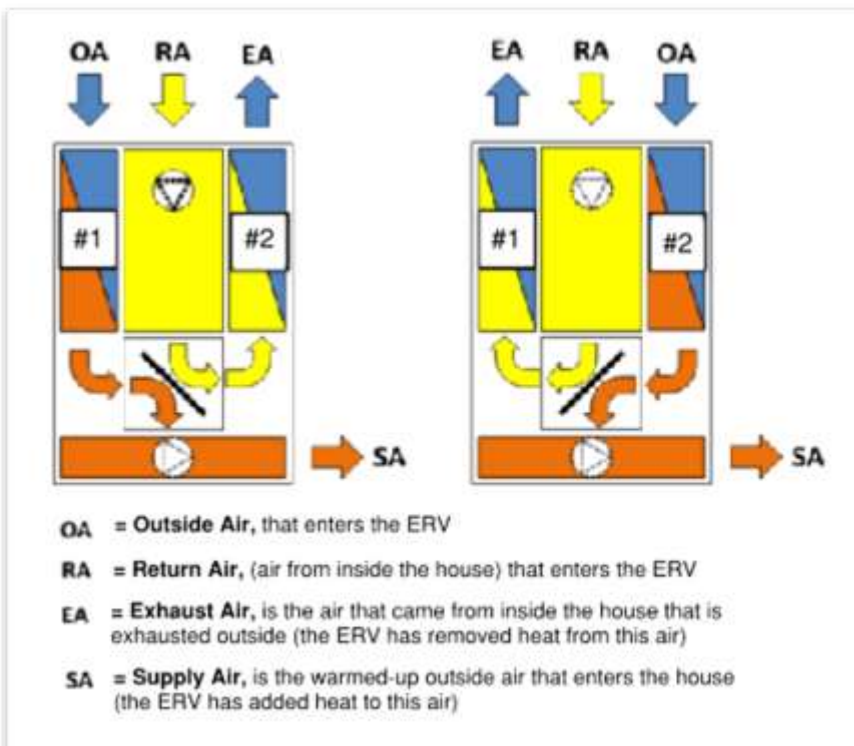
There are exceptions to the general statements about HRVs icing up. Whitehorse, Yukon is on the –25°C boundary and is an exception. HRVs in Whitehorse generally seem to perform satisfactorily, for a number of reasons. The air is very dry there, due to coastal mountains blocking moisture. Houses are relatively large, with fewer overcrowding issues for a northern community, thereby reducing indoor moisture levels. Also, installers and building inspectors have been given additional training to help ensure units are well selected, and installed as per manufacturers' instructions.

DUAL CORE ENERGY RECOVERY VENTILATORS:
The ventilation system for the north that does not have ice-up issues

Conventional residential single-core HRVs and ERVs are not well suited to the north. The National Research Council of Canada initiated research on ventilation systems for northern housing that identified a novel technology, the dual-core ERV system, with promising potential to be frost-resilient in extreme code climates. The technology is fairly new, and not yet certified in North America, but has already been installed in a few places at the Canadian High Arctic Research Station in Cambridge Bay, NU.

Although a dual-core ERV allows transfer of moisture, it does not have a permeable heat-exchanger core that would then become non-permeable due to ice formation. Moisture transfer is achieved by alternating the flow of air through the heat exchanger. In one cycle, warm air is exhausted through one of the cores, resulting in condensation inside the core; in the next cycle, outside air passes through this same path and picks up the condensed moisture in the core. As the period between flow cycles is short (60 seconds), ice does not have time to build up and cause issues before the warm exhaust air-flow arrives. Novel dual-core ERVs are larger and more expensive than conventional HRVs/ERVs. However, they do not require defrost strategies or frost protection, ensure continuous ventilation, and have high thermal efficiencies.

An HRV with dual-core heat exchanger



The two phases of an HRV with dual-core heat exchanger

Dual-core ERVs are a solution for northern housing, recommended for harsh cold climates as an alternative to conventional single-core HRV/ERVs.

HEAT RECOVERY VENTILATORS AND ENERGY RECOVERY VENTILATORS (HRVs AND ERVs): Other issues

Issues other than frost formation lead people to unplug or turn off HRVs/ERVs in their homes, or to have negative views of HRVs/ERVs. However, these issues can be addressed through good design.

The two main complaints about HRVs/ERVs other than freezing are:

- **Noise**
- **Cold air supplied to the indoors (uncomfortable).**

Noise originates from the fans in the HRV or ERV.

To help avoid noise complaints, locate the HRV/ERV in a separate mechanical room well away from bedrooms. If possible, choose HRVs and ERVs with lower sound ratings (i.e. quieter), and follow the manufacturer's instructions about controlling noise and using specified supply grills that reduce airflow noise. An HRV or ERV with a lower sound rating should be selected to avoid noise complaints.

HRVs and ERVs generally don't recover enough heat from the exhaust air to make the incoming air comfortable.

Fresh ventilation air needs to be heated after it passes through the HRV/ERV before it is released into the indoor space(s). This added heat could be provided by a post-heater, electric-coil heater inside the ventilation duct, or running the ventilation air supplied by the HRV/ERV unit through the furnace to be heated before being distributed to indoor spaces and associated duct work, or running the ventilation air through the nested chimney of a wood-burning stove.

Air Distribution Ducts

Ventilation air needs to be evenly distributed throughout the house to ensure all rooms and areas receive enough fresh air. For example, ventilation needs to be provided to a bedroom so that even when the bedroom door is closed, a steady flow of fresh air is provided.

Dedicated ventilation ducts are the recommended way to provide a reliable supply of fresh air to all areas of a house. Ducts are generally installed either in the ceiling or the floor. If the ventilation vents are in the ceiling, it can come out a bit colder (13°C or warmer), as warmer air rises, and the warmest air in the house will be at the ceiling. When air comes out of the vent, it will mix with the warmer air and pull some of it down. Note: In the north’s cold winter temperatures, even the minimum 13°C temperature of ventilation air typically cannot be reached with the HRV or ERV alone.

If the ventilation air comes out of a floor vent (as shown in the image below), it needs to be relatively warm (17° C or warmer).

Dedicated ceiling ducts and supply grills for ventilation air are recommended when there is no furnace, and the fresh air is heated with an in-line electric duct heater after the air passes through the HRV/ERV.

When there is a furnace, ventilation air can share the same heating ducts to supply fresh air to supply grilles on the floor. The HRV/ERV should be interlocked with the furnace so that it can deliver warm air.

Air-distribution ducting installed in a floor service cavity

Air-Distribution Ducts

The best ventilation solution for comfort is to combine ventilation air with the ductwork of a forced-air furnace.

- In larger homes with more rooms, you should install registers that supply warm air from the furnace to each room at the exterior walls and under windows, and grilles that return air from each room at inboard walls back to the furnace.
- In smaller homes, you should install supply ductwork that sends warm air from the furnace to the supply registers at the exterior walls and under windows, and the return air can flow naturally back to the furnace.
- Where rooms do not have return-air ductwork, ensure that all doors are undercut to allow free air movement back to a return-air register. Alternatively, install wall grilles between the closed-room and outer-room wall. To reduce noise transmission and light from passing unhindered between the two grilles, offset them using the same stud space.
- Heating air should be supplied at floor level along exterior walls and at windows and doors.
- Return-air grilles should be located away from supply grilles and the exterior walls.

ADDITIONAL RESOURCES

OTHER RELATED GUIDES

- ***Housing Construction in Nunavik***, Société D'Habitation Du Québec
  (habitation.gouv.qc.ca)

- ***Keeping the Heat In***, Natural Resources Canada
  (www.nrcan.gc.ca)

- ***Illustrated Guide Achieving Airtight Buildings***
  (www.bchousing.org)

- ***Good Building Practices Guidelines***, Government of Nunavut
  (www.gov.nu.ca)

- ***Illustrated Guide for Northern Housing Retrofits***
  (https://emrlibrary.gov.yk.ca/energy/illustrated-guide-for-northern-housing-retrofits-2016.pdf)

BUILDING CODES & STANDARDS

- **ANSI/ASHRAE Standard 62.1, *Ventilation for Acceptable Indoor Air Quality***
  (www.ashrae.org)
  Ventilation for Acceptable Indoor Air Quality is the Canadian standard that contains information on how much ventilation air is required and how to calculate ventilation effectiveness.

- **ANSI/ASHRAE Standard 62.2, *Ventilation for Acceptable Indoor Air Quality in Residential Buildings***
  (www.ashrae.org)
  Ventilation for Acceptable Indoor Air Quality is the Canadian standard that contains information on how much ventilation air is required in a residential building and how to calculate ventilation effectiveness.

- ***National Building Code of Canada***, National Research Council Canada
  (www.nrc.canada.ca)

- ***CANADA BUILDING CODE FOR THE NORTH 1968***, National Research Council
  (www.nrc.canada.ca)

ADDITIONAL RESOURCES—continued

TECHNICAL INFORMATION

- Ouazia B., et al. (2017). “Lab Evaluation of a Dual Core Air Handling Unit for Use in Code Climates,” *NRC Technical Report A1-009461.1*

- Ouazia B., et al. (2017). “Experimental Comparison of Performance between Single and Dual Core Energy Recovery Systems,” *NRC Technical Report A1-009461.2*

- Ouazia B., et al. (2019). “Performance of a Dual Core Energy Recovery System for Housing in the Arctic Repercussions on Ventilation*,” NRC Technical Report A1-009461.5*

- Ouazia B., et al. (2021). “Extended Monitoring of an RGSP 300 Unit in Nunavut,” *NRC Technical Report A1-019006.2*

- CMHC (2016). *Research Report: Survey of HRV/ERV performance issues in Canada’s near north and far north.*

- CMHC Research Highlight: ***Increasing Nunavut Housing Ventilation Rates with HRVs*,** Technical Series 10-102, dated September 2010.

- ***ASHRAE Handbook of Fundamentals***, American Society of Heating, Refrigerating, and Air Conditioning Engineers
(www.ashrae.org)

- ***Canadian Building Digest***, National Research Council Publications Archive
(https://nrc-publications.canada.ca/eng/search/)

- *Building Science Articles***,** Building Science Corporation
(www.building science.com)

- *Building Science Calculators*, Cold Climate Housing Research Center
(www.cchrc.org)

This technical booklet was developed to help community decision makers and building officers choose among different technical options in the delivery of residential housing for First Nations communities in remote northern Ontario.

IMPORTANT NOTE

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