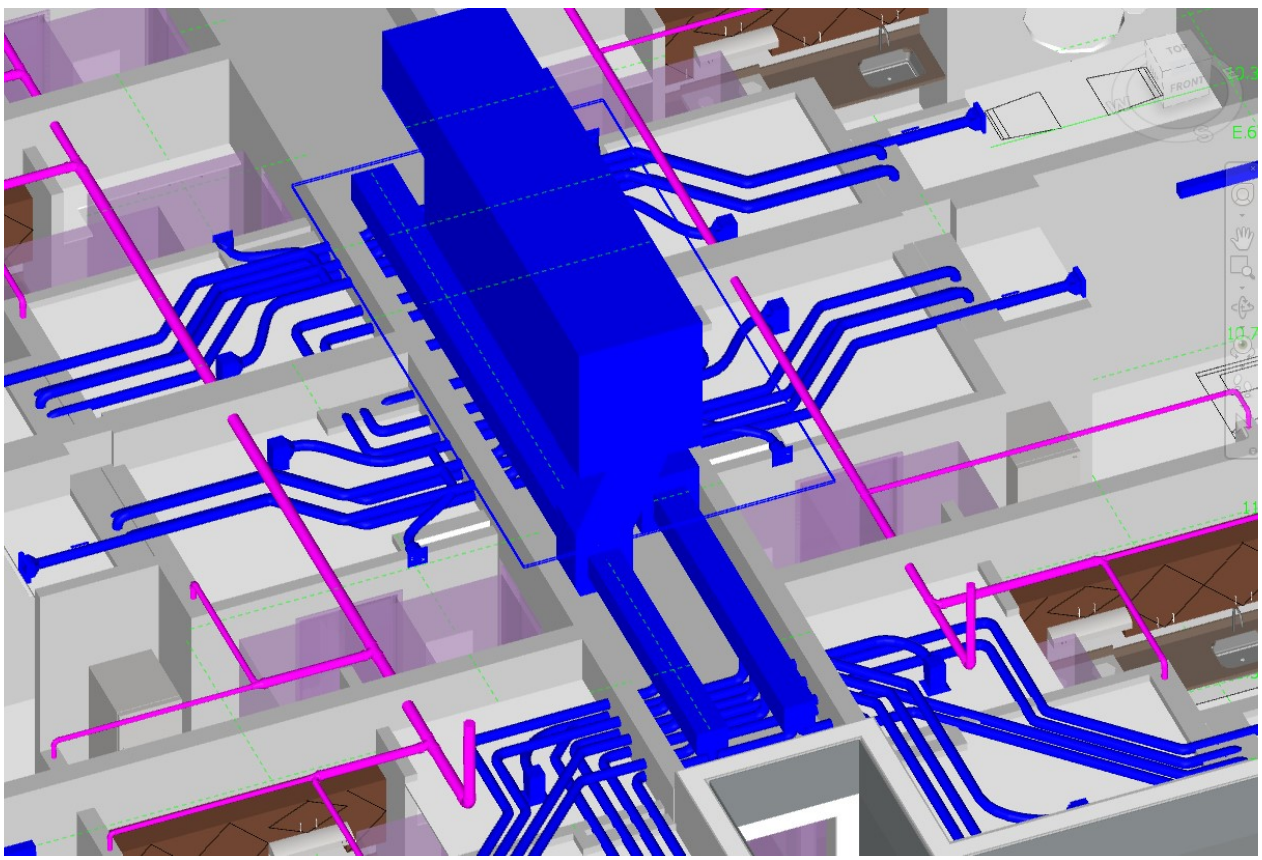
The Housing Development Consortium of Seattle-King County

# GUIDELINES FOR BALANCED VENTILATION WITH HEAT RECOVERY

*Part of a series highlighting techniques for designing & building better affordable housing*



HOUSING DEVELOPMENT consortium

**Exemplary Buildings Program**

***Advancing Ultra-Efficient Buildings in Affordable Housing***

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*Cover image: Walsh Construction Co.*

# OVERVIEW: EBP'S GUIDELINES SERIES

The Housing Development Consortium of Seattle-King County (HDC) launched its Exemplary Buildings Program (EBP) as a regional collaborative effort targeting nothing less than transformation of the affordable housing market. Why? Because the interrelated crises of climate change, equity, and housing demand both boldness and urgency. We believe it's possible to create equitable access to healthy, safe housing that is ***both*** affordable ***and*** ultra-efficient. The EBP task force has defined a comprehensive set of performance standards and building practices designed intended to balance additional capital costs with reliability, efficiency, and occupant satisfaction. These standards are available at exemplarybuilding.housingconsortium.org.

**EBP's Design Charrettes.** Meeting performance goals depends on broad engagement and a relentless focus on best practices, commitments that also characterized the design charrettes EBP convened soon after launch. Each intensive session brought together recognized thought and practice leaders in one of several technical areas: Balanced Ventilation with Heat Recovery; Water Heating, Distribution, and Management; Early Integrative Design; Solar Integration; and Wall Assemblies.

**Charrette participants, including experts from the EBP task force, rigorously sifted through current and emerging technologies, analyzing each in the context of changing construction practices; local construction culture, codes and regulations; cost; and the Puget Sound region's marine climate.**

**EBP's Guidelines Series.** Each charrette produced a set of practical guidelines—such as those presented in this document—to support teams early in their design and pricing efforts, helping them to streamline the process of constructing exemplary buildings. The path to achieving cost efficiency includes standardization, training, and partnerships with suppliers. A fundamental purpose of EBP is to present approaches that are repeatable so that cost efficiencies can be accomplished at scale with partner suppliers and subcontractor familiarity.

**It is important to note that EBP's guidelines are <u>not</u> restricted to developments striving to meet the full set of "exemplary" criteria. In fact, our hope is that they can be used to improve affordable multifamily housing more generally.**

We hope these guidelines facilitate the affordable housing sector's ability to achieve construction cost efficiency, quality, and durability while pursuing the performance goals of the Exemplary Buildings Program and the specifications for projects in King County, Washington. Performance data from the program's demonstration projects will be used to continually refine the guidelines and update these publications.

**EBP's Partners.** We're grateful for the time and exceptional talent of the charrette participants and for the generosity of our program funders and charrette sponsors. Their commitment to this vision is vital.

Marty

Marty Kooistra
Executive Director, Housing Development Consortium of Seattle-King County (HDC)

# EXECUTIVE SUMMARY

For decades, building scientists have wrestled with a key tension: how to “tighten up” our residences to reduce unnecessary energy loss while also ensuring that the environment inside remains healthy.

Back when heating was done with fuels like coal and wood, homes were built with air leakage that provided “accidental ventilation.” As the need grew for energy-efficient homes that didn’t leak air at high volume through the envelope, so did the need to address the potential for poor indoor air quality. Today, our envelope construction, air sealing, and fenestration are pushing as close as we can to minimizing accidental ventilation. Moreover, the “Pacific Northwest’s new normal” includes smoke from wildfires, periods of extreme summer heat, and airborne viruses. Each one adds to concerns regarding how to “build it tight and ventilate it right.” This set of guidelines has been produced in response to those factors and to the building codes driving us to excel in the quality of our residential and commercial construction.

### We believe exemplary buildings push the envelope in seeking to amplify these values:

- **Improved air quality**
- **Improved occupant health**
- **Improved comfort**
- **Lower operating costs**

The complexity of getting this “active ventilation” right in large multifamily residential buildings should not be understated. What follows are the most contemporary promising practices for multifamily ventilation, distilled from the knowledge and expertise of the Exemplary Buildings Program task force. In so doing, we hope to honor the thoughtful planning and design that are essential to “balancing the tensions” and to creating truly exemplary buildings.

Efforts have been made to present information that is true and accurate. Since every building has unique circumstances, design and construction teams will need to independently verify the information provided here. We hope this document proves useful as a resource to assist with the design of high-performance affordable housing developments. HDC’s Exemplary Buildings Program is a work in progress, and we hope to incorporate new strategies in the future. Stay tuned.

**David Reddy, *PE***
Building Performance Principal, O’Brien360
Lead, Exemplary Buildings Program Balanced Ventilation with Heat Recovery Charrette

# SETTING THE STAGE

# Code Requirements

Provisions of the 2018 Washington State Mechanical Code **(WSMC)** and Energy Code **(WSEC)** require multifamily (Group R-2) homes in buildings of four stories or more to have balanced ventilation with heat recovery systems. These are:

**WSMC 403.4.4.1:** Requires balanced whole house ventilation system for Group R-2 occupancies.
**WSEC C403.3.6:** Requires balanced ventilation system to have minimum 60% sensible energy recovery.

**In other words, while balanced ventilation with heat recovery was once an elective option to reduce energy use and/or improve indoor air quality, it is now required by code. Therefore, the challenge ahead of us is not whether this system is used, but rather how to implement it most efficiently.**

Despite Seattle adopting its own commercial code amendments, these same provisions apply to Seattle multifamily development. However, there are differences between the Washington state and Seattle energy/mechanical codes that can impact design. Addressing those differences is not specifically within the scope of these guidelines; therefore, it is still essential to engage engineers and consultants to help interpret and apply these guidelines within the context of local code.

# Balanced Ventilation Standards and Technology

## What is Balanced Ventilation?

The WSMC defines many aspects of a "balanced" ventilation system.

- Any combination of concurrently operating exhaust and supply fans whereby the total exhaust airflow rate is "balanced." Balanced means the exhaust airflow rates are within 10% or 5CFM (whichever is greater) of the total supply airflow rate. Intermittent exhaust sources (such as dryers, range hoods, and bath fans) are exempt from the balanced airflow calculation.
- If the exhaust and supply airflow rates are not balanced, the code-minimum required ventilation rate must be increased by 25%.
- Similarly, the ventilation system is either "distributed" or "not distributed", as discussed further below. For systems that are not distributed, the required ventilation rate must be increased by 25%.

- A system that is both not balanced **and** not distributed requires a combined 50% increase beyond the code-minimum ventilation rate. In other words, if the required minimum air flow is 50 CFM, an unbalanced and non-distributed system must be designed to provide at least 75 CFM. Despite the air flows being small, moving 25-50% more air can have significant impact on equipment and duct sizes, and will use more energy.
- Regardless of whether the system is balanced and/or distributed, it must supply fresh air to each habitable space. For example, it is not acceptable to have a system that only supplies air to a living room and not to the bedrooms. One exception to this rule exists: rooms not directly supplied with ventilation air must be connected to another room that is directly supplied by either a transfer fan (minimum 30 CFM) or a permanent opening (25 $ft^2$ or greater). A common application for this exception is an "urban one-bedroom" apartment.
- **WSMC** has provisions for both intermittent operation and combining the ventilation system with heating and cooling equipment if additional requirements are met. However, these provisions generally require more air flow, advanced controls, and usually result in uneven fan noise from the system turning on and off. Therefore, continuous operation is recommended.

The table below summarizes the pluses and minuses of balanced ventilation in comparison to whole house ventilation using exhaust fans, the status quo for most multifamily housing in Washington state prior to the 2018 codes. **As mentioned earlier, for Group R-2 dwelling or sleeping units, balanced ventilation with heat recovery is now a code requirement.**

| PLUSES [+] | MINUSES [-] |
|---|---|
| Ventilation air is pulled in from the outside, not pulled in from your neighbors' homes or from other areas of the building | Increased capital and maintenance costs |
| Outside air is filtered, which is especially important where outdoor air quality is compromised, as is the case for buildings located near busy roads or ports, or for all buildings during a wildfire smoke event | Takes more effort to design and optimize systems than the previously accepted whole house exhaust fan systems |
| Ventilation air is not pulled through cracks in the building envelope, thereby reducing the contribution of uncontrolled air leakage to envelope failure | Usually requires more space, whether it be roof or floor area. Some system designs require building height to be increased |
| When combined with heat recovery, balanced ventilation generally reduces energy consumption, especially if electric resistance is used to heat the dwellings | Efficiency gains can be marginal if fan power is high, sensible heat recovery efficiency is low, or space is conditioned with very efficient heat pumps |

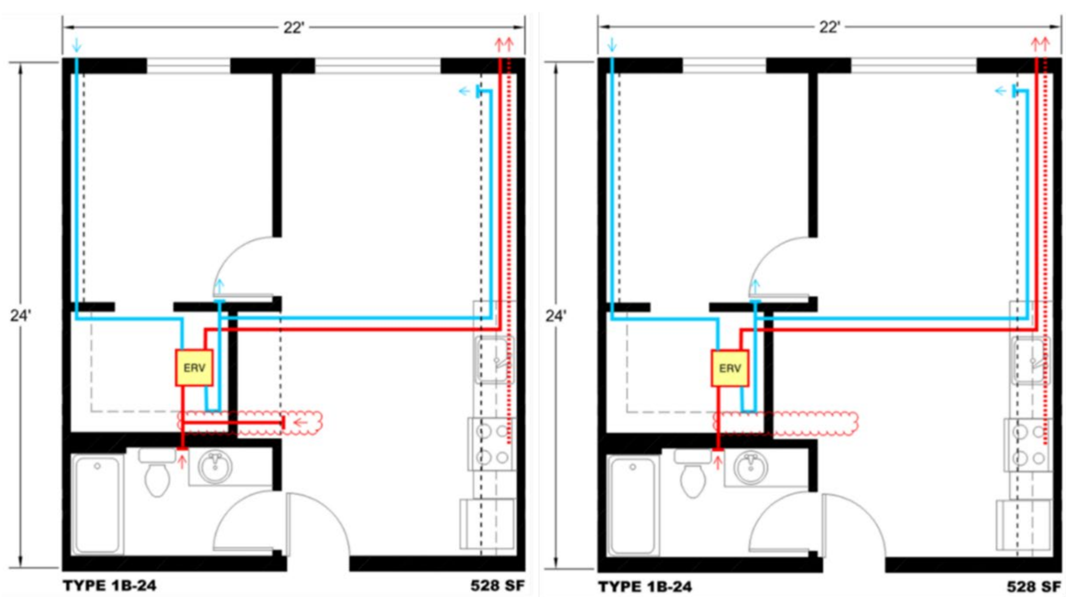
## Distributed vs. Non-Distributed Systems

As alluded to earlier, a key design characteristic is whether the ventilation system is “distributed” or “not distributed” as defined in the **WSMC.**

A ventilation system is considered **“distributed”** if it supplies outdoor air directly (not by transfer air) to each “habitable” space and exhausts air from all kitchens and bathrooms directly to the outside. Examples of habitable spaces include a living room, den, home office, or bedrooms. The **left** portion of the figure below illustrates how a ventilator for a one-bedroom apartment might distribute air to meet the distributed requirement. Note that air is supplied to the living room and bedroom (blue) and exhausted from both the kitchen and bathroom (blue). This results in fresh air being more uniformly distributed throughout the home.

A **“not distributed”** system, shown on the **right**, is similar EXCEPT there is no air exhausted from the kitchen area. In this case, at least 25% more ventilation air must be provided to the home to compensate for the less-effective distribution. Exhausting air from the kitchen, however, comes with a trade-off: fats, oil, and greases (FOG) generated by cooking typically will fill the air, and can foul the ventilation heat recovery core and ductwork. Therefore, it is recommended that the kitchen exhaust grille be located away from the range area and include a washable or disposable grease filter. Additionally, for central systems, the kitchen and exhaust air ducts generally cannot be combined, though there are some exceptions for this in the Seattle Mechanical Code.

**DISTRIBUTED** **NOT DISTRIBUTED**




*The diagram on the left includes an exhaust duct and grille for the kitchen area; the diagram on the right excludes this element. [Floor plan image adapted from Walsh Construction Co.]*

As you can see, the difference between distributed and non-distributed is subtle, but does have both design and maintenance implications. For unitized systems, the minimum air flow of the ventilator may already be higher than the not distributed requirement, particularly for small apartments. However, a distributed system will result in more uniform distribution of ventilation air and better removal of moisture and pollutants from the kitchen area.

The following considerations for in-unit air distribution are also important:

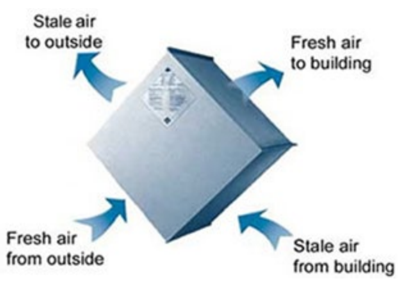
- Make sure supply and exhaust air flows are balanced and are appropriately divided among the habitable spaces.
- Sufficiently separate supply diffusers from exhaust grilles and interior doors so ventilation air can effectively mix into the room before being exhausted.
- Be mindful of where supply air diffusers are located. During the winter in Western Washington, the supply air temperature of a ventilation system with heat recovery will typically be around 60°F, depending on the sensible heat recovery efficiency (described below). Therefore, supply air should not be directed at places where occupants will be sitting or sleeping. Design measures such as specifying ventilators with higher sensible heat recovery efficiency, using ceiling supply diffusers, or discharging in the proximity of a heater are recommended whenever possible.
- Design the system to operate quietly when running at the continuous minimum airflow rate.

A more detailed list of distribution design considerations is provided in the Recommendations chapter of this document.

# Heat Recovery Standards and Technology

In the context of these guidelines, **"heat recovery"** refers to exchanging energy between the ventilation air that is supplied and then exhausted from a home. There are three principal ways to accomplish heat recovery, described in the table below.

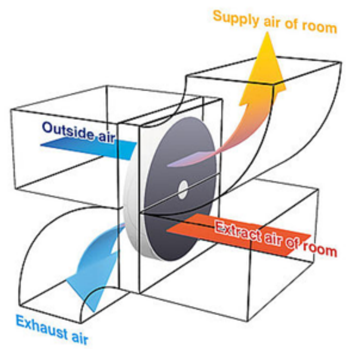
**PLATE HEAT EXCHANGER**




Air flows through passages in a static 'core' that allows the supply and exhaust air to pass by each other without mixing and transfer heat energy through the walls of the core. Plate heat exchangers are used in a wide range of equipment sizes, from small residential units up to large central H/ERVs.

*Figure adapted from:*
[inspiredliving.com/venmar-ventilation/venmar-kubix-hrv-system.htm](inspiredliving.com/venmar-ventilation/venmar-kubix-hrv-system.htm)

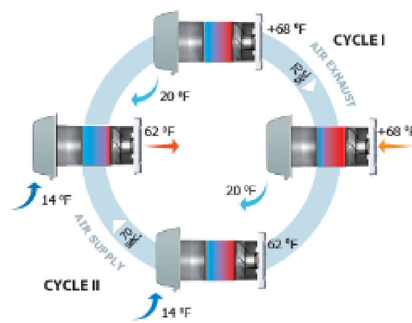
**WHEEL HEAT EXCHANGER**




Air flows through a media on a rotating wheel, transferring heat to the media as it flows through. As the wheel rotates, its sections pass from the exhaust side to the supply side, conveying the heat energy between the two air streams. Wheel heat exchangers are generally only used in larger H/ERVs of central systems.

*Figure adapted from:*
[klingenburg.es/knowledge/regeneration-recuperation/](klingenburg.es/knowledge/regeneration-recuperation/)

**OTHER**




There are other novel ways of accomplishing heat recovery. One example, illustrated above, uses a single fan and cycles the air back and forth across an element that absorbs/dissipates heat energy. When used in pairs, continuous balanced ventilation of a room can be accomplished.

*Figure adapted from:*
[vents-us.com/cat/704/](vents-us.com/cat/704/)

In discussing balanced ventilation with heat recovery within your projects, you will likely hear the terms **"heat recovery ventilator" (HRV)** and **"energy recovery ventilator" (ERV).** Both types of ventilators can provide balanced ventilation, and both reduce heating and/or cooling energy use by recovering energy between the outside air and exhaust air flow streams that would have otherwise been lost. Their difference is based on what portion of the total energy in the air streams is transferred. An HRV is capable of transferring only sensible heat, while an ERV transfers both sensible and latent heat.

**SENSIBLE HEAT TRANSFER:**
*Heat transfer that results in a change of air temperature only.*

**SENSIBLE + LATENT HEAT TRANSFER:**
*Heat transfer that results in a change of air temperature and water vapor content.*

There are trade-offs associated with the two ventilator types, and either can be used in multifamily applications; the table below summarizes differences. ***For the purposes of these guidelines, we will refer to the equipment with the general term 'H/ERV'.***

| **HRV [Heat Recovery Ventilator]** | **ERV [Recovery Ventilator]** |
|---|---|
| Transfers only sensible heat energy between outside air and exhaust air streams | Transfers both sensible **and** latent heat energy between outside air and exhaust air streams |
| **Winter:** Increases the temperature and generally **reduces** the relative humidity of supply air | **Winter:** Increases temperature and generally **increases** relative humidity of supply air |
| **Summer:** Due to the limited need to control relative humidity in Western Washington during the summer months, both have similar performance | |
| Typically needs a condensate drain and defrost controls | Typically does not need condensate drain or defrost controls |
| Typically lower equipment cost | Typically higher equipment cost |

## Heat Recovery Effectiveness

The heat recovery efficiency or **"effectiveness"** of an H/ERV is a measurement of what fraction of heat energy is transferred between the exhaust and supply air. This energy transfer is commonly referred to as 'recovery' because it would have otherwise been 'lost' to the environment. Most equipment is documented with separate heating and cooling effectiveness ratings, as they are determined at different indoor/outdoor air conditions. The higher the effectiveness rating, the more energy the H/ERV can recover. However, equipment with higher effectiveness ratings is generally more costly and larger in size. Sensible heat recovery performance is often considered the most important metric for homes in Western Washington, and is the metric referenced in the WSEC. When comparing the effectiveness of different H/ERVs, make sure the efficiency rating is at the same or very similar air flows and temperature conditions. Otherwise, it's like comparing apples to oranges.

Recovery effectiveness can be increased by:

- using a larger heat exchanger, *i.e.* 'over-sizing' the H/ERV.
- using a counter-flow plate heat exchanger, as opposed to a cross-flow plate heat exchanger that is more commonly used in H/ERV equipment.

## System Power

Another important attribute of an H/ERV is the **system power**, characterized as the total system power input (in Watts) divided by the design outdoor airflow rate (in CFM) supplied by the system. This value, with units of Watts/CFM, can be calculated using the following equation:

$$System\ Power = \frac{Total\ Power\ Input\ (Fans, Controller, etc.)\ (Watts)}{Design\ Outdoor\ Airflow\ Rate\ (CFM)}$$

The lower the system Watts/CFM, the more energy efficient the H/ERV is at moving ventilation air. Some engineers or manufacturers also communicate system power using the reciprocal of the equation above, or in terms of CFM/Watt. In this case, the higher the number, the more efficient the unit. In name, the difference between Watts/CFM and CFM/Watt is subtle, but the energy implications of confusing the two can be dramatic. The actual system fan power is not just a function of the H/ERV equipment itself; rather, it depends on a number of characteristics, with the air distribution system usually the most important. When comparing the system fan power of different H/ERVs, make sure they are compared with the same or very similar air flows, filters, and equipment external static pressure. If not, it is again like comparing apples to oranges.

System fan power can be reduced by:

- Increasing duct sizes
- Designing for shorter ducts with fewer elbows, tees, and other fittings
- Using filters with low pressure drop
- Over-sizing the H/ERV
- Specifying more efficient (ECM) motors

## Cross Leakage

**"Cross leakage"** is the exchange of air between the supply and exhaust air flow streams within an H/ERV. In other words, how much exhaust air can leak into the fresh air supplied to the building, or vice versa. Cross leakage is typically defined as a ratio of the total H/ERV flow at a specified condition. H/ERVs are designed to minimize cross leakage, and the ratio is usually a value tested as part of equipment certification.

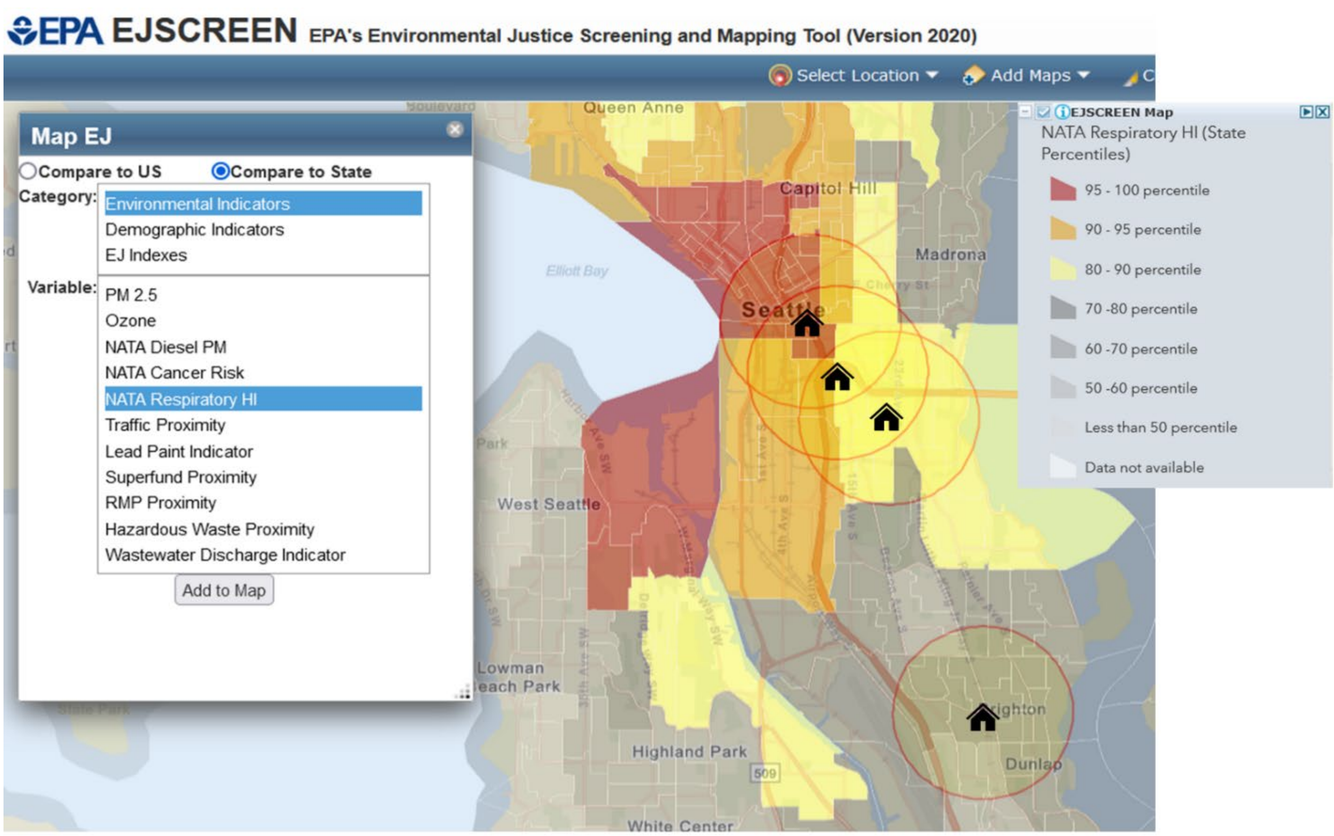
WSMC and most other mechanical/ventilation codes require cross leakage to be no greater than 10% of the rated air flow. In contrast, Passive House ventilator certification requires cross leakage to be no greater than 3%. In most cases, plate heat exchangers will have lowest cross-leakage ratings; however, H/ERVs with wheel heat exchangers that meet Passive House criteria are readily available. Cross leakage can be minimized by ensuring the air flows are balanced; *i.e.,* the supply and exhaust air flows are as close to each other as possible.

Specifying low cross leakage for central systems is important as this mitigates exhaust air from different dwelling units mixing with fresh air from the outside and getting reintroduced back into the building. If the H/ERV only serves one dwelling, cross-leakage performance is of lesser concern since all of the air is contained within the same home. However, if leakage is excessive, it will reduce the amount of fresh outside delivered by the system.

## Filters

One of the most important benefits of using balanced ventilation systems (with mechanical supply) is the ability to filter the air that is pulled in from the outdoors. Outdoor air can be polluted by local factors (such as being adjacent to a busy roadway or port) or by regional factors (such as a wildfire-smoke event). Long-term exposure to particulate matter, especially particulate matter smaller than 2.5µm ($PM_{2.5}$) in size, has been associated with adverse health effects.

One resource for evaluating local outdoor air pollution is the EPA's Environmental Justice Screening and Mapping Tool, or EJScreen, which allows a variety of environmental indicators to be plotted on a map. The EJScreen map below plots the locations of four Exemplary Buildings Program demonstration projects. The map is layered with a color-coding of the National-Scale Air Toxics Assessment (NATA) Respiratory Health Index (HI)[1], just one of many metrics that can be used to inform decisions on local/regional pollution levels.

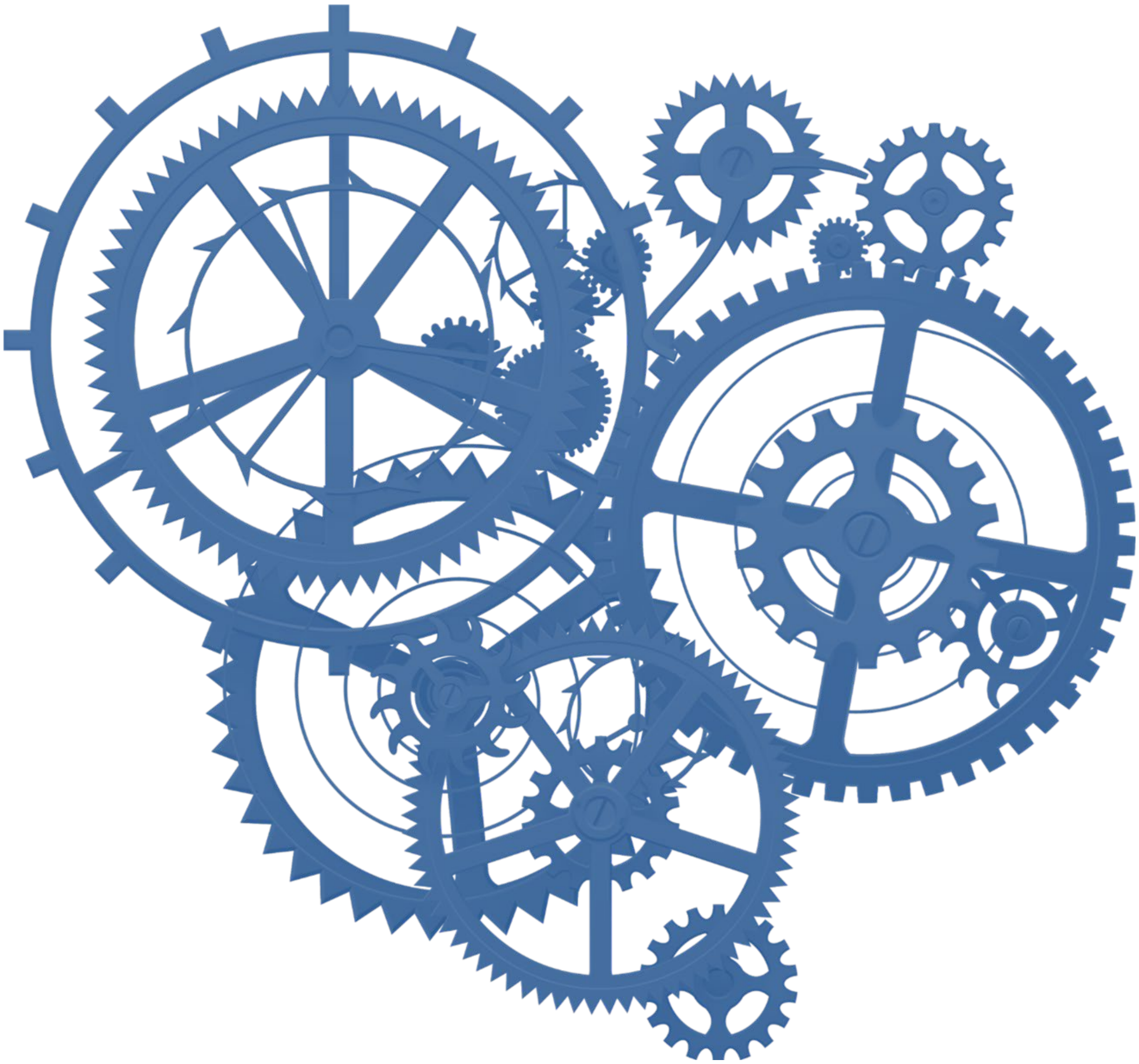



[1]*Source: https://www.epa.gov/national-air-toxics-assessment/2014-nata-assessment-results*

Filters are usually characterized with a Minimum Efficiency Reporting Value, or **MERV** rating. Values range from 1 to 16, with 16 being the most effective at removing particles from the air that passes through. The WSMC requires H/ERVs to have minimum MERV-8 filtration of the outdoor air. However, MERV-13 is a common standard for commercial buildings and is required by some codes (such as Seattle) for most any HVAC system with an airflow capacity greater than 500 CFM.

Filters help improve indoor air quality and keep the ductwork and H/ERV heat exchanger/fan blades cleaner. For this reason, filters must be installed on both the outdoor air and exhaust sides of the H/ERV, and maintenance plans should assume filters are inspected every three to six months and replaced if necessary. Additionally, when H/ERVs are exposed to temporary events causing poor outdoor air quality (such as wildfires or seasonal pollen), additional inspections/filter replacement are warranted. Because filters must be changed regularly, the replacement cost and accessibility of the equipment should be considered in the design phase, especially if the equipment is located inside each dwelling.

# SYSTEM LAYOUT



## Background

A fundamental, first step of integrating balanced ventilation with heat recovery into multifamily buildings is selecting the system distribution approach. There are many different approaches, and currently there is no clear winner. Therefore, these guidelines are intended to provide a common understanding of the principal system options, considerations to keep in mind when evaluating them, and real-world project examples. Four principal categories defined for this discussion are:

**Option A** Centralized, Whole Building (or building wing)

**Option B** Centralized, Vertical (stack-by-stack)

**Option C** Centralized, Horizontal (floor-by-floor)

**Option D** Unitized (for each individual unit)

These options will be schematically described in the context of a midrise, sprinklered, wood-framed building that has Group R-2 dwellings on four stories, with units situated around a double-loaded corridor. Where relevant, some considerations for buildings with 5+ wood-framed stories are mentioned. Besides being able to fulfill EBP recommendations, the overarching goals of each option are to:

- eliminate the need for costly fire and/or smoke dampers on ducts that pass through fire-rated building assemblies, such as corridor walls or floors.
- keep supply and exhaust ductwork connected to the H/ERV within the building thermal envelope. Ductwork located in unconditioned space or outside is less energy efficient, and if located outside on the roof, degrades more quickly, reduces roof area available for solar, and complicates roof replacement.

The systems described in this section are believed to fulfill these criteria as they have been implemented in real buildings. However, design teams should always rely on their own expertise and work with the Authority Having Jurisdiction (AHJ) to confirm building code requirements for their particular system design.

**Options A-C** are different variations of 'centralized' systems, *i.e.,* a system that serves more than one dwelling with H/ERV equipment typically located on a roof curb or in a mechanical room. Option D, on the other hand, is a "unitized" system that limits ductwork and equipment to within individual dwelling units. To satisfy building codes and other building design constraints (such as number of stories, building aspect ratio, and location for outdoor air inlets), design teams should not limit their evaluation to only one option for a project. For example, the best solution for a building may be a centralized system Option A (described below) for studio and one-bedroom apartments that are organized together, while unitized systems may be considered for dwellings with 2+ bedrooms or corner units only. The integrated design process should allow for considering all options and hybrid solutions, especially when it reduces life-cycle cost or improves health of residents.

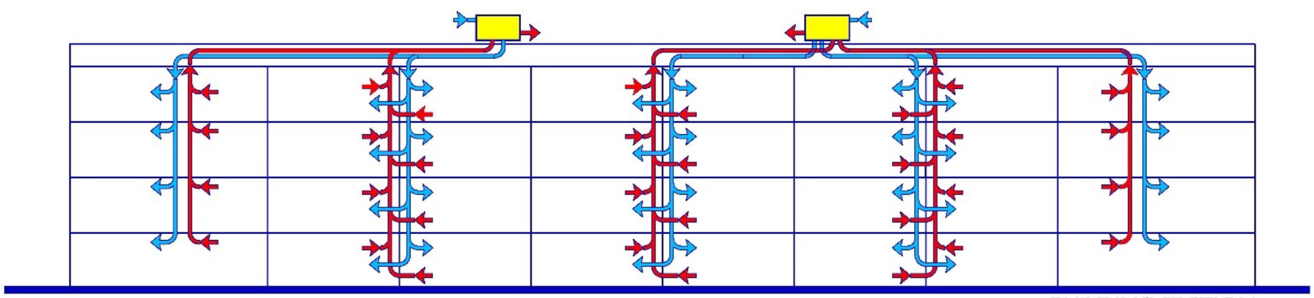
The table below summarizes pluses and minuses of centralized and unitized system approaches.

| CENTRALIZED VENTILATION SYSTEM(S) | UNITIZED VENTILATION SYSTEM(S) |
|---|---|
| PLUSES [+] | |
| No intake/exhaust penetrations at exterior of each unit | Potentially lower first cost |
| Does not require entering apartments to maintain H/ERV filters or replace ventilator | Cross leakage of air at H/ERV is isolated to one unit |
| Can provide both unit and corridor ventilation with same equipment | Energy to run system is on tenant meter |
| Can have bypass, and even heating/cooling coils | Most H/ERVs offer a switch in bathroom to “boost” (temporarily increase) ventilation rate |
| Typically can accommodate larger and/or higher efficiency filters | Fan energy can typically be designed to be lower |
| Can be integrated in to building control and/or monitoring systems | Equipment and air flow balancing is less complex |
| MINUSES [-] | |
| Typically requires roof or mechanical room space for equipment | Requires space for equipment within a dropped ceiling or in a closet within the dwelling |
| Can be cross leakage of supply/exhaust air among units at H/ERV | Generally require intake/exhaust penetrations at each unit |
| Energy to run system is on house meter | Must enter apartments to maintain H/ERV filters or replace H/ERVs |
| Airflow rate is variable only on a system basis unless individual variable volume dampers are provided for each apartment | Can be noisy if not properly designed/isolated |
| Challenge of balancing of air flows across many more registers or added cost for constant airflow regulators | High-efficiency equipment and filters are generally more expensive |

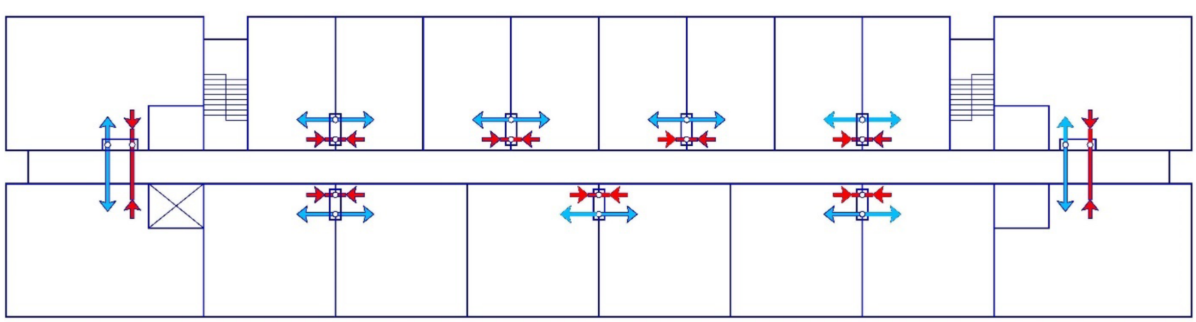
# Option A: Centralized Layout, Whole Building or Building Wing

**Option A** consists of locating H/ERVs on an insulated roof curb, and distributing air through larger trunk ducts located in the ceiling of the top floor, typically above the corridor. From the main trunk duct, a 4” round metal duct “home-run” duct branches off from the trunk that runs through the corridor partition wall into a drop ceiling of the top floor unit, with the ducts serving apartments on lower floors traveling vertically within non-rated chases.

For this option, the home-run ducts are continuous from the trunk duct to the dwelling and otherwise satisfy the requirements of Washington State Building Code (WaBC) Section 717.6.1 Exception for fire dampers. Therefore, if there are four stories of apartments, one set of supply and exhaust ducts serves the top floor unit, and then three individual pairs of supply and exhaust home-run ducts run vertically and continuously to each of the lower floor units. If more than four floors of apartments must be served, the home run ducts serving lower floors cannot use this WaBC exception and must be located in shafts or have fire-rated duct wrap. As noted in the introduction, it’s recommended that the trunk duct is located within the building envelope to mitigate the need to insulate the ducts and to minimize the impacts of duct leakage and thermal losses. In this case, however, the design team should be prepared to work with the AHJ to obtain approval to allow the trunk ducts to be considered “exterior to the building.” In the case of Hobson Place South (see case study on p. 16), the design team was successful in getting approval to use this exception on the condition that the duct was separated from the corridor by a 1-hour rated assembly and the H/ERVs were provided with standby power via a power tap ahead of the main distribution.



BUILDING SECTION



TYPICAL FLOOR PLAN

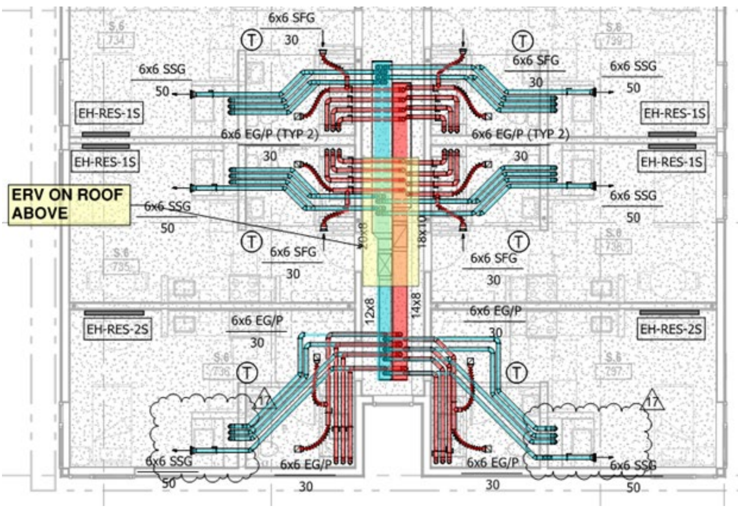
The table below summarizes pluses and minuses of the centralized, whole building/building wing option.

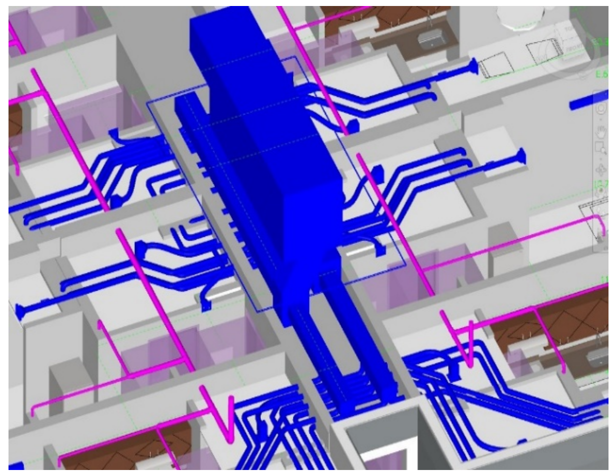
| OPTION A: CENTRALIZED, WHOLE BUILDING OR BUILDING WING | |
|---|---|
| **PLUSES [+]** | **MINUSES [-]** |
| Fewer H/ERVs to install and maintain than other centralized options | Generally requires extra building height on top floor (12-18”) if trunk duct is located within the building envelope |
| More area available on roof for solar and other equipment than centralized Option B | Requires close coordination of extensive ductwork on top floor to avoid conflicts with other systems |
| Does not require mechanical rooms on building floors | Serving 5+ floors of units adds more costly requirements, like shafts or fire-wrapping ducts |
| May require less soffiting of ductwork within the units if vertical ducts are located in walls or chases close to the room where the duct terminates | More challenging to achieve low fan power if home-run ducts are limited to 4” |

# Case Study: Hobson Place South

## BUILDING CHARACTERISTICS

Four stories residential; 92 studio apartments
Three rooftop ERVs, one for each building wing
Owner: DESC
Architect: Runberg Architecture
Mechanical Engineer: Rushing
General Contractor: Walsh Construction Co.



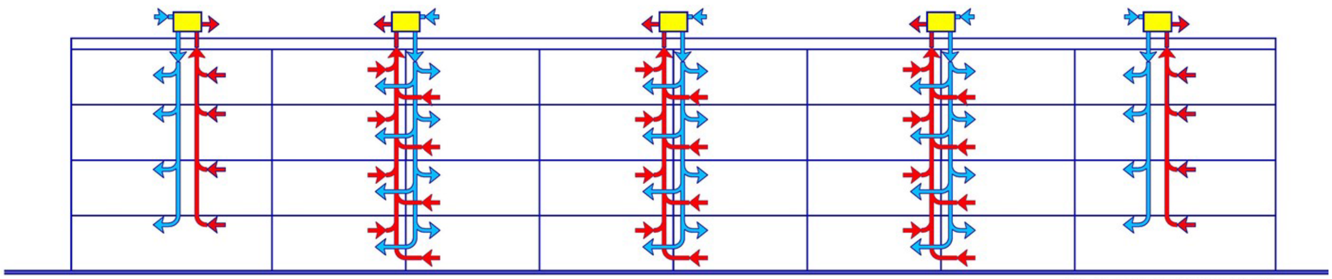
**The two images above** show the duct routing on the top floor of the building in both plan view and in 3-D. As mentioned above, the trunk ducts are located in a space above a 1-hour rated corridor ceiling assembly. 4” round metal ducts take off from the bottom of the supply and exhaust trunks and pass into a drop ceiling above the bathroom and closet of the top floor units. In this case, there is only one supply grille for the living area and two exhaust grilles: one in the bathroom and one in the kitchen. The kitchen exhaust satisfies the local kitchen exhaust requirement, making it possible to use a recirculating range hood. This eliminates the horizontal ducting and penetrations to exterior that is common for range exhaust, which makes it simpler to achieve Passive House level air tightness. It also qualifies it as a distributed system.

**The image to the right** shows the installed duct routing on the top floor of the building. Note the extensive sealing of joints using mastic to reduce duct leakage, and in turn, building air leakage to outdoors, which must be minimized as much as possible to achieve Passive House air leakage target. Fire caulking penetrations of the corridor wall is required by building code to prevent fire movement, but also compartmentalizes air and sound within apartments. Metal channel for the 1-hour rated corridor ceiling panels is shown.

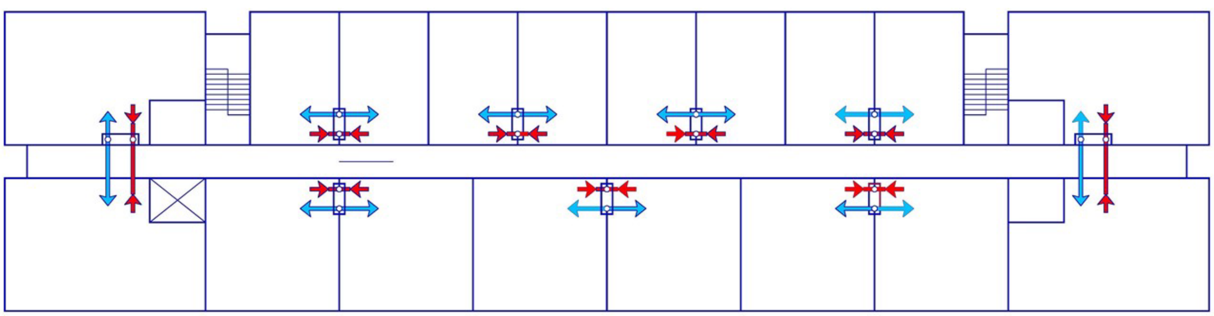
*Images on this page are from or adapted from: DESC, Runberg Architecture, Rushing, and Walsh Construction Co.*

## Option B: Centralized, Vertical (Stack-by-Stack)

**Option B** is similar to **Option A** in that home-run ducts are again used to serve dwelling units on floors below. However, the main trunk duct is eliminated by installing an H/ERV over each stack of units on an insulated curb. The number of H/ERVs is reduced by orienting dwelling units “back-to-back” in stacks, meaning the bathroom and living space for two adjacent units are mirrored about an interior partition wall. Therefore, two units on each floor of the stack can be served by one H/ERV. This design can leverage the same WaBC Section 717.6.1 Exception for fire dampers, though in this case, the ducts run through the roof deck to the H/ERV without passing through other conditioned space, and therefore can readily be considered “continuous to the exterior of the building.” Again, if the building has more than four stories of dwellings, shafts or fire-rated duct wrap for ducts penetrating more than three floor assemblies would be required.



BUILDING SECTION



TYPICAL FLOOR PLAN

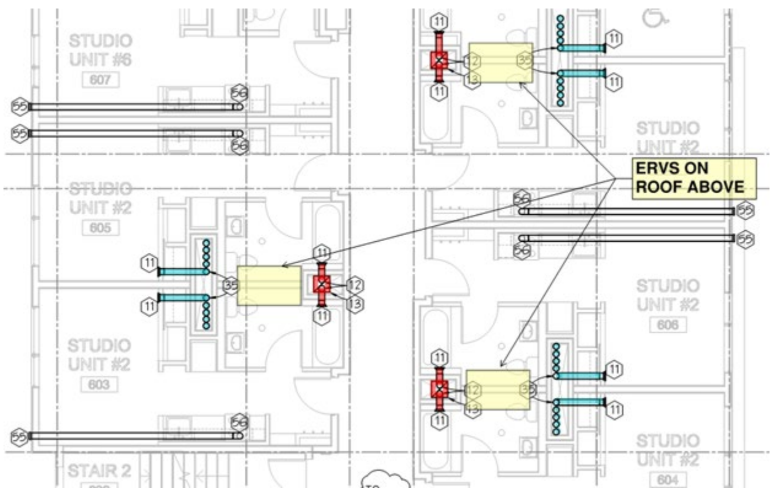
The table below summarizes pluses and minuses of the centralized, vertical (stack-by-stack) option.

| OPTION B: CENTRALIZED, VERTICAL (STACK-BY-STACK) | |
|---|---|
| **PLUSES [+]** | **MINUSES [-]** |
| Does not require mechanical rooms on building floors, and generally does not impact building height | Typically requires more H/ERVs than centralized Options A and C, especially if one H/ERV can't serve two stacks of units. Reduces area on roof available for solar and other uses |
| Does not require mechanical rooms on building floors | Serving 5+ floors of units adds more costly requirements, such as shafts or fire-wrapping ducts |
| May require less soffiting of ductwork within the units if vertical ducts are located in walls or chases close to where the duct terminates | Outdoor air intake/exhaust separation among H/ERVs may be more difficult to achieve since there are more units on roof |
| Fewer dwellings affected by equipment service or replacement | More challenging to achieve low fan power and design flow rates if home run ducts are limited to 4" |

# Case Study: Estelle

## BUILDING CHARACTERISTICS

Five stories residential; 92 studio apartments
Nine rooftop ERVs, roughly one ERV for each stack of two apartments
Owner: DESC
Architect: SMR Architects
Mechanical Engineer/Contractor: United Systems Mechanical
General Contractor: Walsh Construction Company




**As seen in the floor plan view at left**, the ERVs are located above the dwelling unit stacks. Homerun supply ducts run vertically in shafts. At each level, one home run duct turns and runs horizontally, terminating at an interior wall of each dwelling unit. Another shaft located adjacent to the bathroom includes a common exhaust duct with a sub-duct for each bathroom exhaust grille. In this case, a non-recirculating range exhaust hood with a dedicated horizontal duct to the exterior was used, so exhaust is only drawn from the bathroom.

**The photo at the right** shows the equipment for this option on the roof, with duct plenums located at curbs at either side of the ERV. In some cases, such as corners and ends of the building, additional ductwork above the roof was needed to connect the supply and exhaust to the ERVs. For this 92-unit building, a total of nine ERVs were required. As an alternative, the ductwork can be located fully inside the conditioned space if the H/ERV is mounted on a taller insulated curb and uses a downward discharge configuration.

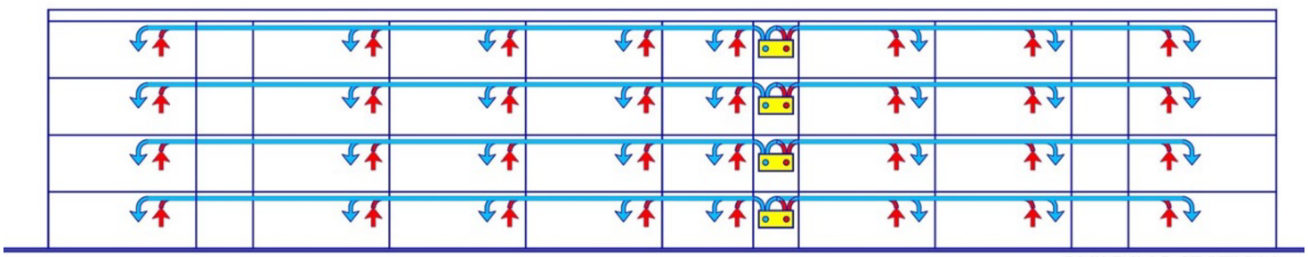

*Images on this page are from or adapted from: DESC, SMR Architects, and United Systems Mechanical.*

# Option C: Centralized, Horizontal (Floor-by-Floor)

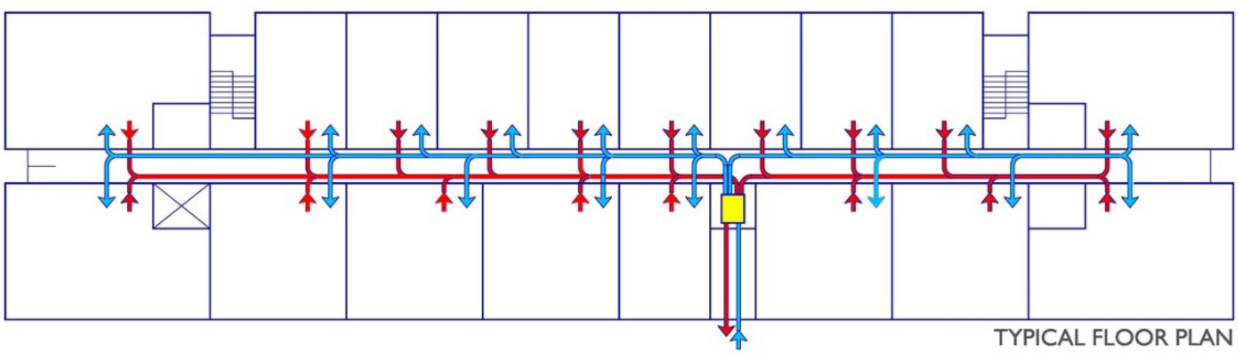
**Option C** changes the primary distribution approach from vertical to horizontal. Trunk ducts are generally run in space above the corridor ceiling, though they can also be run above drop ceilings of dwelling units. Fire dampers are not required where passing through fire partitions like corridor or interior partition walls if the penetration meets one of the exceptions of WaBC Section 717.5.4. In the conceptual diagram below, outdoor air and exhaust are both run to the outside wall of the H/ERV mechanical room. However, common variations on the floor-by-floor distribution approach include:

- H/ERV on each floor, but outdoor intake and exhaust ducts run up to roof. This eliminates the horizontal ducts to outside wall of building on each floor.
- H/ERV on roof, with vertical ducts down and branches off to horizontal trunk ducts on each floor. This eliminates the need for mechanical room space on each floor for the ERV.

In both cases, fire smoke dampers are generally required between the vertical and horizontal duct transitions as they pass through fire-rated shaft walls.



BUILDING SECTION



TYPICAL FLOOR PLAN

The table below summarizes pluses and minuses of the centralized, horizontal (floor-by-floor) option.

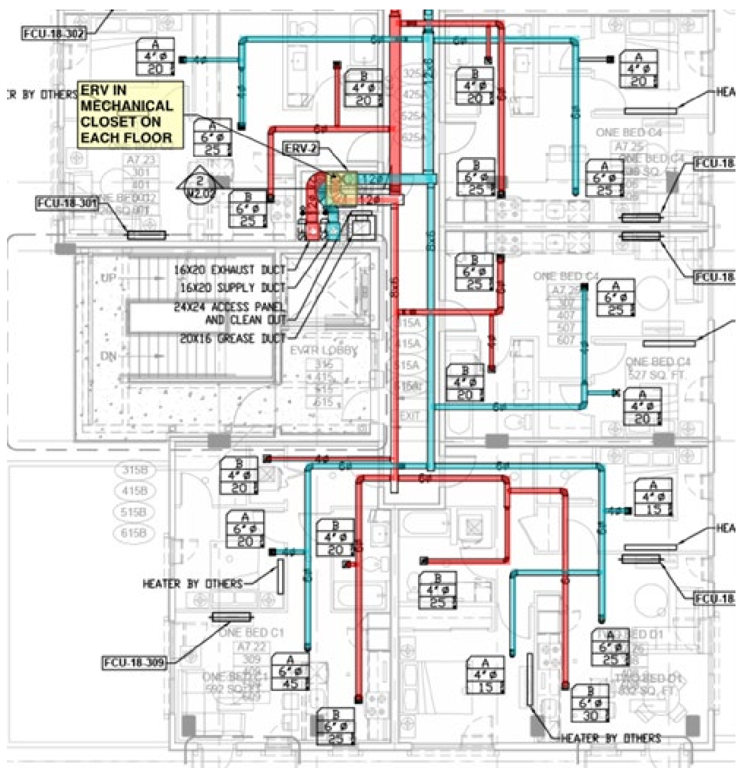
| OPTION C: CENTRALIZED, HORIZONTAL (FLOOR-BY-FLOOR) | |
|---|---|
| **PLUSES [+]** | **MINUSES [-]** |
| No area required on the roof except potentially for outdoor air intake/exhaust | A room or closet required on each floor for H/ERV; may require additional height on every floor for trunk ducts |
| No vertical shafts if H/ERVs are located on each floor | Outdoor air intake/exhaust separation more challenging if vented through side of building |
| Equipment is located within the building, eliminates roof curbs and allows for use of equipment designed only for indoor installation | May require more height at each floor to accommodate horizontal trunk ducts in corridors and within units |
| Potentially lowest equipment replacement cost since indoor H/ERVs are often small enough to fit in elevator | Coordination and potential for conflicts with other systems on every floor |

# Case Study: Solis

## BUILDING CHARACTERISTICS

Five stories residential; 45 apartments (1- or 2-bedroom)
One ERV on each floor
Owner: SolTerra
Architect: Weber Thompson
Mechanical Engineer/Contractor: Emerald Aire
General Contractor: Cascade Built

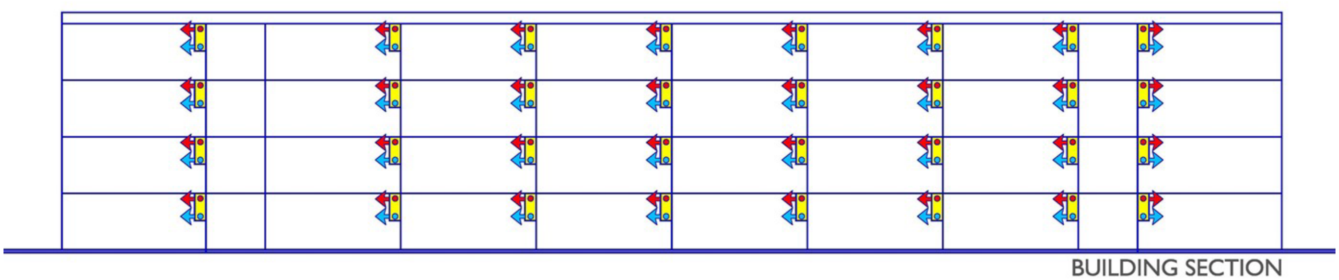
As seen in the floor plan view (**image below right**), the ERVs are located in a closet on each floor (**image below left**), connected to trunk ducts running above ceiling of corridor. Branch ducts take-off from trunk and run to the rooms of each apartment in drop ceiling or soffits. In this case, each ERV is connected to a common outdoor air and exhaust duct that runs to the roof, eliminating duct penetrations on each floor. Similar to Option A, a recirculating range hood with local kitchen exhaust by the ERV was provided to eliminate exterior wall penetrations.

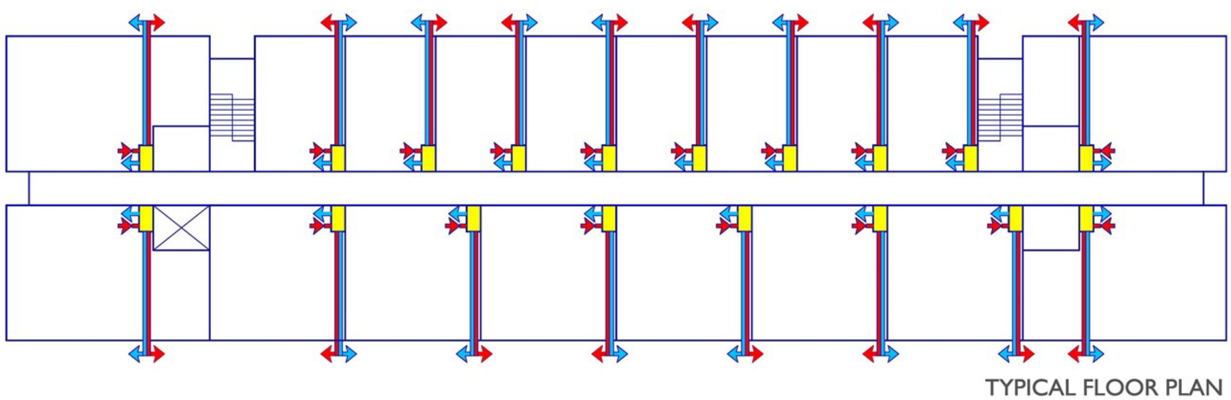



*Images on this page are from or adapted from: Emerald Aire, SolTerra, and Weber Thompson.*

# Option D: Unitized (Individual Unit)

**Option D** fundamentally differs from the centralized options by providing one small H/ERV in every dwelling unit. As shown in the concept diagram below, each unit has its own outdoor and exhaust duct terminations at the exterior, and the H/ERV is typically located horizontally in a drop ceiling of a hallway or mounted vertically to a wall in a closet. The location of the H/ERV should account for regular maintenance, typically every six months, and access panels should be lockable to impede tampering. The supply air inlet and exhaust air outlet at the exterior façade must be located at least 10’ from each other unless local code allows for using a factory-built intake/exhaust combination termination fitting, per WSMC 401.4. The unitized approach eliminates penetrations through fire-rated assemblies, and therefore does not require exceptions for fire/smoke damper requirements. Duct routing is simplest if accommodated in drop ceilings or soffits, as ducts that penetrate the fire-rated ceiling assembly require additional fire-proofing measures.



The table below summarizes pluses and minuses of the unitized option.

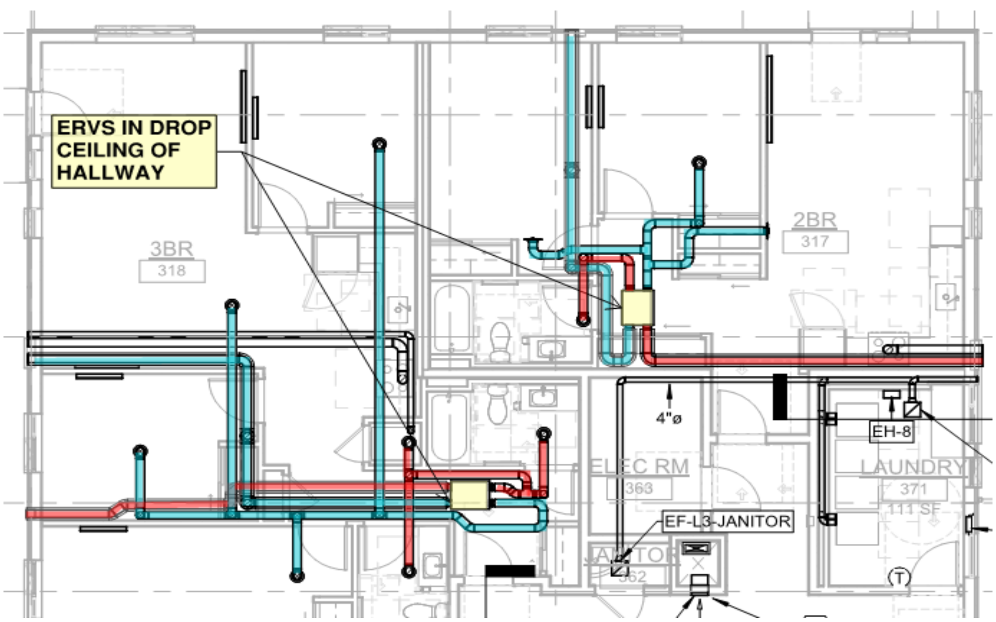
| OPTION D: UNITIZED (INDIVIDUAL UNIT) | |
|---|---|
| **PLUSES [+]** | **MINUSES [-]** |
| All ducts and equipment are within the unit, mitigating conflicts/coordination with other systems | Requires many more H/ERVs than centralized options, i.e. more pieces of equipment/filters to maintain and eventually replace |
| No roof area, building height increase, or mechanical rooms required | Many exterior wall penetrations; intake/exhaust separation may be difficult to achieve and needs to be coordinated with operable window openings and other mechanical penetrations |
| Uses simpler, smaller H/ERVs that can be replaced individually by a wide range of contractors | Supply and exhaust ducts from exterior to H/ERV must be insulated and wrapped with a vapor barrier |
| Many product brands and configurations available | Noise from ventilator is transmitted inside the dwelling unit |

# Case Study: Sawara

### BUILDING CHARACTERISTICS

Six stories residential; 114 apartments (1- to 4-bedroom)
One ERV for every unit
Owner: Seattle Housing Authority
Architect: Ankrom Moisan
Mechanical Engineer: Ecotope
General Contractor: Marpac Construction

As seen in the floor plan view **below**, ERVs are located above an access panel in the ceiling of the bathroom, along with the water supply meters and manifolds (not shown). The outdoor air intakes for apartments are located adjacent to each other, as are the exhaust terminations to maintain adequate separation. The exhaust of the ERV is routed to the exterior in the same soffit as the ducted range exhaust. To distribute air centrally to rooms, short sections of some supply ducts are run up in between ceiling joists wrapped in fiber insulation. A wall switch in the primary bathroom wired to the ERV is used to signal 'boost' mode, whereby the ERV fan speed is increased to provide a higher ventilation rate for a short (15 min) time period.




*Images on this page are from or adapted from: Ankrom Moisan Architects, Ecotope, and Seattle Housing Authority.*

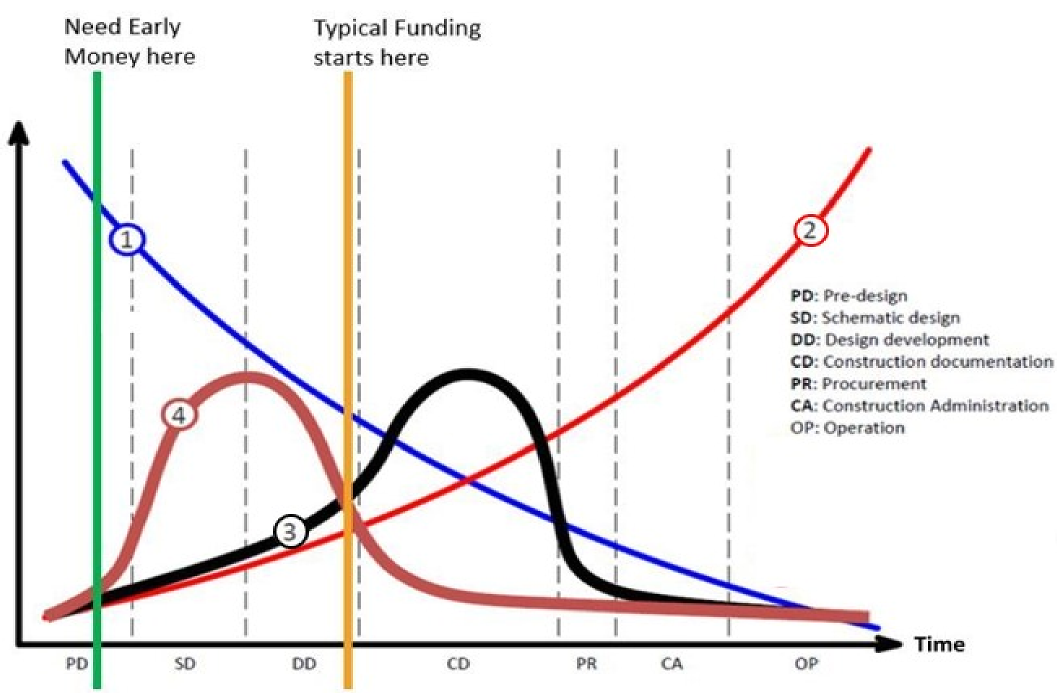
# EBP's RECOMMENDATIONS FOR
# BALANCED VENTILATION WITH HEAT RECOVERY

# Early Integrative Design

## *EBP Recommendation*

**Analyze distribution approaches early in schematic design using an integrative design process beginning with the developer and architect and then expanding to the engineer, consultants (acoustics, energy, sustainability), general contractor (GC), and mechanical subcontractor.**

As illustrated in the figure below, early integrative design fosters the ability to make decisions that balance up-front capital costs with occupant health, comfort, resilience, and long-term operating and maintenance costs most relevant to your building/organization. EBP has created an application-oriented set of guidelines for teams interested in applying early integrative design to their exemplary project. The free guide is available at: [https://exemplarybuilding.housingconsortium.org/our-results-practical-tools/](https://exemplarybuilding.housingconsortium.org/our-results-practical-tools/)




*Graphic originated by Patrick MacLeamy, AIA/HOK*

**In this figure:**

- **Line** (1) shows the declining ability to impact cost and capabilities of a project over time.
- **Line** (2) shows the increasing cost of design changes late in a project timeline.
- **Line** (3) shows the level of effort put forth over time in a traditional design process.
- **Line** (4) shows the level of effort put forth over time in the preferred design process.

Evaluating system options and making decisions early in design allow for the necessary elements of balanced ventilation with heat recovery to be accounted for at the entitlement phase, and if necessary, allows teams to pursue cost-saving variances or code alternates before developing detailed design documents.

Examples include:

- Variances for additional building height for distribution systems, or roof area coverage/height for mechanical equipment.
- Design and location of fenestration openings on building facades, with respect to intake and exhaust points.
- Research and confirm code requirements for centralized distribution systems, such as exceptions for fire/smoke dampers.
- Determine where distribution ducts will be located.

# In-Unit Ventilation Strategy

## Distributed System

### EBP Recommendation

**Design a ‘distributed’ system, per WSMC. If using a recirculating range hood for studio and one-bedroom units (see “Residential Range Exhaust” below), a distributed system <u>must</u> be used. Ventilation rates should be as close to code-minimum as possible.**

### Benefits

- Provides more balanced and effective distribution of ventilation air throughout the dwelling unit.
- Including an exhaust grille in kitchen helps improve odor/moisture removal from this area.
- Distributed design results in lowest code-required ventilation rate, which can translate to reduced duct and equipment sizes.

### Considerations

- Requires one more duct and exhaust grille for the kitchen.
- Kitchen exhaust grille should include a grease filter that must be maintained.

## In-Unit Laundry

### EBP Recommendation

If provided, **the laundry equipment** should be located within bathroom or kitchen area and utilize a ventless heat pump dryer.

### Benefits

- Dryers are one of the largest residential appliance energy users; heat pump dryers can cut energy use in half compared to conventional electric dryers.
- Ventless dryers require no make-up air.
- Ventless dryers eliminate a separate exhaust duct to exterior and the resulting dryer duct cleaning that would be required over the life of the building.

### Considerations

- Heat pump dryers have longer drying times.
- Ventless dryers generate some heat/moisture.
- Drying performance is sensitive to filter maintenance.
- Requires discharging condenser water into a drain, though the washer drain is acceptable.

# Residential Range Exhaust

## *EBP Recommendation*

**Range hoods are ducted to exterior and tenants instructed to crack a window when running hood fan. Recirculation range hoods only considered for studio/one-bedroom units with distributed ventilation where less cooking is anticipated and where the system meets local code or rating system requirements (i.e., ESDS).**

## *Benefits*

- Can exhaust air at higher rates from kitchen to ensure effective removal of $PM_{2.5}$ particulates, oils, moisture, and odors during cooking.
- Cracking windows ensures range hood is not "starved of air" if the building envelope is very tight.

## *Considerations*

- Recirculating range hoods don't remove moisture and are limited in their ability to neutralize odors.
- Recirculating range hoods have additional on-going costs to replace charcoal filter.
- Recirculating range hoods have more limited capacity to remove $PM_{2.5}$ than a properly implemented exhaust range hood.
- Local kitchen exhaust cannot be combined with the bathroom exhaust unless a code alternate is pursued. 2018 Seattle Mechanical Code Section 505.5 includes an exception to allow this, provided the kitchen exhaust grille is at least six feet from the cooktop and provided with a MERV-3 washable filter.

# Filtration

## *EBP Recommendation*

**Utilize MERV-13 filters on central systems and on unitized system when the project is in area with consistently poor outdoor air quality. Otherwise, utilize minimum MERV-8 filters. Central systems should be equipped with sensors that trigger an alert when filters should be changed. Capacity to run MERV-15 or higher during wildfires and other periods of poor air quality should be considered.**

## *Benefits*

- Results in cleaner air for people with respiratory health conditions (e.g., asthma, COPD).
- Higher levels of filtration are critical if the project is located in an area of localized pollutants. EPA's EJScreen mapping tool is one tool used to evaluate these criteria; suggested metrics are the National Air Toxics Assessment (NATA) Respiratory Hazard Index (HI) and Traffic Proximity rating of 90% or higher.

## *Considerations*

- Higher cost for equipment and filters. This is generally a greater consideration for unitized systems.
- Availability on unitized systems may be limited or may require external filter box.
- High efficiency filters need more frequent cleaning/replacement to maintain performance; easy access is important in both unitized and centralized systems.

# Equipment Specs

## Ventilator Type and Sizing

### *EBP Recommendation*

**Heat recovery ventilators (HRV) are generally recommended over energy recovery ventilators (ERV), and the ventilator has maximum flow capacity that is greater than 25% greater than design flow rate; *i.e.* over-sizing the equipment achieves greater heat recovery efficiency and lower fan power.**

### *Benefits*

- HRVs are typically less expensive.
- Densely occupied multifamily buildings can have higher indoor humidity conditions; HRVs help moderate this.
- Ventilators which are "over-sized", *i.e.* running at 50-75% of their maximum flow capacity, have the following benefits:
    - Allow for additional ventilation flow rates when required, such as for cooling or reduction in system performance over time
    - Typically have a higher sensible effectiveness and deliver the air flow at lower Watts/CFM
    - Typically last longer because motors/drives don't have to work as hard
    - Typically result in lower noise levels

### *Considerations*

- Higher equipment cost.
- HRVs typically require condensate drains; ERVs sometimes do not.
- Larger centralized equipment with wheel heat exchangers are typically ERVs.

## Sensible Effectiveness

### *EBP Recommendation*

**Sensible effectiveness ≥ 75% at design flow rate.**

### *Benefits*

- More heat is recovered by the H/ERV, reducing heating capacity required and energy costs.
- Better tempering of ventilation air (air supplied in winter is warmer), which is more comfortable for occupants.

### *Considerations*

- Higher equipment cost.
- Availability on unitized systems may be limited.
- Higher efficiency equipment typically has larger footprint.

# System Power

### EBP Recommendation

**System fan power ≤ 0.8 Watts/CFM at design ventilation flow rate with clean filters.**

### Benefits

- Energy benefits of heat recovery are diminished if fan power is too high.
- Generally associated with quieter systems.

### Considerations

- Achieving this usually requires larger ducts and/or larger ventilation equipment.

# Cross Leakage

### EBP Recommendation

**Cross leakage ≤3% at rated airflow for central systems.**

### Benefits

- Minimizes potential for airborne pollutants and pathogens to be transferred from exhaust to supply air.
- Consistent with Passive House standard.

### Considerations

- Some equipment that uses a wheel heat exchanger may not be able to meet this specification.

# Continuous Operation

### EBP Recommendation

**Operate system continuously and use equipment that automatically adjusts fan speed to maintain balanced flow at the desired flow.**

### Benefits

- Fan speed automatically adjusted to achieve desired flow, even as filters get dirty.
- Simplifies balancing and commissioning.
- Easier to identify if unit is functioning or not.
- Typically associated with more efficient ECM fan motors.

### Considerations

- Limited availability of systems with the automatic adjustment feature

# Heat Recovery Bypass

## *EBP Recommendation*

**Central systems have heat recovery bypass option and automatic economizer mode.**

## *Benefits*

- Automatic bypass can help cool down interior spaces when outdoor conditions are appropriate by circumventing the energy exchange and delivering cooler outdoor air.

## *Considerations*

- Bypasses can increase the size and cost of equipment and may limit equipment options.

*Rafn Company*

# Distribution Design

## *EBP Recommendations*

- Design and install all ducting systems to achieve design airflow rates at an average velocity below 600 feet per minute (fpm).
- Locate diffusers to promote full mixing of supply air into habitable rooms and full removal of contaminates via exhaust flow. Consider where tenants will typically be sitting or sleeping when locating supply air grilles, and increase distance between supply and exhaust points as much as possible.
- Locate all ductwork within conditioned space to increase system efficiency and eliminate need for installing supply duct insulation and/or maintaining ductwork exposed to outside elements.
- Locate ductwork within soffits/drop ceilings below fire-rated floor/ceiling membrane.
- If H/ERV is located inside the conditioned space, minimize the lengths of the ducting between the unit and the exterior wall or roof.
    - A maximum length of 10’ is recommended.
    - Install insulation (min. R-8) and vapor barrier on this ducting from exterior wall/roof to H/ERV with no gaps or voids.
- Kitchen exhaust grilles should be located a minimum of 6’ horizontally from the primary cooking appliance and include a MERV-3 or washable mesh filter.
- Coordinate supply and exhaust grille placement with architects and owners.

## *Benefits*

- Distribution design is more important than equipment selections.
- Using more expensive, high-efficiency equipment will be undermined if distribution system is not efficient or tenants disable it because of comfort or noise concerns.

## *Considerations*

- Adopting these recommendations requires an integrated effort among the design/construction team to implement and may impact dwelling unit layouts, so best to be considered as early in design as possible.
- Engaging the construction team for pre-construction services to evaluate distribution options comes with additional up-front time and cost.

# Optimized Equipment Placement

### *EBP Recommendations*

- Choose designs that minimize the number of fire and/or smoke dampers and fire-rated shafts.
- Locate equipment below fire-rated floor/ceiling membrane.
- Consider structural requirements, zoning requirements, impact on solar and tenant amenity real estate, and equipment replacement when locating equipment on roof.
- Locate main intake to H/ERV to minimize contamination from outdoor pollutants (smells, particulates) and consider temperature of air at intake location during summer and winter.
- Engage an acoustical consultant to evaluate requirements for equipment mounting and sound attenuation devices.
- Ensure equipment is accessible for maintenance and future replacement. The expected useful life of ventilation equipment is 10-20 years if properly maintained.

### *Benefits*

- More efficient system design.
- Better access for maintenance.
- Better acoustic control.
- Lower construction cost and improved coordination.

### *Considerations*

- The space requirements for H/ERV are inevitably more than exhaust systems, so best to evaluate options early in design.
- Engaging the construction team for pre-construction services to evaluate equipment options comes with additional up-front time and cost.

# Common-Area Ventilation Strategies

## Common-Area Ventilation with Heat Recovery

### EBP Recommendation

**Serve corridors and other habitable common areas with systems that comply with optional WSEC C403.3.5 DOAS and provide no more than 130% of the code-required ventilation.**

### Benefits

- Minimizes or potentially eliminates need for corridor heat.
- Qualifies for WSEC/SEC C406 credits.
- If using centralized H/ERV options for dwelling units, can use the same H/ERVs to provide corridor ventilation, and therefore eliminate separate additional air handlers.

### Considerations

- May add additional shafts/mechanical penetrations (as compared to 100% outside air systems).

## Common-Area Laundry Rooms

### EBP Recommendation

**Use un-tempered outdoor air supplied to laundry room or back of dryers for make-up air.**

### Benefits

- Eliminates need for transfer ducts and oversizing corridor ventilation systems to provide sufficient dryer make-up air.
- Reduces energy used to temper make-up air.

### Considerations

- Laundry room may not be as warm and will result in longer drying times on cold winter days.

# Related Building Attributes

## *EBP Recommendation*

**Confirm architects/engineers/contractors have accounted for the following in their scope:**

- HVAC systems sizing calculations, as well as electrical service space heating loads account for reduced heating demand due to lower ventilation air loads and tighter envelope.
- Trickle vents in windows are no longer required and should be excluded from early cost estimates.
- Centralized systems may require standby power to satisfy fire/smoke damper exceptions or approved code alternates.
- Centralized systems and layout of in-unit ducts often require additional coordination among design team and contractors.

## *Benefits*

- Accounting for H/ERV system efficiencies can reduce the costs of other systems.

## *Considerations*

- Providing balanced ventilation with heat recovery for every apartment is a major change, and has many implications that should be accounted for when seeking proposals for design services and early cost estimating efforts.

# Construction & Commissioning

## EBP Recommendations

- Review plans to confirm equipment access for maintenance.
- Properly protect distribution system and ventilation equipment from dust during construction and install new filters prior to balancing/commissioning.
- Prior to covering of ducts, test distribution systems for leakage and remediate in order to provide a system where leakage is below 5% of design flow rate (at design pressures).
- 100% balancing and commissioning of all ventilation systems, including:
  - Measurement of supply/exhaust flow rates (CFM) at all diffusers.
  - Verification that clean filters with correct MERV rating are installed.
  - Measure system power (Watts) and calculate Watts/CFM for all centralized systems.
  - For unitized, measure a minimum sample of 10% representative unit types. If any system power measurement does not meet the Watts/CFM power specification for the project, test all units to confirm how many systems do not meet the specification and investigate why.

## Benefits

- Keeping the inside of ductwork clean during construction reduces debris capture in dampers or equipment and improves indoor air quality because filters are upstream from most ductwork.
- Testing and commissioning verification activities help ensure the system will achieve expected efficiency and useful life.

## Considerations

- Unitized systems are simpler, but result in many more pieces of equipment to track through the commissioning process.
- Fan power is traditionally not reported on balancing reports and requires test equipment that some contractors may not possess. Air flow meters and power meters are available on loan from the Smart Building Center Tool Lending Library.
- Balanced ventilation increases scope for balancing contractor because supply register flows must now be tested.

# Operations

## *EBP Recommendations*

- Supply and exhaust filters are readily accessible, are inspected every three to six months, and are replaced at minimum every year.
- Inspect filtration after seasonal smoke events.
- Consider washable/vacuumable pre-filters as a way to extend life of primary filter.

## *Benefits*

- Regular maintenance extends life of equipment.

## *Considerations*

- Cost of filters and time to replace them can be significant.

*Rafn Company*

# REFERENCES & ADDITIONAL RESOURCES

## Ventilation System Guidance

- BC Housing, Heat Recovery Ventilation Guide for Multi-Unit Residential Buildings: An overview of current good practice in the design and installation of residential heat recovery ventilation systems, https://www.bchousing.org/research-centre/library/residential-design-construction/heat-recovery-ventilation-guide-murbs
- Building Science Corporation, Measure Guideline: Ventilation for Residential High-Performance New Construction – Multifamily: Ventilation guidance for residential high-performance multifamily construction that incorporates the requirements of the ASHRAE 62.2 ventilation and indoor air quality standard, https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/67581.pdf

## Indoor and Outdoor Air Quality Assessment

- NEEA, Ventilation Effectiveness Study Final Report:
  Findings and conclusions of a ventilation effectiveness study in houses with low air leakage, https://conduitnw.org/Handlers/conduit/FileHandler.ashx?rid=2585
- United States Environmental Protection Agency (EPA), National Air Toxics Assessment (NATA) Results: Emissions data, ambient concentrations and health-effect results from the 2014 assessment, incorporated into the EPA Justice Screening and Mapping Tool (EJ Screen), https://www.epa.gov/national-air-toxics-assessment/2014-nata-assessment-results
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# STAY CONNECTED

If you're considering developing an exemplary building and would like a sounding board or technical assistance, please reach out to us. If you've applied our guidelines, we hope you'll share your feedback. Continuous learning is both a guiding principle and a core method of HDC's Exemplary Buildings Program; your experiences will help us continually improve our model and refine the practices we champion.

**Contact the Exemplary Buildings Program Task Force at:**
206.682.9541 (HDC office) or https://exemplarybuilding.housingconsortium.org/contact-us/

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