Single Family HRV: REPI-093-21 Supporting Documentation

# Executive Summary

The proposed HRV measure expands the requirement for heat or energy recovery ventilation systems (HRVs or ERVs) for single-family homes to climate zones 5 and 6. The measure is already required in climate zones 7 and 8.

**Original Proposal:**

**R403.6.1 Heat or energy recovery ventilation**

Dwelling units 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 percent at 32°F (0°C) at a flow greater than or equal to the design airflow.

Exceptions:

1. Dwelling units in single- and two-family dwellings and townhouses in Climate Zones 0-4.

2. Dwelling units in Climate Zone 3C.

**Revised Proposal to Align with REPI-69:**

*REPI-69 requires heat recovery ventilation for multifamily units in all climate zones except 3C, with additional exceptions for dwelling units < 500 sf. REPI-69 was approved by the Residential Consistency and Administration subcommittee (2/15/22), and the Residential Consensus Committee (3/2/22)*.

**403.6.1 Heat or energy recovery ventilation**

Dwelling units 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 percent at 32°F (0°C) at a flow greater than or equal to the design airflow.

Exceptions:

1. Dwelling units in single and two-family buildings in Climate Zones 0-~~6~~4.

2. Dwelling units in Group-R occupancies that comply with Section C403.7.4.1.

**Methodology supporting this proposal (REPI-093)**

* Energy savings:
  + Modeled with EnergyPlus v9.5 and PNNL detached single-family house prototype.
  + Assumed 2-story above grade (with conditioned basement for select climate zones), 3-bedroom, with 60 cfm continuous ventilation
* Cost Assumptions:
  + Estimated cost of HRV (proposed) compared to exhaust-only ventilation (base case)
  + Total incremental first cost for HRV $1,084, including:
    - Cost of HRV $738, based on average HRV/ERV product cost from online research
    - HRV ducted into supply side of furnace air handling unit (no additional cost), but with separate HRV return duct and HRV return register (estimated using floor plan that aligns with PNNL prototype): $169
    - Installation labor: $177
  + Assumed weighted mix of heating systems: 83% gas furnace, 11% heat pumps, 6% propane furnace in CZ5A and 6A; 76% gas furnace, 18% heat pumps, 6% propane furnace in CZs 5B, 5C, and 6B

Table 1. LCC Assumption Summary

| **Parameter** | **Value** | **Source** |
| --- | --- | --- |
| Real discount rate | 3% or 7% | IECC subcommittee |
| Inflation Rate | 2.3% | Energy Information Administration (EIA) Annual Energy Outlook (AEO) 2021 |
| **Nominal discount Rate** | 3%, 5.3%, or 9.3% | DOE/PNNL, or real rate from IECC subcommittee plus inflation |
| **First cost for measure** | $1,084 | Online research of HRVs and ERVs, including ductwork |
| **Replacement cost** | $806 | Assumes HRV replaced at year 15 |
| **Baseline fuel prices** | $0.137 / kWh  $1.1803 / therm natural gas  $2.48 / gallon propane | 2021 US residential price from EIA |
| **Fuel price escalators** | -0.10% for electricity  0.50% for natural gas  1.4% for propane | EIA AEO 2021 reference case, residential by fuel, national |
| **Social cost of carbon** | $51/metric ton in 2020 | Interagency Working Group on Social Cost of Greenhouse Gases |
| **Period of Analysis** | 30 years | Mortgage loan |

**Cost Effectiveness Results**

All climate zones analyzed (5 and 6) are cost effective under a nominal discount rate of 3%, 5.3%, and 9.3%, ignoring the social cost of carbon (SCC: assumes SCC = $0). (The 5.3% and 9.3% nominal discount rates assume a real discount rate of 3% and 7% respectively, plus 2.3% for inflation.) Results are more cost-effective when the SCC of $51 per metric ton is included.

Table . Cost Effectiveness Results

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| LCC Assumptions | **3% nominal discount rate** (DOE/PNNL)  **SCC = $0** | **3% nominal discount rate** (DOE/PNNL)  **SCC = $51** | **5.3% nominal** 3% real discount rate (IECC) + inflation  **SCC = $0** | **5.3% nominal** 3% real discount rate (IECC) + inflation **SCC = $51** | **9.3% nominal** 7% real discount rate (IECC) + inflation **SCC = $0** | **9.3% nominal** 7% real discount rate (IECC) + inflation **SCC = $51** |
| LCC ($) CZ 5A | $1,529 | $2,435 | $1,037 | $1,681 | $591 | $983 |
| LCC ($) CZ 5B | $517 | $1,146 | $304 | $752 | $132 | $404 |
| LCC ($) CZ 5C | $1,236 | $2,051 | $825 | $1,405 | $458 | $812 |
| LCC ($) CZ 6A | $2,139 | $3,200 | $1,479 | $2,233 | $869 | $1,329 |
| LCC ($) CZ 6B | $1,692 | $2,606 | $1,158 | $1,807 | $670 | $1,066 |
| **Cost effective CZs** | **All analyzed** | **All analyzed** | **All analyzed** | **All analyzed** | **All analyzed** | **All analyzed** |

**Response to HVACR Subcommittee Questions**

In response to HVACR subcommittee questions from the March 7, 2022 HVACR subcommittee meeting on simple payback:

* Assuming a Social Cost of Carbon (SCC) of $51: simple payback is 9 years in CZ 5A and 5C, 12 years in CZ 5B, and 7-8 yrs in CZ 6
* Assuming SCC = $0 (so ignoring SCC): simple payback is 11 years in CZ 5A and 5C, 15 years in CZ 5B, and 9-10 years in CZ 6
* Side note: Past IECC cycles have used LCC (Taylor, 2018), and current guidance from the ICC is to continue to use LCC. For example, ICC, [Leading the Way to Energy Efficiency](https://www.iccsafe.org/wp-content/uploads/ICC_Leading_Way_to_Energy_Efficiency.pdf) – R101.3 (Intent) specifically cites LCC, and not simple payback.[[1]](#footnote-2) So we still think LCC is the better metric.

We estimated current HRV/ ERV prevalence in CZs 5 and 6 using RESNET data in response to subcommittee questions. This data is based on ratings from March 2020 through February 2022. The values for 6A are surprisingly high. RESNET staff reported that most rated homes in 6A are in MN, and that many production home builders in St. Paul / Minneapolis use ERVs/HRVs.

Table 3. Estimate of ERV/HRV Prevalence by Climate Zone

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **RESNET single-family\* home data by Climate Zone (CZ)** | **5A** | **5B** | **6A** | **6B** |
| Single family homes with ERV or HRV | 4,351 | 1,176 | 15,955 | 120 |
| All single family homes rated in CZ | 71,127 | 38,792 | 21,194 | 843 |
| Percent of Single-family homes with ERV or HRV | 6% | 3% | 75% | 14% |

\*Single-family includes duplexes, but not low-rise multifamily

Detailed Analysis

Table of Contents

[Executive Summary 1](#_Toc98448612)

[Overview 4](#_Toc98448613)

[Code Language 4](#_Toc98448614)

[Methodology 5](#_Toc98448615)

[Simulation tool 5](#_Toc98448616)

[Description of Prototype 5](#_Toc98448617)

[Weather Locations 7](#_Toc98448618)

[Site, Source, Carbon Emissions and Energy Cost Calculations 8](#_Toc98448619)

[Energy Analysis 8](#_Toc98448620)

[Description of base case 8](#_Toc98448621)

[Proposed Case 8](#_Toc98448622)

[Incremental Cost 9](#_Toc98448623)

[LCC Approach 11](#_Toc98448624)

[Cost Effectiveness Results 12](#_Toc98448625)

[HRV/ ERV Prevalence 16](#_Toc98448626)

[References: 17](#_Toc98448627)

# Overview

The proposed HRV measure expands the requirement for heat or energy recovery ventilation systems (HRVs or ERVs) for single-family homes to climate zones 5 and 6. The measure is already required in climate zones 7 and 8. There was a separate proposal submitted by NBI to expand the requirement in multifamily dwelling units (REPI-069) to all climate zones except 3C, with further exceptions for dwelling units < 500 square feet, which the Residential Consistency and Administration subcommittee passed.

# Code Language

**Original Proposal:**

**R403.6.1 Heat or energy recovery ventilation**

Dwelling units 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 percent at 32°F (0°C) at a flow greater than or equal to the design airflow.

Exceptions:

1. Dwelling units in single- and two-family dwellings and townhouses in Climate Zones 0-4.

2. Dwelling units in Climate Zone 3C.

**Revised Proposal to Align with REPI-69.**

**403.6.1 Heat or energy recovery ventilation**

Dwelling units 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 percent at 32°F (0°C) at a flow greater than or equal to the design airflow.

Exceptions:

1. Dwelling units in single and two-family buildings in Climate Zones 0-~~6~~4.

2. Dwelling units in Group-R occupancies that comply with Section C403.7.4.1.

# Methodology

## Simulation tool

This analysis used EnergyPlus v9.5 for modeling energy savings.

## Description of Prototype

The proposal team selected one single-family prototype house to evaluate the cost-effectiveness of the proposed measure. The building geometry was consistent with PNNL’s 2021 IECC determination (Salcido R. , Chen, Xie, & Taylor, 2021a), also reflected in DOE’s prototype building files (US Department of Energy, 2021). The detailed specifications are documented in an earlier PNNL report evaluating the 2012 IECC revisions (Lucas, Mendon, & Goel, 2013). Where the PNNL reports are silent, the proposal team used building attributes consistent with the Standard Reference Design established for the Total Building Performance Option in the 2021 IECC, or common building construction practice if no requirements are specified in any of the reference documents.

The proposal team assumed the foundation types shown in Table 4, considering both typical construction for the PNNL representative city and for the region included in that climate zone. The proposal team assumed a basement for Climate zone 6, since basements are common in the representative cities for 6A and 6B, and because climate zone 6 is mostly in the Midwest and Northeast where basements are common. (Although Climate zone 6 also includes small parts of the West, where many homes use slab-on-grade construction.) The analysis assumed a basement for Climate Zone 5A, since the representative city is Buffalo, NY and this region includes the Midwest and Northeast where basements are common. For 5B and 5C, the analysis assumed slab-on-grade, since this is common in the representative cities and in the western regions of the U.S. (of which large portions are in these climate zones). The basement was assumed to be conditioned.

Table . Foundations Assumed

|  |  |  |  |
| --- | --- | --- | --- |
| **Climate Zone** | **Representative City** | **Typical Construction for Single-Family New Construction for Representative City** (NAHB, 2019) | **Foundation Assumed** |
| 5A | Buffalo, NY | Basement | Basement |
| 5B | Denver, CO | Mix of slab-on-grade and basement | Slab-on-grade |
| 5C | Port Angeles, WA | Slab-on-grade | Slab-on-grade |
| 6A | Rochester, Minnesota | Basement | Basement |
| 6B | Great Falls, Montana | Mix of slab-on-grade and basement | Basement |

Basic characteristics that apply to the model include the following:

* 2-story above grade (with conditioned basement for select climate zones – described in Table 4, 3-bedroom, detached single-family house
* 2,400 ft2 of conditioned space for slab-on-grade homes, and 3,600 ft2 for homes with basement
* 40 ft. x 30 ft. exterior dimensions, 8.5 ft ceilings
* 2x6 wood framing, 16” OC for walls, 24” OC for ceiling
* Fiberglass batt insulation, with R-5 insulating sheathing added for walls where required
* No exterior shading
* Ducts in vented attic
* 60 cfm continuous ventilation

For the heating system, this analysis used a weighted average of the following, based on U.S. census 2020 data[[2]](#footnote-3). The division between the West and Midwest in the census (Figure 1 - left image) align with the break between the IECC division between moist (A) and dry (B) climates (Figure 1 - right image).

Figure 1. Comparison of U.S. Census Regions with IECC Moist (A) vs. Dry (B) Climate Zones

Map

Description automatically generated

Based on the 2020 census data, after removing for other types of heating systems, furnaces comprise 89% and heat pumps comprise 11% of heating systems in new homes in the Northeast and Midwest. In the West, furnaces comprise 82% and heat pumps 18% of heating systems.

Table . Heating Systems Found in Census

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Raw Percentages from Census | | | Normalized to 100% for just furnaces and heat pumps (Removing Other) | |
| Region | Heat pump | Forced air furnace | Other | Heat pump | Forced Air Furnace |
| Northeast | 10% | 79% | 11% | 11% | 89% |
| Midwest | 10% | 85% | 5% | 11% | 89% |
| West | 17% | 80% | 3% | 18% | 82% |

Because the EIA found that 6% of U.S. homes use propane as a heating source (U.S. Energy Information Administration, 2017), this analysis assumed 6% of the forced air furnaces were propane, and assumed the remainder were natural gas. This led to the assumed weights for heating systems shown in Table 6.

Table 6. Heating Scenarios Assumed for Analysis

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario for LCC | Prevalence for Northeast and Midwest: CZ 5A and 6A (% of single family homes) | Prevalence for West: CZ 5B, 5C, 6B (% of single family homes) | **Source for Assumption** |
| Natural gas furnace | 83% | 76% | U.S. 2020 census for split between gas furnaces and electric heat, with “gas furnaces” appropriated between natural gas and propane based on EIA (2017) |
| Electric heat pump | 11% | 18% | U.S. 2020 census for split between gas furnaces and electric heat, with “gas furnaces” appropriated between natural gas and propane based on EIA (2017) |
| Propane furnace | 6% | 6% | EIA (U.S. Energy Information Administration, 2017) |

## Weather Locations

Representative cities and corresponding TMY3 weather stations for each Climate Zone were consistent with the DOE Energy Codes website (US Department of Energy, 2021), as summarized in Table 7 below.

Table 7. Representative cities and weather stations for modeling energy savings in each Climate Zone.

|  |  |  |
| --- | --- | --- |
| **Climate Zone** | **Representative City** | **TMY3 Weather Station** |
| 5A | Buffalo, NY | Buffalo Niagara Intl. Airport |
| 5B | Denver, CO | Denver-Aurora-Buckley Air Force Base |
| 5C | Port Angeles, WA | Port Angeles – Williams Fairchild Intl. Airport |
| 6A | Rochester, Minnesota | Rochester Intl. Airport |
| 6B | Great Falls, Montana | Great Falls Intl. Airport |

## Site, Source, Carbon Emissions and Energy Cost Calculations

This analysis calculated site energy, source energy, carbon emissions, and energy costs using generally accepted engineering methods and authoritative references. The following sections provide details.

# Energy Analysis

This analysis focused on climate zones 5 and 6. The measure is already required in climate zones 7 and 8; the measure is more cost effective in climate zones 7 and 8 than climate zone 6 because of the higher heating degree days in climate zones 7 and 8 (Taylor, 2018).

### Description of base case

The energy analysis used EnergyPlus to model a 2021 IECC minimally-compliant prototype single-family home. The above-grade interior space was modeled as a single thermal zone. The PNNL energy model for the prototype single-family home uses balanced ventilation, so the proposal team used this as the base case for the model. However, as described in the Incremental Cost section, the proposal team assumed an exhaust-only ventilation system in the base case for costs, since that is the most common ventilation strategy for single-family homes in climate zones 5 and 6. The ventilation fans (both supply and exhaust fans) in the base case used the values in the PNNL single family prototype model: 10.7 W and deliver 60 cfm and therefore have an efficacy of 5.6 cfm/W, which (as described below for the Proposed Case) have a much higher efficacy than what the proposal team assumed for the HRV.

### Proposed Case

For the HRV specifications, the analysis assumes:

* An HRV energy consumption of 37.5 W to deliver 60 cfm of pre-conditioned supply air to the home (and remove 60 cfm of exhaust air from the home). This translates to an HRV efficacy of 1.6 cfm/W. This includes fan energy and energy used for any ancillary loads, such as controllers. This efficacy is slightly higher than the federal minimum requirements (1.2 cfm/W) but slightly lower (i.e., more conservative) than the average of the products reviewed (1.9 cfm/W), shown in Table 8.
* A Sensible Recover Efficiency (SRE) of 65. This is lower (more conservative) than the average of the products reviewed (SRE = 70), shown in Table 8.
* A cost of $738

These values were based on a review of ERVs/ HRVs identified through online research, shown in Table 8. The proposal team used SRE, airflow, and power consumption (wattage) from the Home Ventilating Institute (HVI) where possible. Two of the products were not listed in the HVI directory, so product data were obtained from other online sources.

The average retail cost of the products is $738, which the proposal team assumed for the cost effectiveness calculations. The proposal team did find cheaper products that did not meet the specifications here, so did not include them.[[3]](#footnote-4)

Table 8. Summary Characteristics of HRVs and ERVs from Online Research

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Product Category** | **Manufacturer** | **Model** | **Airflow (CFM)** | **Wattage** | **CFM/W** | **Cost** | **SRE** |
| HRV | Broan[[4]](#footnote-5) | B110H65RS | 64 | 33 | 1.9 | $808 | 68 |
| ERV | Panasonic[[5]](#footnote-6) | FV-10VES | 66 | 39 | 1.7 | $942 | 77 |
| ERV | Fantech[[6]](#footnote-7) | SE704N | 78 | 40 | 2.0 | $545 | 66 |
| ERV | Aldes[[7]](#footnote-8) | E110-TF | 65 | 32 | 2.0 | $656 | 68 |
| *Average* |  |  | *68* | *36* | *1.9* | *$738* | *70* |

This analysis only included sensible energy recovery (from both heating and cooling), which would be captured by an HRV or ERV. It does not include latent energy recovery which would be captured by an ERV. Consequently, ERV energy savings would be higher than what is shown in this analysis.

In addition to the 37.5 W assumed for the HRV, the proposed case also assumes the same supply and ventilation fans as the base case: 10.7 W each. Consequently, the HRV energy savings are underestimated in this analysis, since it assumes fan energy of the balanced ventilation system without heat recovery (the supply fan and exhaust fan) and the fan energy of the HRV.

# Incremental Cost

This section describes the incremental cost associated with an HRV. The analysis assumes a replacement of equipment at year 15 (a typical assumption for residential HVAC equipment[[8]](#footnote-9)), when the HRV is assumed to be replaced (at the end of its estimated Effective Useful Life). The analysis assumes no maintenance costs, because many HRVs have washable filters. To estimate the incremental cost for the proposed case (HRV), this analysis considered the following differences between the base case: exhaust-only ventilation without heat recovery, and proposed case: balanced ventilation with an HRV, including:

* Materials and labor for the HRV (proposed) case
* Additional ductwork needed for the HRV
* Additional return register needed for the HRV
* Insulation for the HRV for the ductwork connecting it to the outdoors – i.e., for the outdoor air supply duct to the HRV to prevent condensation.[[9]](#footnote-10)

To determine duct lengths, the proposal team developed a floor plan for the prototype home, and identified differences for the base case (exhaust-only ventilation) and proposed case (HRV).

The proposed case assumes one HRV serving the home. The proposal team assumed that HRV return grille is located in the middle of the home, close to the heating system return grille. The team assumed the HRV’s supply duct (providing pre-heated or pre-cooled fresh air) connects to the heating and cooling system ductwork, which would distribute the ventilation air. For heating and cooling systems with no ductwork, such as ductless heat pumps, the HRV’s supply air would simply be discharged at one location in the home, because many jurisdictions do not require distribution of fresh air within the dwelling unit[[10]](#footnote-11). Thus, there is no significant difference in HRV costs for a home with a ductless heating system (e.g., ductless heat pump) than one with a ducted system (e.g., ducted furnace).

Figure 2. Floor plan of HRV, exhaust fans, and duct layout for proposed case.

Diagram, engineering drawing, schematic

Description automatically generated

The following table shows the incremental cost for the proposed (HRV) case compared to the base (exhaust-only ventilation without heat recovery) case. Labor assumptions and assumptions for the cost of ductwork and duct insulation are from RSMeans. This table only shows incremental costs, not costs included in both the proposed and base case.

Table 9 . Incremental Costs for HRV installed in Single-family Home

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Category** | **Unit** | **Material Costs ($/Unit)** | **Total Material Costs ($)** | **Crew (RSMeans)** | **Crew Labor Rate with O&P and 10% GC markup** | **Labor Hours (Hrs/Unit)** | **Total Labor Costs ($)** | **Total Installed Cost ($)** |
| Duct | 18 linear feet | $7.80 | $140 | Q9 | $66 | 0.057 | $68 | $208 |
| Duct Insulation | 1.5 sf | $3.81 | $6 | Q9 | $66 | 0.163 | $16 | $22 |
| Return register | 1 register | $23.00 | $23 | 1 Sheet metal worker | $73 | 0.333 | $24 | $47 |
| HRV | 1 HRV | $738.00 | $738 | Q20 | $68 | 1 | $68 | $806 |
| **Total cost** |  |  |  |  |  |  |  | **$1,084** |

As shown in Table 9, this analysis found an incremental cost of $1,084. This is lower than what a PNNL study (Taylor, 2018) assumed, which is the primary reason why this analysis finds this measure cost effective in Climate zone 6 while Taylor (2018) did not. While Taylor (2018) assumed a total measure cost of $1,500 in its analysis, that study found a “best-case” cost assumption of $500 for the HRV. As stated in Taylor (2018), “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.” These costs include equipment and labor costs for both the HRV appliance itself as well as related ductwork.

# LCC Approach

The Life Cycle Cost (LCC) approach used is similar to the DOE/PNNL cost analysis methodology[[11]](#footnote-12), but it uses updated sources for some parameters and is simplified to ease the burden for proponents to analyze their proposed amendments.

The methodology uses an LCC approach, where the cashflows over a 30-year analysis period for cash outflows (expenses, negative values) and inflows (savings, positive values) are used to calculate a net present value based on the time value of money. A positive LCC value indicates that the savings of a measure exceed its costs over the analysis period, while a negative value indicates the opposite.

For costs, the methodology assumes that any up-front incremental costs are financed through the mortgage on the home. Most proposed code amendments will predominantly impact new construction, and most new homes are financed through a 30-year mortgage. Given the high standard deductible for federal income taxes ($25,900 for joint filers), it is assumed that the increase in mortgage payments does not result in a change in income taxes. It is also assumed that proposed measures have a minimal impact on property assessments for local taxes, so changes in property taxes are assumed to be zero. Property tax assessments tend to be based on high-level data points, such as floor area, general condition, location, number of bedrooms and bathrooms, presence of air conditioning, and types of wall and floor finishes. It is not clear that the cost of efficiency-related features will result in an identical increase in property-tax valuation, and the DOE/PNNL methodology document provides no supporting evidence for the assumption that it will.

Energy prices used to calculate savings are based on national averages of projected prices. The LCC is calculated both with the social benefit of avoided carbon, and assuming a zero societal cost of carbon (SCC). When included, the SCC is calculated using the energy savings, U.S. EIA emissions factors, and social cost data from the technical support document of the Interagency Working Group on Social Cost of Greenhouse Gases (2021). Specifically, this proposal used the 2020-2050 5-year time series of social cost of carbon dioxide at a 3% discount rate in Interagency Working Group on Social Cost of Greenhouse Gases (2021), interpolating for interim years.

The following table summarizes the parameters in the LCC modeling and their sources.

Table 10. LCC Assumptions

| **Parameter** | **Value** | **Source** |
| --- | --- | --- |
| Real discount rate | 3% or 7% | IECC subcommittee |
| Inflation Rate | 2.3% | Energy Information Administration (EIA) Annual Energy Outlook (AEO) 2021 |
| Nominal discount Rate | 3%, 5.3% or 9.3% | DOE/PNNL, or real rate from IECC subcommittee (based on Office of Management & Budget – OMB) plus inflation |
| First cost for measure | $1,066 | Online research of HRVs and ERVs  See Incremental Cost section |
| Replacement cost for measure | $806 | Assumes HRV replaced but not ductwork |
| Baseline fuel prices | $0.137 / kWh  $1.1803 / therm natural gas  $2.48 / gallon propane | 2021 US residential price from EIA |
| Fuel price escalators | -0.10% for electricity  0.50% for natural gas  1.4% for propane | EIA AEO 2021 reference case, residential by fuel, national |
| Social cost of carbon | $51 in 2020. See source document for time series. | Interagency Working Group on Social Cost of Greenhouse Gases, 3% discount rate values. |
| Period of Analysis | 30 years | Mortgage loan |
| Mortgage Interest Rate | 3.00% nominal | DOE / PNNL 2021 Analysis |
| Down Payment Rate | 12% | DOE / PNNL 2021 Analysis |
| Points and Loan Fees | 1.00% nominal | DOE / PNNL 2021 Analysis |

# Cost Effectiveness Results

The estimated energy savings are summarized below in Table 11. The proposal team used the gas results (in therms) for both natural gas and propane savings results. As shown, the energy use (in kBTU) is higher for the base case than the HRV case in all climate zones.

Table 11. Energy Savings from HRV

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **CZ** | **Heating system** | **Case** | **Total Energy (kBtu)** | **Electricity (kBtu)** | **Natural Gas (kBtu)** | **Fans (Elec kBtu)** | **Heat Recovery (Elec kBtu)** | **Heating (Gas kBtu)** | **Cooling (Elec kBtu)** | **Total kBtu savings** | **kWh savings** | **Therms savings** |
| 5A-Buffalo, NY | Gas furnace | Base | 141,266 | 42,502 | 98,763 | 3,914 | 0 | 76,084 | 3,492 |  |  |  |
| Proposed (HRV) | 131,068 | 43,552 | 87,516 | 3,629 | 1,122 | 64,836 | 3,706 | 10,198 | -308 | 112 |
| Heat Pump | Base | 94,637 | 94,637 | 0 | 3,990 |  | 47,984 | 2,563 |  |  |  |
| Proposed (HRV) | 88,872 | 88,872 | 0 | 3,868 | 1,122 | 41,085 | 2,702 | 5,765 | 1690 | 0 |
| 5B-Denver, CO | Gas furnace | Base | 106,370 | 39,132 | 67,238 | 4,675 | 0 | 44,935 | 6,238 |  |  |  |
| Proposed (HRV) | 98,812 | 40,090 | 58,722 | 4,328 | 1,122 | 36,419 | 6,422 | 7,558 | -281 | 85 |
| Heat Pump | Base | 70,858 | 70,858 | 0 | 4,629 | 0 | 26,340 | 4,899 |  |  |  |
| Proposed (HRV) | 67,727 | 67,727 | 0 | 4391 | 1,122 | 22,212 | 5,015 | 3,131 | 918 | 0 |
| 5C-Port Angeles, WA | Gas furnace | Base | 100,215 | 33,797 | 66,418 | 3,608 | 0 | 43,841 | 1,971 |  |  |  |
| Proposed (HRV) | 90,415 | 34,775 | 55,641 | 3,140 | 1,122 | 33,064 | 2,294 | 9,800 | -286 | 108 |
| Heat Pump | Base | 62,631 | 62,631 | 0 | 3,530 | 0 | 22,958 | 1,401 |  |  |  |
| Proposed (HRV) | 59,343 | 59,343 | 0 | 3251 | 1,122 | 18,589 | 1,642 | 3,289 | 964 | 0 |
| 6A-Rochester, MN | Gas furnace | Base | 168,813 | 42,950 | 125,863 | 4,061 | 0 | 102,190 | 3,793 |  |  |  |
| Proposed (HRV) | 157,060 | 43,992 | 113,068 | 3,801 | 1,122 | 89,394 | 3,973 | 11,754 | -305 | 128 |
| Heat Pump | Base | 117,455 | 117,455 | 0 | 4,424 | 0 | 69,670 | 2,857 |  |  |  |
| Proposed (HRV) | 111,009 | 111,009 | 0 | 4,309 | 1,122 | 62,128 | 2,962 | 6,446 | 1889 | 0 |
| 6B-Great Falls, MT | Gas furnace | Base | 146,607 | 42,545 | 104,062 | 4,141 | 0 | 80,641 | 3,308 |  |  |  |
| Proposed (HRV) | 136,415 | 43,547 | 92,869 | 3,851 | 1,122 | 69,448 | 3,478 | 10,192 | -293 | 112 |
| Heat Pump | Base | 98,829 | 98,829 | 0 | 4,821 | 0 | 51,036 | 2,380 |  |  |  |
| Proposed (HRV) | 93,695 | 93,695 | 0 | 4,617 | 1,122 | 44,906 | 2,469 | 5,134 | 1505 | 0 |

The proposal team calculated the LCC for each climate zone, for each heating system, using the approach described above. As an example, Table 12 shows the LCC inputs and results for Climate Zone 6A, for the natural gas furnace.

Table 12. Example LCC Calculation for Climate Zone 6A and Natural Gas Furnace

|  |  |  |
| --- | --- | --- |
| Net measure cost | $1,084 | 2021$ |
| Measure electric savings | -305 | kWh/year |
| Measure natural gas savings | 128 | therms/year |
| Measure propane savings | 0 | gallons/year |
| Change in maintenance or other non-energy operating costs | 0 | 2021$/year |
| Year of first replacement | 15 | For measures with life <30 years, # of years from date of construction |
| Year of second replacement | Not Applic. | For measures with life <30 years, # of years from date of construction |
| **Net measure cost for replacement** | $806 | 2021$. Includes cost for HRV, but assumes ductwork, duct insulation, and return grille (all specifically serving HRV) can be retained (not replaced) |
| **Without Social Cost of Carbon (SCC)** |  |  |
| Measure incremental LCC | $1,388 | 2020$ (+ for savings, - for increased cost) |
| Simple payback | 9.9 | Years |
| **With Social Cost of Carbon** |  |  |
| Measure incremental LCC | $2,409 | 2020$ (+ for savings, - for increased cost) |
| Simple payback | 7.8 | Years |

Simple payback was estimated by dividing measure incremental cost by annual energy savings (in $).

For each climate zone, the proposal team generated a table similar to the one above for the three heating systems: natural gas furnace, electric heat pump, and propane furnace, and weighted results based on the prevalence of that heating system type. The proposal team repeated the process for all climate zones studied.

The cost effectiveness results excluding the SCC (assuming a zero cost for carbon) are shown in **Error! Reference source not found.** below for each heating system type, and for the weighted average for each climate zone. As shown, the proposed measure is cost-effective in all climate zones analyzed using the approach of weighting results by heating-fuel prevalence. As an aside, although there was higher energy savings from the gas furnace than heat pump, because of the higher cost of electricity per kBTU than natural gas, the monetized energy savings is higher in the heat pump scenario. The monetized energy savings is the highest in the propane scenario, because of the higher relative cost of propane.

The cost-effectiveness results are shown below, at different discount rates. For each discount rate, this analysis first shows LCC results excluding SCC (assuming SCC = $0), followed by results that include the SCC: assumes SCC = $51 per metric ton.

For a nominal discount rate of 3%, assuming SCC = $0 (ignoring carbon):

Table 13. LCC Results for All Climate Zones, **excluding** SCC, nominal discount rate of **3%**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Scenario** | **Heating System Prevalence for CZ5 (% of single family homes)** | **Heating System Prevalence for CZ6 (% of single family homes)** | **LCC ($) 5A** | **LCC ($) 5B** | **LCC ($) 5C** | **LCC ($) 6A** | **LCC ($) 6B** |
| Natural gas furnace | 83% | 76% | $842 | $35 | $779 | $1,388 | $896 |
| Electric heat pump | 11% | 18% | $4,237 | $1,476 | $1,641 | $4,949 | $3,575 |
| Propane furnace | 6% | 6% | $6,074 | $3,747 | $5,814 | $7,368 | $6,128 |
| **Weighted LCC Results** | **100%** | **100%** | **$1,529** | **$517** | **$1,236** | **$2,139** | **$1,692** |

For a nominal discount rate of 3%, assuming SCC = $51 per metric ton:

Table 14. LCC Results for All Climate Zones, **including** SCC, nominal discount of **3%**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Scenario** | **Heating System Prevalence for CZ5 (% of single family homes)** | **Heating System Prevalence for CZ6 (% of single family homes)** | **LCC ($) 5A** | **LCC ($) 5B** | **LCC ($) 5C** | **LCC ($) 6A** | **LCC ($) 6B** |
| Natural gas furnace | 83% | 76% | $1,706 | $657 | $1,618 | $2,409 | $1,770 |
| Electric heat pump | 11% | 18% | $5,430 | $2,124 | $2,321 | $6,282 | $4,638 |
| Propane furnace | 6% | 6% | $7,026 | $4,401 | $6,737 | $8,489 | $7,090 |
| **Weighted LCC Results** | **100%** | **100%** | **$2,435** | **$1,146** | **$2,051** | **$3,200** | **$2,606** |

For a nominal discount rate of 5.3% (real discount rate of 3%), assuming SCC = $0 (ignoring carbon):

Table 15. LCC Results for All Climate Zones, **excluding** SCC, nominal discount rate of **5.3%**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Scenario** | **Heating System Prevalence for CZ5 (% of single family homes)** | **Heating System Prevalence for CZ6 (% of single family homes)** | **LCC ($) 5A** | **LCC ($) 5B** | **LCC ($) 5C** | **LCC ($) 6A** | **LCC ($) 6B** |
| Natural gas furnace | 83% | 76% | $538 | ($47) | $493 | $935 | $577 |
| Electric heat pump | 11% | 18% | $3,052 | $1,029 | $1,150 | $3,573 | $2,567 |
| Propane furnace | 6% | 6% | $4,238 | $2,576 | $4,054 | $5,164 | $4,278 |
| **Weighted LCC Results** | **100%** | **100%** | **$1,037** | **$304** | **$825** | **$1,479** | **$1,158** |

For a nominal discount rate of 5.3% (real discount rate of 3%), assuming SCC = $51 per metric ton:

Table 16. LCC Results for All Climate Zones, **including** SCC, nominal discount of **5.3%**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Scenario** | **Heating System Prevalence for CZ5 (% of single family homes)** | **Heating System Prevalence for CZ6 (% of single family homes)** | **LCC ($) 5A** | **LCC ($) 5B** | **LCC ($) 5C** | **LCC ($) 6A** | **LCC ($) 6B** |
| Natural gas furnace | 83% | 76% | $1,153 | $396 | $1,089 | $1,660 | $1,199 |
| Electric heat pump | 11% | 18% | $3,900 | $1,490 | $1,634 | $4,521 | $3,323 |
| Propane furnace | 6% | 6% | $4,915 | $3,041 | $4,710 | $5,961 | $4,962 |
| **Weighted LCC Results** | **100%** | **100%** | **$1,681** | **$752** | **$1,405** | **$2,233** | **$1,807** |

For a nominal discount rate of 9.3% (real discount rate of 7%), assuming SCC = $0 (ignoring carbon):

Table 17. LCC Results for All Climate Zones, **excluding** SCC, nominal discount rate of **9.3%**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Scenario** | **Heating System Prevalence for CZ5 (% of single family homes)** | **Heating System Prevalence for CZ6 (% of single family homes)** | **LCC ($) 5A** | **LCC ($) 5B** | **LCC ($) 5C** | **LCC ($) 6A** | **LCC ($) 6B** |
| Natural gas furnace | 83% | 76% | $277 | ($91) | $249 | $526 | $302 |
| Electric heat pump | 11% | 18% | $1,910 | $617 | $694 | $2,243 | $1,600 |
| Propane furnace | 6% | 6% | $2,514 | $1,493 | $2,401 | $3,083 | $2,539 |
| **Weighted LCC Results** | **100%** | **100%** | **$591** | **$132** | **$458** | **$869** | **$670** |

For a nominal discount rate of 9.3% (real discount rate of 7%), assuming SCC = $51 per metric ton:

Table 18. LCC Results for All Climate Zones, **including** SCC, nominal discount of **3%**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Scenario** | **Heating System Prevalence for CZ5 (% of single family homes)** | **Heating System Prevalence for CZ6 (% of single family homes)** | **LCC ($) 5A** | **LCC ($) 5B** | **LCC ($) 5C** | **LCC ($) 6A** | **LCC ($) 6B** |
| Natural gas furnace | 83% | 76% | $652 | $179 | $613 | $969 | $681 |
| Electric heat pump | 11% | 18% | $2,427 | $898 | $989 | $2,821 | $2,061 |
| Propane furnace | 6% | 6% | $2,926 | $1,776 | $2,802 | $3,569 | $2,956 |
| **Weighted LCC Results** | **100%** | **100%** | **$983** | **$404** | **$812** | **$1,329** | **$1,066** |

The analysis did not consider climate zones 7 and 8, since PNNL (2018) already found the measure cost effective in those climate zones. Furthermore, since those have higher heating loads (greater number of heating degree days – HDDs), if the measure is cost effective in CZ6, it will be cost effective in CZs 7 and 8.

# HRV/ ERV Prevalence

The proposal team estimated the prevalence of HRV and ERVs in climate zones 5 and 6 using data provided upon request by RESNET. RESNET provided the following information, by climate zone:

* All rated homes with an HRV, by home type (single-family, duplex, and low-rise multifamily), for March 2020 – February 2022
* All rated homes with an ERV, by home type (single-family, duplex, and low-rise multifamily), for March 2020 – February 2022
* All rated homes (*not* broken out by home type) for March 2020 – February 2022
* All rated homes, by home type (single-family combined with duplex, and low-rise multifamily graphed separately) for 2020

The proposal team used the following calculation methodology to estimate prevalence of single-family homes (including duplexes) with HRVs and ERVs:

Table 19. Calculation of Prevalence of Single-Family Homes with ERVs or HRVs

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Step | Calculation | 5A | 5B | 6A | 6B | Total |
| 1 | Number of homes with ERV – single family + duplex:  March 2020 – Feb 2022  *From the RESNET ERV workbook. Filtered out (removed) multifamily* | 3409 | 740 | 7557 | 92 | 11,798 |
| 2 | Number of homes with HRV – single family + duplex: March 2020 – Feb 2022  *Same thing as above, but for the RESNET HRV workbook.* | 942 | 436 | 8398 | 28 | 9,804 |
| 3 | Number of single family homes (includes duplex) with ERV or HRV: March 2020 – Feb 2022  *Add 2 rows above.* | 4351 | 1176 | 15,955 | 120 | 21,602 |
| 4 | Number of rated homes in climate zone – all homes types, March 2020 – Feb 2022  *From RESNET “Climate Zone data” excel workbook* | 104,598 | 48,490 | 25,535 | 1,095 |  |
| 5 | Percent of single family homes / total.  *Based on bar graph of Multifamily vs. single-family ratings by CZ for 2020.* | 68% | 80% | 83% | *Almost no data from 2020. Use the average for other climate zones: 77%* |  |
| 6 | Percent of Single-family homes (including duplex) with ERV or HRV:  Step 3 / (Step 4 x Step 5) | 6% | 3% | 75% | *14%* |  |

Prevalence for most climate zones analyzed ranged from 3% to 14%. The value for 6A is surprisingly high. RESNET staff reported that most rated homes in 6A are in MN, and that many production home builders in St. Paul / Minneapolis use ERVs/HRVs.

# References:

Interagency Working Group on Social Cost of Greenhouse Gases, United States Government (2021, February), *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990,* Retrieved from whitehouse.gov: https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument\_SocialCostofCarbonMethaneNitrousOxide.pdf

Lucas, R., Mendon, V., & Goel, S. (2013, April 01). *Energy Use Savings for a Typical New Residential Dwelling Unit Based on the 2009 and 2012 IECC as Compared to the 2006 IECC.* Retrieved from osti.gov: https://www.osti.gov/biblio/1764648-energy-use-savings-typical-new-residential-dwelling-unit-based-iecc-compared-iecc

NAHB. (2019, December 26). *Are Rising Construction Costs Killing the American Basement?* Retrieved from nahbnow.com: https://nahbnow.com/2019/12/are-rising-construction-costs-killing-the-american-basement/

Salcido, R., Chen, Y., Xie, Y., & Taylor, T. (2021a, June). *National Cost Effectiveness of the Residential Provisions of the 2021 IECC.* Retrieved from www.energycodes.gov: https://www.energycodes.gov/sites/default/files/2021-07/2021IECC\_CostEffectiveness\_Final\_Residential.pdf

Salcido, V. R., Chen, Y., Xie, Y., & Taylor, Z. T. (2021b, April). *Preliminary Energy Savings Analysis: 2021 IECC for Residential Buildings.* Retrieved from energycodes.gov: https://www.energycodes.gov/sites/default/files/2021-07/2021\_IECC\_PreliminaryDetermination\_TSD.pdf

Taylor, Z. (2018, December 27). *Residential Heat Recovery Ventilation*. Retrieved from www.osti.gov: https://www.osti.gov/biblio/1488935

U.S. Energy Information Administration. (2017, February). *RESIDENTIAL ENERGY CONSUMPTION SURVEY.* Retrieved from www.eia.gov: https://www.eia.gov/consumption/residential/data/2015/hc/php/hc6.1.php

US Department of Energy. (2021). *Prototype Building Models*. Retrieved from Prototype Building Materials: https://www.energycodes.gov/prototype-building-models

1. From ICC, [Leading the Way to Energy Efficiency](https://www.iccsafe.org/wp-content/uploads/ICC_Leading_Way_to_Energy_Efficiency.pdf) – R101.3: “The International Energy Conservation Code-Residential provides market-driven, enforceable requirements for the design and construction of residential buildings, providing minimum efficiency requirements for buildings that result in the maximum level of energy efficiency that is safe, technologically feasible, and **life cycle cost** effective, considering economic feasibility, including potential costs and savings for consumers and building owners, and return on investment.” [↑](#footnote-ref-2)
2. https://www.census.gov/construction/chars/ [↑](#footnote-ref-3)
3. For example, the Lifebreath RNC6 has a price of $650 and SRE of 65, but a fan efficacy of 1.3 cfm/W so was not included. With this model the average HRV price would be lower. [↑](#footnote-ref-4)
4. Pricing: [Camperid.com](https://www.camperid.com/broan-nutone/ai-series-heat-recovery-ventilator-mpn-b110h65rs.html#specifications), HRV SRE, cfm, W: [HVI directory](https://www.hvi.org/hvi-certified-products-directory/section-iii-hrv-erv-directory-listing/) [↑](#footnote-ref-5)
5. Pricing: [Supplyhouse.com](https://www.supplyhouse.com/Panasonic-FV-10VE2-Intelli-Balance-100-Energy-Recovery-Ventilator-Temperate-Climate#product-overview) , HRV SRE, cfm, W: [HVI directory](https://www.hvi.org/hvi-certified-products-directory/section-iii-hrv-erv-directory-listing/) database shows 81 SRE and 54 cfm at the max SRE; the proposal team used product cutsheet to select a lower SRE (77) with a higher corresponding airflow (66 cfm) [↑](#footnote-ref-6)
6. Pricing, W, cfm: [Supplyhouse.com](https://www.supplyhouse.com/Fantech-SE704N-SE-Series-Energy-Recovery-Ventilator-4-Side-Ports-up-to-1200-Sq-Ft) , HRV SRE: [SupplyHouse.com](https://s3.amazonaws.com/s3.supplyhouse.com/manuals/1305562243209/56233_PROD_FILE.pdf) [↑](#footnote-ref-7)
7. Pricing: [HVACQuick.com](https://hvacquick.com/products/residential/Indoor-Air-Quality/Residential-HRV-ERV/Aldes-Aeromatic-Series-Energy-Recovery-Ventilators-ERV) , HRV SRE, cfm, W: [HVACQuick.com](https://hvacquick.com/catalog_files/Aldes_E110TF_Specs.pdf) [↑](#footnote-ref-8)
8. The PNNL study of HRVs, PNNL (2018), assumed 20 years. The proposal team assumed 15 years, to be conservative, and since many resources (such as the California Database of Energy Efficiency Resources) assume 15 years for residential HVAC equipment. [↑](#footnote-ref-9)
9. The exhaust duct running from the return register to the HRV was not assumed to be insulated, since it is in conditioned space. The exhaust duct running from the HRV to the outside was not assumed to be insulated, since it is also in conditioned space and heat losses from this duct do not matter. [↑](#footnote-ref-10)
10. The International Mechanical Code (IMC) does require distribution of ventilation air to living spaces. Depending on the interpretation of the jurisdiction, this could require ducting of ventilation air to living rooms and bedrooms. However, this would be required regardless of the ventilation system type – HRV/ERV or systems without heat recovery system, so would not increase incremental cost for an HRV/ERV. [↑](#footnote-ref-11)
11. Methodology for Evaluating Cost- Effectiveness of Residential Energy Code Changes, Pacific Northwest National Laboratory, 2015, https://www.energycodes.gov/sites/default/files/2021-07/residential\_methodology\_2015.pdf [↑](#footnote-ref-12)