PHIUS 2021
MECHANICAL SUMMIT
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summit.phius.org

BALANCED VENTILATION DESIGN PRINCIPLES

for low load homes and buildings

PASSIVE | ENERGY | DESIGNS

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Overview

1. Balanced Mechanical Ventilation
2. Product Choices: ERV or HRV
3. Sizing
4. Distribution
5. Installation

Ventilation

Definition:
Controlled movement of air into and out of a building, generally using mechanical means, through deliberately placed holes in the building envelope

Purpose:
Provide the necessary fresh (supply) air and remove the necessary stale (exhaust) air to maintain high indoor air quality (control temperature, humidity, odors, carbon dioxide, airborne contaminants, etc) inside the building

Why Mechanical Ventilation

Controlled Ventilation vs Random Ventilation

- Constant Supply
- Optimal Locations
- Controlled Quantity
- Comfortable Temperature
- Filtered, Clean Source
- “Recycles” 8-15x the energy of operation

- Random Times
- Random Locations
- Random Quantity
- Random Temperature
- Random Quality
- Over or Undersized (Windy vs Calm Day)

Role of Mechanical Ventilation

Ventilation Basics

1. Healthy Indoor Air
   - Introduce “fresh” air while removing “stale” air
   - Mitigate accumulation and concentration of pollutants
   - Limit odors
   - Control air humidity for comfort and to avoid mold growth

2. Filtering
   - Clean supply air as it is brought into the building
   - Protect Equipment and cut down on interior dust
   - Depending on filtration level can increase IAQ by decreasing pollutants and allergens

3. Heat Recovery
   - Save energy through high recovery efficiencies (climate dependent)

Why Balanced Mechanical Ventilation

Exhaust Only
- Depressurizes Building
- Draws Air in Randomly
- Poor Efficiency
- May Hurt Building Durability

Supply Only
- Pressurizes Building
- Forces Air Out Randomly
- Poor Efficiency
- May Hurt Building Durability

Balanced
- Neutral Pressure
- Air Inlet and Exhaust Controlled
- Very efficient with Heat Recovery

The Effect of Heat Recovery:

Exhaust or Supply Only Ventilation Heating Loss is equal to 6.3-9.5 kBTU/ft²yr for Central Europe

This is 133-200% of the original PH Heating Limit (4.75 kBTU/ft²yr)!

Heat Recovery Ventilation Heating Loss is equal to 0.6-2.2 kBTU/ft²yr for Central Europe

This is 13-46% of the original PH Heating Limit (4.75 kBTU/ft²yr)!

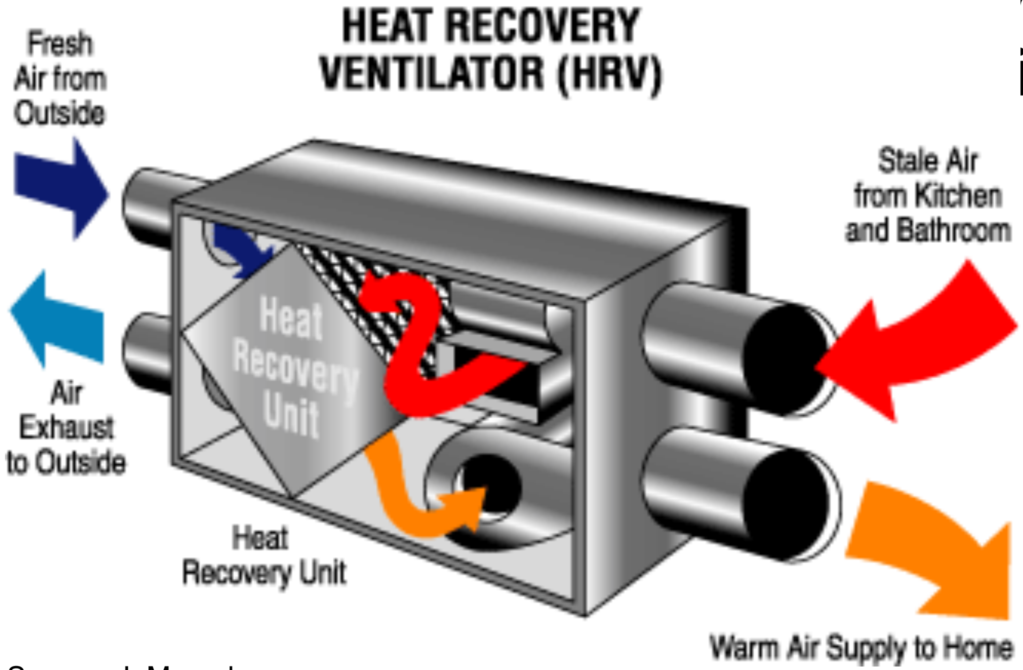
Energy or Heat Recovery Ventilation

Heat Recovery Ventilation:

Recovers only sensible heat from the outgoing (exhaust) airstream by transferring it to the incoming (supply) airstream

Energy Recovery Ventilation:

Recovers both sensible and latent heat from the outgoing (exhaust) airstream by transferring it to the incoming ...irstream



Source: J. Morosko

ERV or HRV – That is the question...

Ventilation Basics

Factors:

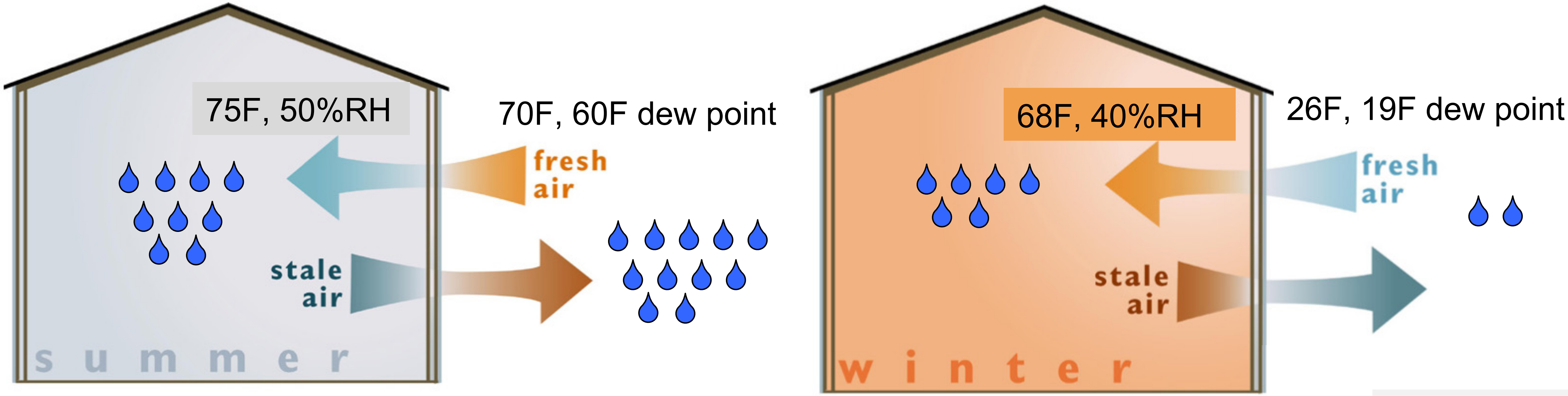
- Climate
- Ventilation Rate
- Infiltration
- Occupant Density or Internal Sources

In most applications it is better to have moisture transfer!

Hot Humid Outside	• Remove humidity from incoming air (ERV)
Cold Outside + Dry Inside	• Return as much humidity as possible to the inside (ERV)
Cold Outside + Very Humid Inside	• Exhaust some humidity, but not all (ERV)

ERV or HRV – an example…

Toronto, ON – Seasonal Averages – 2010/2011



Summer 2011

Winter 2010-2011

ERV and HRV Ratings

PHIUS, HVI, AHRI, and PHI ratings are all acceptable for certification.

When possible, use the following spreadsheet, which has PHIUS adjusted numbers for all HVI rated ERV/HRV products.

https://www.phius.org/Tools-Resources/Protocols-Calculators/HVI_Winter_Ratings-PHIUS_March_2021.xlsx

ERV and HRV Ratings

Ventilation Basics

Summary of ERV/HRV Efficiency Numbers:

HRV's have higher Sensible Recover Efficiency (SRE) when compared to the similar model ERV

Product Category	Brand Name	Model Name	Net Airflow (cfm)	Power Consumed (Watts)	Sensible Recovery Efficiency (SRE)	Total Recovery Efficiency (TRE)	Humidity Recovery Efficiency Heating	Humidity Recovery Efficiency Cooling	Electric Efficiency (W/cfm)	Coefficient of Performance COP
HRV	Zehnder	CA200HRV	66	34	90%	n/a	3%	n/a	0.52	21.5
HRV	Zehnder	CA200HRV	87	44	90%	n/a	3%	n/a	0.51	21.9
HRV	Zehnder	CA200HRV	108	60	90%	n/a	1%	n/a	0.56	20.0
ERV	Zehnder	ComfoAir200ULRLuxeERV	65	29	80%	65%	77%	61%	0.45	22.2
ERV	Zehnder	ComfoAir200ULRLuxeERV	85	38	78%	n/a	73%	n/a	0.45	21.6
ERV	Zehnder	ComfoAir200ULRLuxeERV	108	56	77%	n/a	69%	n/a	0.52	18.2

ERV "Speed" or CFM Flow Rate has big impact on SRE an on Electrical Efficiency (W/CFM)

Product Category	Brand Name	Model Name	Net Airflow (cfm)	Power Consumed (Watts)	Sensible Recovery Efficiency (SRE)	Total Recovery Efficiency (TRE)	Humidity Recovery Efficiency Heating	Humidity Recovery Efficiency Cooling	Electric Efficiency (W/cfm)	Coefficient of Performance COP
ERV	RenewAire	EV Premium L	61	25	86%	72%	77%	0%	0.41	25.9
ERV	RenewAire	EV Premium L	121	45	82%	n/a	70%	n/a	0.37	27.1
ERV	RenewAire	EV Premium L	201	124	76%	n/a	60%	n/a	0.62	15.2
ERV	RenewAire	EV Premium L	227	182	76%	n/a	57%	n/a	0.80	11.6

ERV Defrost/Preconditioning Strategies

Ventilation Basics

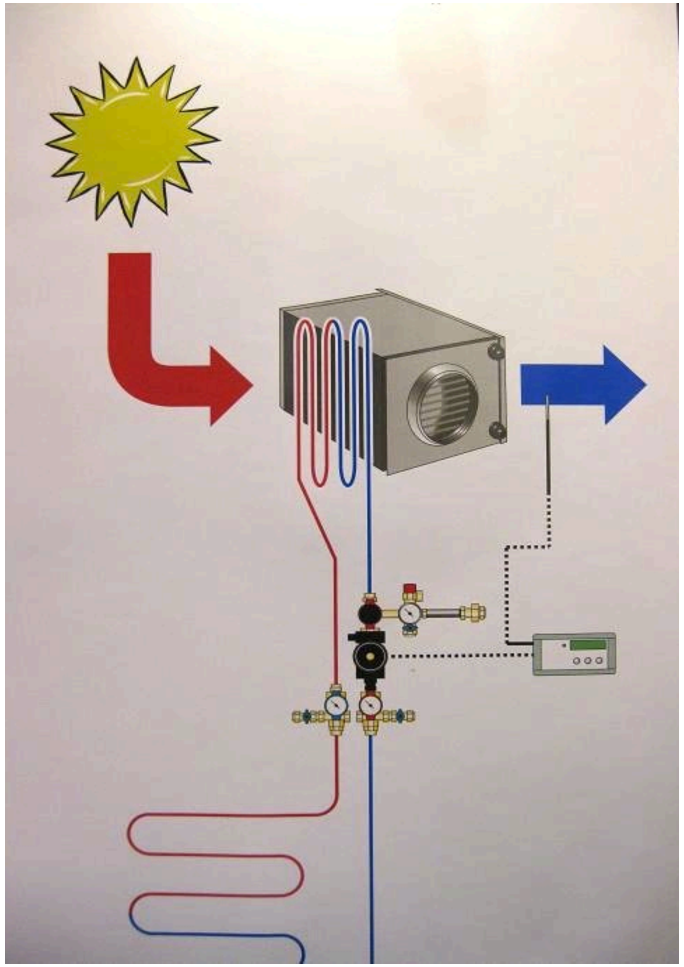
Some, but not all, ERV's require:

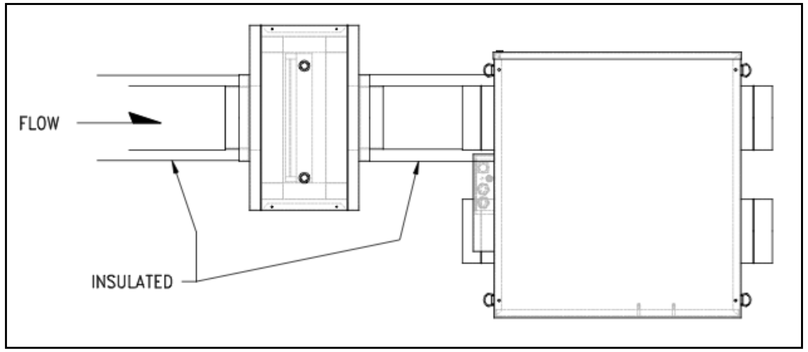
1. Defrost in cold climates
2. Condensation drain line

Options for Defrost:

1. Duct Heater
    1. Electric Resistance
    2. Hot Coil
2. Subsoil Heat Exchanger
    1. Ground Loop
    2. Earth Tube

Source: www.ultimateair.com





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Ventilation System Concept

- All Ventilation Through HRV/ERV
- Air Extracted from “Wet” Rooms
- Supplied to Living/Sleeping Rooms

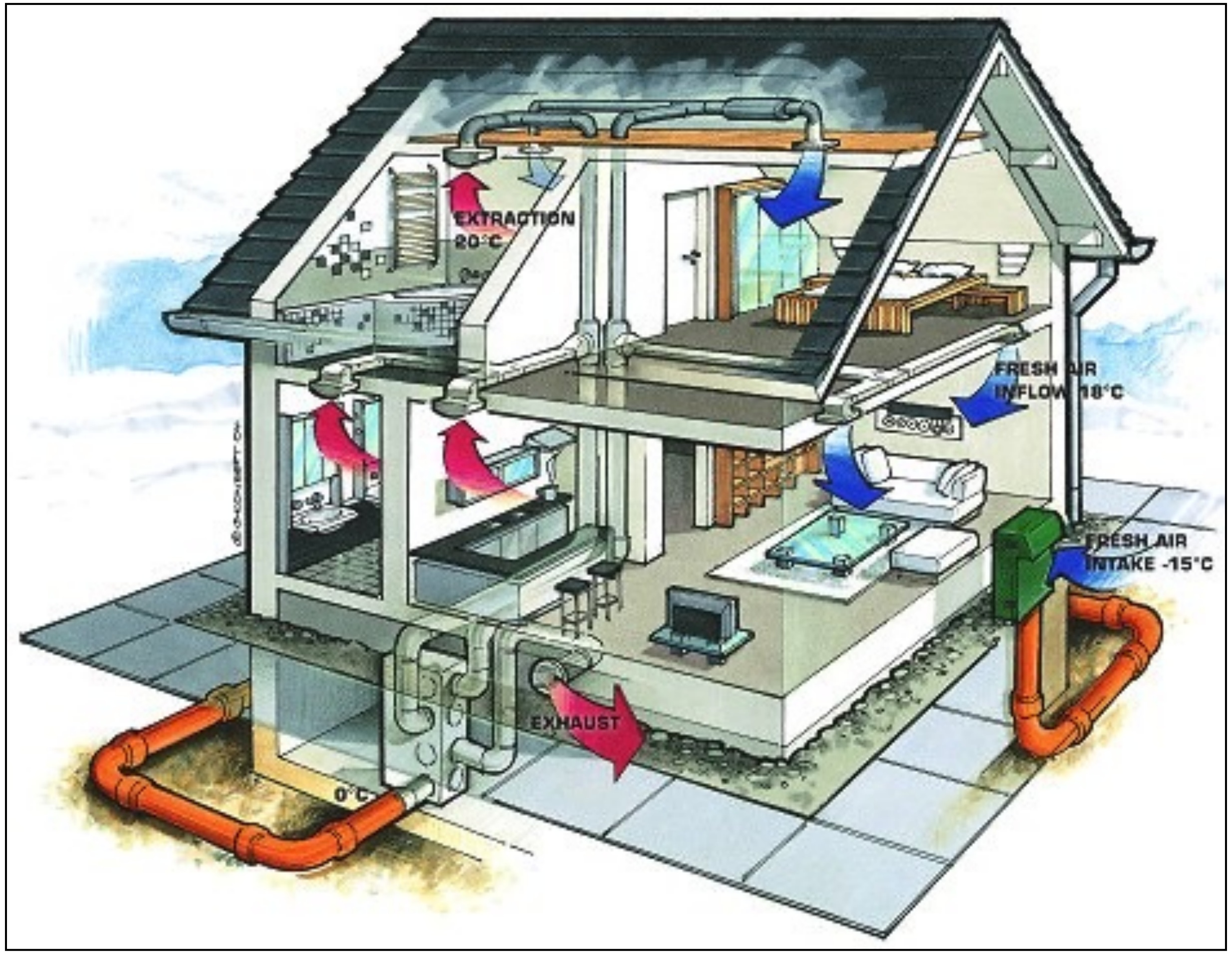


Image source: www.greenbuildingstore.co.uk/mvhr.php

Determining Ventilation Flows

Maximum Design Airflow Required is the Greater of:

Supply Air:

18 cfm per person
(Residential)

Example:
3 Bedrooms = 4 people
4 people x 18cfm = 48 cfm
Total 48 CFM

Extract Air:

Kitchen – 35 cfm
Bathrooms – 24 cfm
½ Bath – 12 cfm

Example:
1 Kitchen = 35 cfm
2 Bathrooms = 48 cfm
1 ½ Bath = 12 cfm
Total 83 CFM

Volume:

0.3 Air Changes per Hour
(0.3 ACH)

Example:
1800 sq ft house with 9' Ceilings:
Net Volume = 16,200 cfm
Math:
16,200 ft3/min * 0.3 ACH * 1/60 min
Total 81 CFM

Determining Ventilation Flows

Ventilation Sizing and Layout

ASHRAE 62.2 – 2010 Whole Building Requirements:

Total CFM = .01 CFM[1] per 1ft^2 (gross) + (7.5 cfm x # of Bedrooms +1)

Example: 1800ft^2 (3 Beds)

3 Bedrooms = 4 people
(.01 cfm * 1800) + 7.5cfm x4
Total 48 CFM

Example: 3000 ft^2 (3 Beds)

3 Bedrooms = 4 people
(.01 cfm * 3000) + 7.5cfm x4
Total 60 CFM

Passive Building Example:
3000 ft^2 (gross)
~2250 iCFA – Min 0.3 ACH

Volume = 2,250 x 8’
Volume = 18,000 ft^3
18,000 * 0.3 * 1/60 = 90
Total = 90 CFM

1. ASHRAE calls for 0.03cfm/ft^2, but assumes 0.02cfm/ft^2 infiltration

Determining Ventilation Flows

Ventilation Sizing and Layout

ASHRAE 62.2 Local Exhaust Requirements:

Bathrooms:

50 CFM Intermittent

20 CFM Continuous

During PHIUS+ Certification Review, the PHIUS Team wants to see each bathroom getting at least 20 CFM at the nominal flow rate!

Kitchens:

100 CFM Intermittent

5 ACH Continuous

Continuous exhaust in kitchens are almost always not feasible unless the cooking area is very small and the exhaust is one of only a few exhaust locations!

Example: 10'Wx20'Lx9'H Kitchen = 150cfm

Example:

1800 ft2 House

3 Bedrooms, 2.5 Baths

Int. Bathroom Exhaust: 150 CFM

Int. Kitchen Exhaust: 100 CFM

Intermittent Total of 250 CFM

Cont. Bathroom Exhaust: 60 CFM

Int. Kitchen Exhaust: 100 CFM

Mixing Cont. and Int. Is Allowed

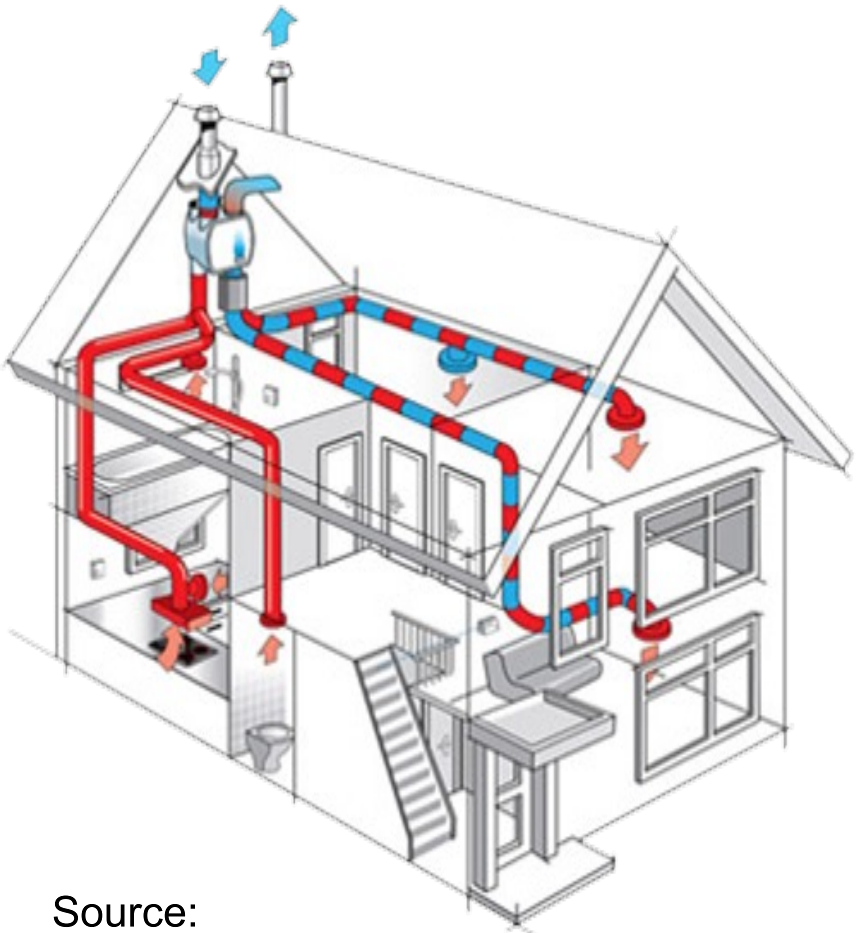
Determining Ventilation Flows

Final Disclaimer(s):

1. Be aware of local code and code compliance.
2. DOE Zero Energy Ready Home Program requires full certification through EPA's Indoor airPLUS program. (PHIUS+ Certification requires DOE ZERH Certification – and therefore EPA's Indoor airPLUS).
3. There are potential situations where the basic information provided to this point may not result in an optimal ventilation rate (due to building type, occupancy, or building features).

Ventilation System Layout

Principles of a Highly Efficient Ventilation System:



Source:
www.proairservices.i.e.com

- Keep Ambient (Outside) Intake and Exhaust Ducts Short Between the Unit and Exterior Wall
- Well-Insulated Intake and Exhaust Ducts w/ Vapor Impermeable Insulation
- Keep Conditioned (Inside) Air Ducts Within the Thermal Envelope
- Minimize Duct Losses
- Balance the System: At Each Register/Diffuser
  Overall Flow, In and Out w/in 10%
- Overflow Openings Between Rooms: 1 Pa Max. Differential
- Avoid “Short Circuits”: No Recirculating Air Streams
- Controls: Typically Simple, low Medium or High w/ override or Boost in Kitchens and Baths

Duct Types

Ventilation Sizing and

Flex Duct

$

Easy+Fast Installation

Friction Losses

Hard to seal

Custom sizing

Trunk+Branch

HDPE Rigid-Flex

$$

Easy+Fast Installation

Home-Runs

Flexible Ext.

Smooth Int.

3.5” diameter

UL Listing?

Sheet Metal

$$$

Labor Intensive

Trunk+Branch

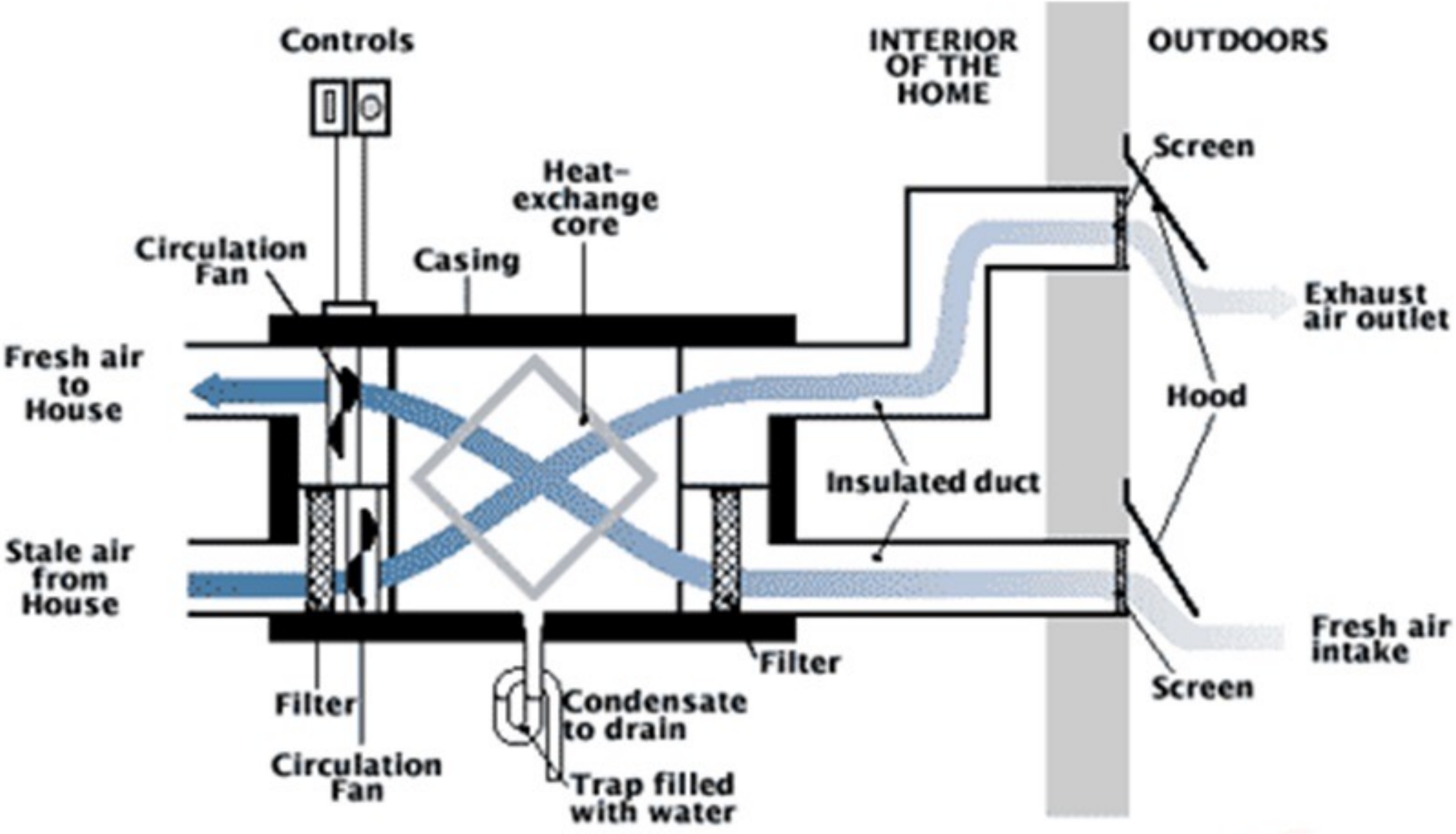
Smooth Ext+Int

Custom sizing

Harder to seal

Installation and Duct Insulation

Diagram showing typical ERV installation



Insulation must be vapor tight and at least R4. Higher is preferable and targets of R8 are advisable in many climates.

ERV close to wall to save on duct insulation requirements

Intake and exhaust should be at least 6’ apart… ASHRAE 62.2 requires 10’

Duct Layout

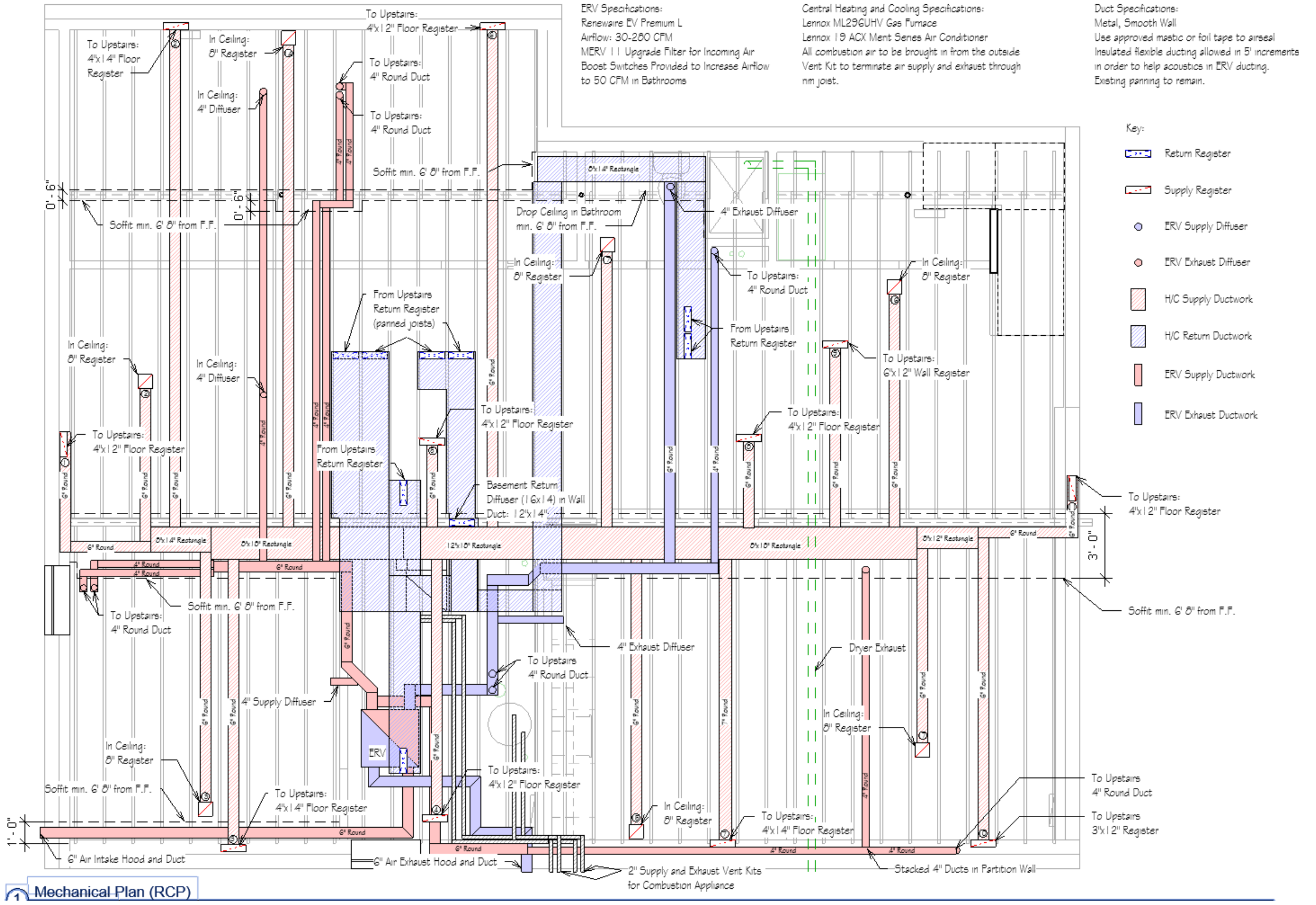
Layout Review:

- Find Exhaust Locations and Flow Rates
- Balance with Supply Locations
- No Short Circuits
- Short runs with distribution towards perimeter
- Duct sized properly for flow – and accounts for boost

- Supply Locations in Bedrooms, Living Spaces
- Exhaust Locations in Kitchens, Bathrooms and possibly laundry/mudroom
- Attempt to balance per floor
- Determine locations based on overall floor plan. May not need to supply living space if bedroom air is being pulled across it, etc.

Duct Layout

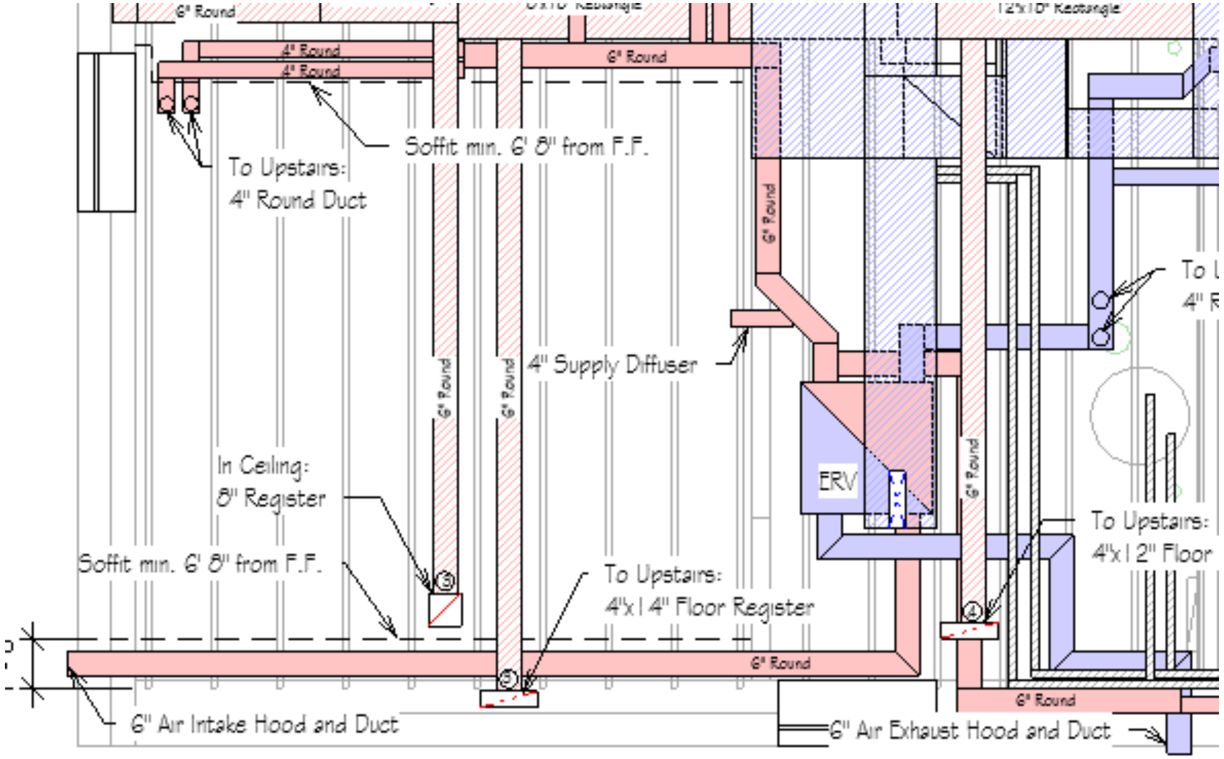
Ventilation Sizing and



Things can get complicated quickly when the real world comes into play. Take for instance this retrofit ERV plan. The existing heating and cooling ductwork, plumbing, etc take up most of the joist bays. Additionally, there are doors, windows, exterior grade and decks/overhangs, and existing vents to contend with when looking for supply and exhaust locations!

Duct Layout

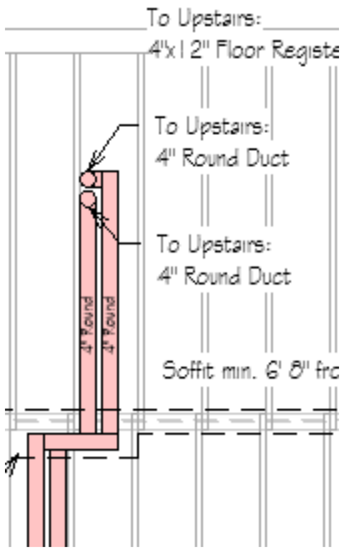
The Intake and Exhaust ducts to the outside are longer than the ideal version. However, this is a retrofit. It is difficult to find a better spot for the ERV than the existing mechanical room and on the side of the building, there is a sliding door, window and covered patio, which all impact where the intake and exhaust penetrations can be located!



Regarding Acoustics:

All acoustic issues are amplified in a passive house because they are so quiet relative to outside noise.

There is a concern regarding noise transfer between rooms through ductwork. Hence some of the double runs of 4" ductwork when a single 6" duct with a tee or branch would suffice. This significantly lengthens the path but has an effect on static pressure/fan energy.



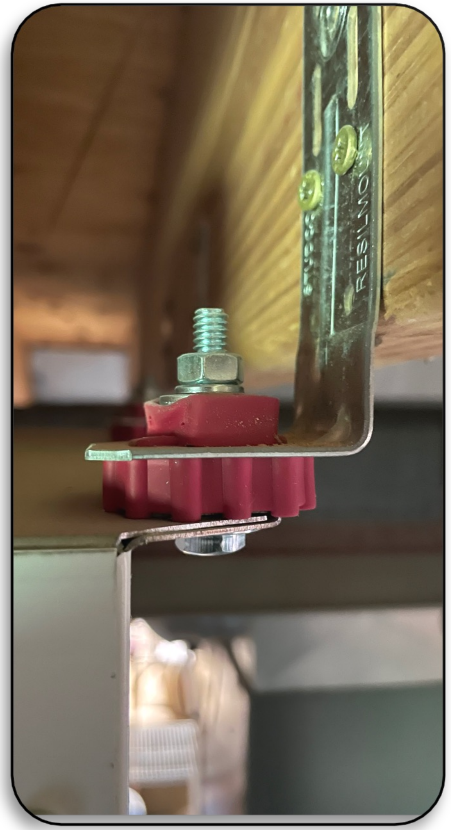
Duct Noise

Ventilation Sizing and

Sound Attenuation

- Vibration isolate ERV/HRV from floor joists
- Use flex duct or silencers to mitigate noise from rigid ducts
- Consider sound attenuation in walls/ceiling/floor of mechanical room

Source: Fantech



Source:
Ryan Abendroth

Duct Placement

Supply Placement

Bedrooms
- High in the room for Coanda effect
- Typ. pointed towards windows

Living Rooms
- High in the room for Coanda effect
- Typ. pointed towards windows

Offices
- Dependent on occupancy
- For residences, treat as bedroom

Conditioned Basements

Similar to other floors

Exhaust Placement

Bathrooms
- in far corner of bathroom
- away from door

Kitchens
- at least 6' away from cooktop
- with grease filter

Duct Losses and Sizing

Ventilation Sizing and

Minimize Duct Losses

- Smooth Interior
- Minimize Bends/Kinks/Constrictions
- Low Velocity (< 3 m/s | ~600fpm)
- Tightly Sealed (< 3% Leakage)
- Size for Low & High Speed (Air Flow)
- Short & Centralized Duct Layout
- (Use Far-Throwing Diffusers & Coanda Effect)

Ducts should really be sized per ACCA Manual D, but here are some velocity values based on flow rate and duct size:

200 CFM – 6" duct = 1019 FPM

200 CFM – 8" duct = 573 FPM

100 CFM – 6" duct = 509 FPM

50 CFM – 4" duct = 573 FPM

(PHIUS Recommends that the air velocity be < 600 FPM)

Balancing

- Airflow at each register must be balanced within:
  - 20% of the design value or 5 cfm (whichever is greater).
- Airflow between rooms must be balanced to less than 1.0 Pascal
  - A 1” door undercut is adequate for airflows up to ~ 40 CFM
  - A 1/2” door undercut is adequate for airflows up to ~ 20 CFM
- 3.0 Pascals are acceptable for rooms with ducted space conditioning included.

Controls

- Methods of Control
  - Constant flow
  - Constant flow with boost mode
  - CO2 Controlled
  - Temperature Controlled
  - Humidity Controlled
  - Variable based on external factors

Smart Controls are coming (or already here)!

What if we could adjust the ventilation rate by sensing the air quality and temperature inside and out, knowing the weather and air quality forecast and delaying or accelerating our ventilation rates to compensate…

Maintenance

- Every 2-3 Months (Quarterly +/-)
  - Clean filters
  - Check intake/exhaust hoods
  - Check controls
- Annually
  - Clean core and interior
  - Flush condensate drain hose
  - Inspect blowers and defrost dampers
  - Check blowers for caking
  - Clean exhaust grilles as needed

IMPORTANT!

Educate end-user or facilities staff on maintenance needs, process, schedule, and OPERATION!

Questions?

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