



**Pacific
Northwest**
NATIONAL LABORATORY

Residential Heat Recovery Ventilation

Technical Brief

December 2018

ZT Taylor

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Pacific Northwest National Laboratory
Richland, Washington 99352

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Background

This study was conducted by Pacific Northwest National Laboratory (PNNL) in support of the U.S. Department of Energy (DOE) Building Energy Codes Program (BECP). BECP was founded in 1993 in response to the *Energy Policy Act of 1992*, and fulfills several key functions specified under federal statute and related to building energy codes. Section 307 of ECPA, as amended, requires DOE to periodically review the technical and economic basis of the voluntary building energy codes, such as the International Energy Conservation Code (IECC) and Standard 90.1, and participate in the industry process for review and modification, including seeking adoption of all technologically feasible and economically justified energy efficiency measures. (42 U.S.C. 6836(b)) Section 304(a) of ECPA, as amended, also directs DOE to review published editions of the IECC and Standard 90.1, and issue a determination as to whether the revised edition would increase energy efficiency in residential and commercial buildings, respectively.

PNNL supports this mission by evaluating concepts being considered for future code updates, conducting technical reviews and analysis of potential changes and their associated impacts, including energy savings analysis, cost-effectiveness analysis, and providing guidance on how changes can be more readily adopted by states and localities. This helps to ensure successful implementation of advancing technologies, construction practices, and related industry standards, and encourages building practices that are proven affordable and efficient.

This technical brief represents a compilation of relevant information on a specified concept. An overview of the concept is presented, followed by supporting technical analysis, related research and recommended code language. Additional context may also be provided, such as known consideration in previous model code development, state code proceedings, or incorporation in existing codes or standards. Each brief is intended as a resource for interested and affected stakeholders, particularly those charged with considering impacts of proposed code updates. Further technical assistance may be available from PNNL to adapt content to the needs of individual states or municipalities, such as specific building types, climate weightings, or utility rates.

Learn more at www.energycodes.gov.

1.0 Heat Recovery Ventilation for Residential Dwelling Units

Modern energy-efficient homes are built to resist uncontrolled air infiltration, limiting the otherwise widely varying (with temperature and wind) energy load and corresponding comfort issues that result from leaky envelopes. But getting control of the leakage can result in insufficient fresh air to a home during times of moderate outdoor temperature and little/no wind. Consequently, mechanically induced ventilation is required. Mechanical ventilation carries an energy penalty that can be reduced by the use of a heat recovery ventilator (HRV), which is simply a heat exchanger that recovers heat from exhaust air and transfers it to the HRV's supply-air stream.

Some devices also include a means to transfer moisture between the exhaust and supply streams; these are called energy recovery ventilators (ERVs). ERVs are more effective in the humid south, where they assist with cooling as well as heating. However, ERVs are not considered in this paper.

This technical brief evaluates HRV systems in typical residential dwelling units. The intent is to outline advantages of HRV systems, and identify in broad terms the climates in which an HRV's heat recovery benefits exceed its fan-power penalty.

1.1 Summary

This technical brief investigates the potential benefits of HRVs in residential buildings and presents a potential approach to incorporating HRVs into typical residential energy codes.

1.2 Technical Considerations

How does heat recovery ventilation work?

An HRV is a heat exchanger that recovers heat from a home's exhaust air. It transfer this heat to the ventilation supply air. The ventilation air is thus preheated using heat that would otherwise be wasted. A typical unit includes two fans: one on the supply side and one on the exhaust side.

What maintenance is required?

Regular maintenance is needed on HRVs including:

- Inspect weatherhoods and screens for debris
- Inspect, service and adjust fan motors
- Inspect and clean the heat exchanger cores
- Replace air filters

How does the proposed measure compare to what's required in current codes?

The national model energy code for residential buildings, the International Energy Conservation Code (IECC), does not require heat recovery ventilation, though it does establish minimum efficacy ratings for HRV fans if a home has one. All new homes are currently required to have mechanical ventilation based on the International Residential Code (IRC), with continuous fresh air requirements ranging from 30 to

165 CFM depending on the home's conditioned floor area and number of bedrooms. For dwelling units between 1200 ft² and 4500 ft², with two to four bedrooms, the range is 45 to 90 CFM.

Why is heat recovery a better approach to ventilation than alternatives?

In years past, the overall leakiness of building envelopes provided sufficient fresh air for occupants, but brought with it substantial energy penalties and comfort issues from widely varying ventilation rates depending on outdoor temperature and wind speed. As construction practices have gained better control of envelope leakage, mechanical ventilation systems have become a necessity and are required by modern building codes. In sufficiently cold climates, heat recovery can enhance comfort—as occupants are not subjected to uncomfortably cold supply air—and may be cost effective in their recovery of heat that would otherwise be exhausted.

HRVs have experienced significant growth in the residential market in recent years. This market is projected to continue growing at 11% per year per MarketsandMarkets (2018). North America is the largest market in the world for HRVs.

ERVs are not considered in this paper because their performance and cost effectiveness is more dependent on local humidity and on the interplay of heating and cooling performance. These factors do not map as cleanly to the high-level climate zones typically used in state and local building energy codes.

How is system performance demonstrated in the field?

HRVs come in several forms, ranging from systems integrated into the HVAC distribution system, to separate systems with their own ductwork, to simple unducted heat exchangers. System performance is easy to verify based on the unit's nameplate performance ratings and straightforward inspection of the installation.

1.3 Energy and Cost Impacts

Energy Savings: An analysis of energy impact shows that annual energy cost savings from HRVs is positive in climate zones four and higher, as shown in Table 1.

Table 1. Annual Energy Cost Savings per Dwelling Unit of Heat Recovery Ventilators

Climate Zone	4	5	6	7	8
Annual Energy Cost Savings of HRV (2018\$)	\$5.97	\$38.43	\$70.84	\$138.15	\$233.23

Cost Impact: The cost of HRV equipment ranges from about \$500 to a few thousand dollars, depending on the manufacturer, capacity, configuration, and the base design of the home. The present analysis assumes a total measure cost of \$1,500 for a single-point HRV system. NREL (2018) gives a cost of \$1,300, inclusive of equipment and installation. Russell, Sherman and Rudd (2007) found a similar cost of \$1,350 including installation. Fixr.com (2018), a home remodeling website, gives a range of \$1,200 to \$1,550, inclusive of materials and installation. Moore (2018) suggests a typical cost of \$1,500.

This analysis uses a primary first cost of \$1,500 for an HRV in a typical dwelling unit as a best estimate that includes installation. It is acknowledged that real costs can vary greatly, especially if the cost of

installation is minimized, as when the home was already designed to integrate ventilation into the distribution system. In that case, the HRV cost can be quite low. To show the sensitivity of HRV cost effectiveness to first cost, a secondary cost of \$500 was evaluated in addition to the primary cost of \$1,500.

Cost-effectiveness: At a first cost of \$1,500, the life-cycle cost of an HRV is negative (i.e., life-cycle savings is positive) in climate zones 7 and 8, as shown in Table 2.

Table 2. Life-Cycle Cost Savings per Dwelling Unit of Heat Recovery Ventilators Assuming a First Cost of \$1,500

Climate Zone	7	8
Life-Cycle Cost Savings of HRV (2018\$)	\$824.25	\$3111.00

If the best-case first cost of \$500 is assumed, HRVs are life-cycle cost effective in zones 5 through 8, as shown in Table 3.

Table 3. Life-Cycle Cost Savings per Dwelling Unit of Heat Recovery Ventilators Assuming a First Cost of \$500

Climate Zone	5	6	7	8
Life-Cycle Cost Savings of HRV (2018\$)	\$190.33	\$1188.29	\$2529.25	\$4816.00

1.4 Sample Code Language

The suggested code language is based on the primary first cost of \$1,500, for which HRVs are cost effective in climate zones 7 and 8.

Sample code language is outlined below based on the current 2018 IECC. Similar language can also be adapted to state and local codes that are based on the IECC or contain similar provisions.

Modify Section R403.6 as follows:

R403.6 Mechanical Ventilation (Mandatory). The building shall be provided with ventilation that meets the requirements of the *International Residential Code* or *International Mechanical Code*, as applicable, or with other approved means of ventilation. Outdoor air intakes and exhausts shall have automatic or gravity dampers that close when the ventilation system is not operating.

~~**R403.6.1 Whole-house mechanical ventilation system fan efficiency.** Fans used to provide whole-house mechanical ventilation shall meet the efficacy requirements of Table R403.6.1.~~

~~**Exception:** Where an air handler that is integral to tested and listed HVAC equipment is used to provide whole-house mechanical ventilation, the air handler shall be powered by an electronically commutated motor.~~

R403.6.1 Heat recovery ventilation (Prescriptive). The building shall be provided with a heat recovery or energy recovery ventilation system in climate zones 7 and 8. The system shall be balanced with a minimum sensible heat recovery efficiency of 65% at 32°F (0°C) and at rated airflow.

R403.6.1.2 Whole-house mechanical ventilation and heat recovery ventilation system fan efficacy. Fans used to provide whole-house mechanical ventilation shall meet the efficacy requirements of Table R403.6.1.

Exception: Where an air handler that is integral to tested and *listed* HVAC equipment is used to provide whole-house mechanical ventilation, the air handler shall be powered by an electronically commutated motor.

2.0 References

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Appendix

Additional Cost-effectiveness Analysis Detail

Purpose: Determine cost-effectiveness of heat recovery ventilators (HRVs) in residential dwelling units.

Basis of Analysis

The analysis was conducted based on the methodology¹ used by the U.S. Department of Energy for evaluating the impacts of code changes. Energy simulations were conducted in cities as specified by the methodology to represent typical weather in each IECC climate zone.

Energy Prices

Residential sector pricing is appropriate for most dwelling and sleeping units. National average fuel prices were taken from the Energy Information Administration's latest Annual Energy Outlook.²

Energy Type			Unit Price	
Natural Gas	10.55	\$/ kCuFt	\$1.0169	\$/therm
Heating Oil	3.01	\$/ gal	\$2.1700	\$/therm
Electricity			\$0.1290	\$/kWh

Economic Parameters

Cost effectiveness calculations assume the HRV is part of a home purchase using a typical residential-style mortgage. The following economic parameters were assumed in the calculations.

Parameter	Value
Term of Mortgage	30 years
Mortgage Interest Rate	5%
Downpayment Amount	10% of home price
Loan Fee	0.7% of loan amount
Private Mortgage Insurance Cost	0.052% of loan amount
Private Mortgage Insurance Cutoff	PMI eliminated when mortgage principal drops below 80% of home value
Inflation Rate	2.52%
Discount Rate	5% nominal (equal to mortgage rate)
Income Tax Rate (federal + state)	12% marginal
Property Tax Rate (annual)	1.5% of home value
Analysis Period	30 years
HRV Measure Life	20 years
HRV Replacement Cost Fraction	100%

¹ <https://www.energycodes.gov/development/residential/methodology>

² <https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2018&cases=ref2018&sourcekey=0>, accessed 10 December 2018, tables labeled Energy Prices by Sector and Source.

Conclusions

At the primary first cost of \$1,500, HRVs are cost effective in climate zones 7 and 8. At a lower cost (assuming minimal installation costs) of \$500, HRVs are cost effective in zones 5, 6, 7, and 8.



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