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VERY HIGH EFFICIENCY DEDICATED OUTSIDE AIR SYSTEMS

An overview of the system, benefits and economic analysis for industry stakeholders, building owners and designers.

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INTRODUCTION

The following is an introduction to very high efficiency dedicated outside air systems (very high efficiency DOAS) for industry stakeholders, building owners and designers in the Northwest. It is intended to expand awareness and understanding of the very high efficiency DOAS approach developed by the Northwest Energy Efficiency Alliance (NEEA). The enclosed information and findings are the result of pilot installations, research, a cost-effectiveness analysis, and market knowledge of very high efficiency DOAS, and includes:

WHAT IS VERY HIGH EFFICIENCY DOAS?

ASHRAE defines DOAS as: *"An air system that uses separate equipment to condition all of the outdoor air brought into a building for ventilation and delivers it to each occupied space, either directly or in conjunction with local or central HVAC units serving those same spaces. The local or central HVAC units are used to maintain space temperature."*

Very high efficiency DOAS improves the efficiency of the DOAS approach by 1) fully decoupling heating and cooling from a building's ventilation system to provide optimal control of each critical function, 2) pairing a high-performance heating/cooling system with a very high efficiency heat recovery ventilator (HRV) or energy recovery ventilator (ERV) with >=82% sensible effectiveness, and 3) optimizing the system design by optimally sizing equipment and minimizing fan power by using design principles to minimize pressure drop and operate ventilation fans at ideal conditions.

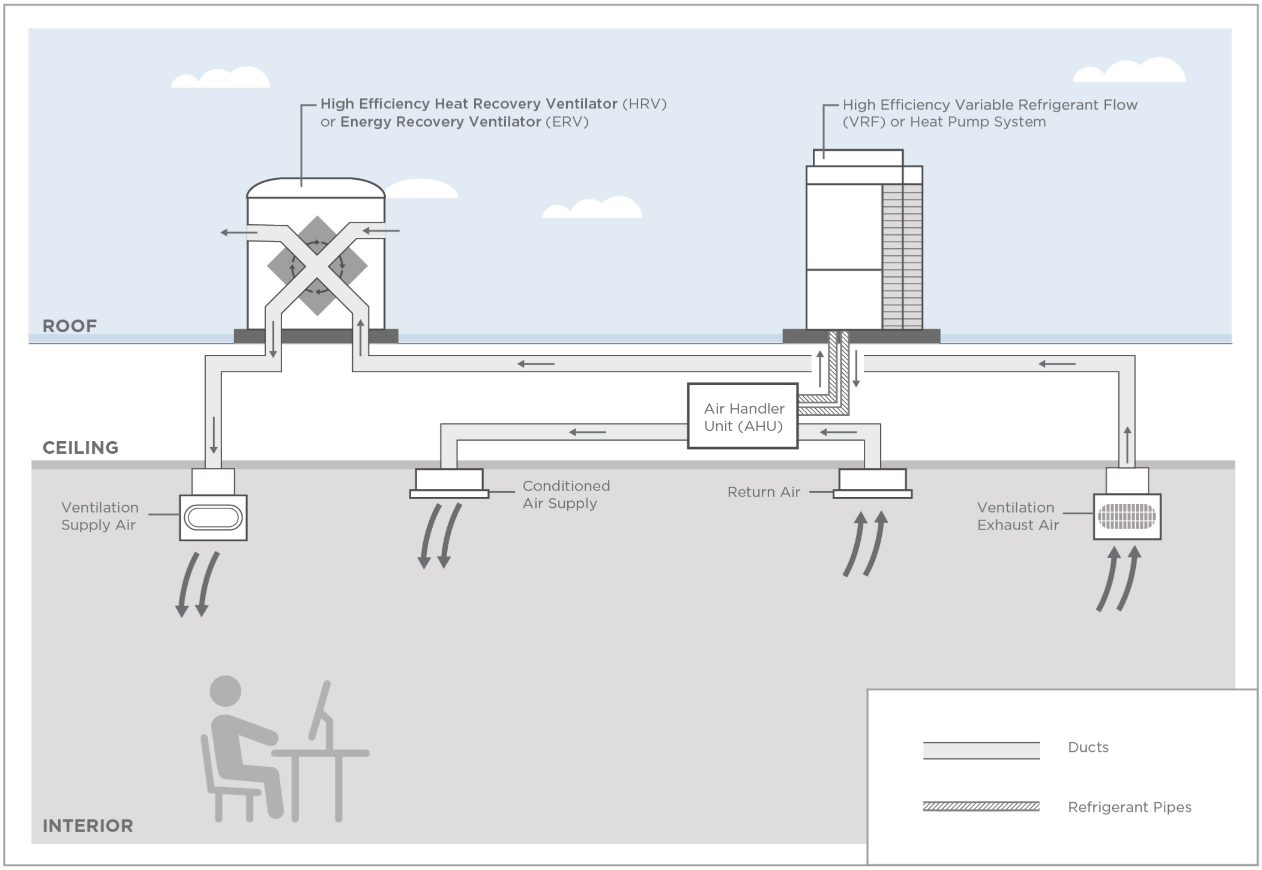
[Figure 1: Very High Efficiency DOAS installed on rooftop in Portland, Oregon]

In the very high efficiency DOAS approach, the HRV/ERV provides ventilation to occupied spaces independently from heating/cooling in a fully decoupled system, and pre-conditions incoming outside air by recapturing heat (or rejecting it when in cooling mode) from the outgoing airstream without supplemental heating or cooling of the ventilation air (in most cases). In these systems, it is critical to select high efficiency HRV/ERV technology and to right-size the high-efficiency heating/cooling equipment for the best energy performance.

There are several types of high-performance heating/cooling systems particularly suited to the very high efficiency DOAS approach, including variable-refrigerant flow (VRF), hydronic systems served by high efficiency air-to-water heat pump central plants, and systems utilizing ground-source or ground-water heat pumps.

In Figure 2 below, the ventilation and heating/cooling systems depicted represent examples of specific technology types (counter-flow HRV and VRF), but other equipment types and systems are eligible.

[Figure 2: Very High Efficiency DOAS Schematic]



For an HVAC system to be considered very high efficiency DOAS, it must meet or exceed the following criteria:

- Include an HRV/ERV that meets the following requirements:
  - Passive House Institute (PHI) certified, or minimum 82% sensible heat exchange effectiveness at standard testing conditions.
  - PHI certified, or minimum 1.4 cfm/watt total HRV fan efficacy at 50% airflow and 0.5” external static pressure.
  - Control capabilities that include time-of-day scheduling and variation in fan airflow as a function of an external input such as CO2 or duct-static pressure.

- Economizer function capable of proportional economizer control up to 100% outside air when OSA temperature is suitable to provide free cooling.
- Crossflow leakage (or exhaust air transfer ratio) of less than 3%.

- Include a high efficiency heating/cooling system:
  - Air-source heat pump, including VRF systems.
  - Ground-source or ground-water heat pump.
  - Hydronic systems utilizing air-water heat pump as central plant.

- Comply with the following critical system design requirements:
  - Decoupled system design where ventilation and heating/cooling system are controlled separately with independent ducting and zoning.
  - Design operating conditions with minimum HRV heat exchange of 75% and fan efficacy of 1.3 cfm/watt.
  - Right-sized heating/cooling systems supported by load calculations and not buffered with safety factors greater than 10%.

WHAT VERY HIGH EFFICIENCY DOAS IS *NOT*

The following characteristics would disqualify an HVAC system from being a very high efficiency DOAS:

- DOAS that primarily uses supplemental heating/cooling energy to condition ventilation air.
- Systems that use the same ducts to deliver heating, cooling and ventilation.
- HRVs that have lower sensible heat recovery than 82% at 75% of their rated airflow.
- Variable air volume (VAV) systems with heat recovery, or any system in which heating/cooling air and ventilation air are combined.
- Systems using terminal conditioning for supplemental heating/cooling of ventilation air, such as terminal reheat systems.
- VRF systems with simultaneous heating and cooling (often designated as "heat recovery") are discouraged. In this instance, zoning plans and energy savings analysis would be required.

BENEFITS OF VERY HIGH EFFICIENCY DOAS

ENERGY, ENERGY-COST, AND FIRST-COST SAVINGS

Very high efficiency DOAS can reduce a building's total energy costs by using significantly less energy than most other HVAC systems. Analysis of several Northwest pilot installations of very high efficiency DOAS, as benchmarked and monitored for energy performance before and after installation, demonstrates an average of 42% whole-building energy savings and a 70% reduction of HVAC energy use compared to a code-minimum replacement of existing equipment. More information on these eight pilot studies can be found at: betterbricks.com/resources/vhe-doas-pilot-project-summary-report.

ENERGY-SAVINGS POTENTIAL

Very high efficiency DOAS results in substantial energy savings due to:

- High efficiency heating/cooling equipment

- Heat recovery from 82% sensible heat exchange effectiveness: The HRV efficiency can eliminate the need for supplemental heating/cooling of the ventilation air because the incoming air is pre-heated or pre-cooled to within 3–5 degrees F of the conditioned space temperature. This ultimately decreases the run time and energy consumption of the heating/cooling system.

- Fan energy reduction by using smaller, more efficient fans in heating/cooling equipment and more efficient HRV fans.
- Right-sized heating/cooling equipment to reduce the amount of short-cycling during part-load conditions.
  The heating/cooling system can be downsized because the ventilation load is mostly eliminated from the equipment. Additionally, equipment is traditionally oversized in current buildings. Improvements in lighting power density, plug loads, envelope, and over-cautious safety factors represent overall reductions in loads and, therefore, the systems that accommodate those loads.
- Decoupled systems: Separating the ventilation air from the heating/cooling system also leads to energy savings. Air is a poor conduit of energy—decoupled system designs typically utilize water or refrigerant-based systems for transferring heat to, from and within the building, which is a more efficient strategy than traditional systems. Also, decoupled systems help alleviate the energy intensive practice of simultaneous heating and cooling that often occurs in traditional system design.

- Enabled demand control ventilation (DCV): Ventilation rates in very high efficiency DOAS can automatically reflect occupancy patterns and rely less on pre-programmed schedules, which can result in significant energy reductions and an increase in occupant comfort. Education about proper use of controls for building occupants and operators is needed to fully maximize these benefits.
- Integrated design: Very high efficiency DOAS can gain the most efficiency through an integrated approach in conjunction with other needs and services of the building (e.g., envelope, loads, and operations). This will maximize the energy performance and enhance comfort and system usability. Note that this type of conversion, using brand new HRV technology (in the U.S.), is unfamiliar to most project teams. Given these interactions between technical components and professional expertise, cross-team communication is critical for successful realization of very high efficiency DOAS. In some Northwest pilot projects where team members were not well aligned in regard to design and installation, the teams encountered numerous problems, increased cost, and installation mistakes or failures.

The Northwest pilot projects utilized these strategies to realize significant energy savings. Some pilot project sites were able to downsize the heating/cooling system by up to 50%. These savings are based on a one-to-one replacement where building occupancy, schedule, and use did not change in the renovation. Equipment efficiency and size accounted for roughly 15–20% of the savings, with 30% of the savings realized by eliminating the simultaneous heating/cooling on the existing dual-duct HVAC systems. In renovations where downsizing the heating/cooling system is not feasible, subsequent energy savings will likely be less significant.

BENEFITS BEYOND ENERGY EFFICIENCY

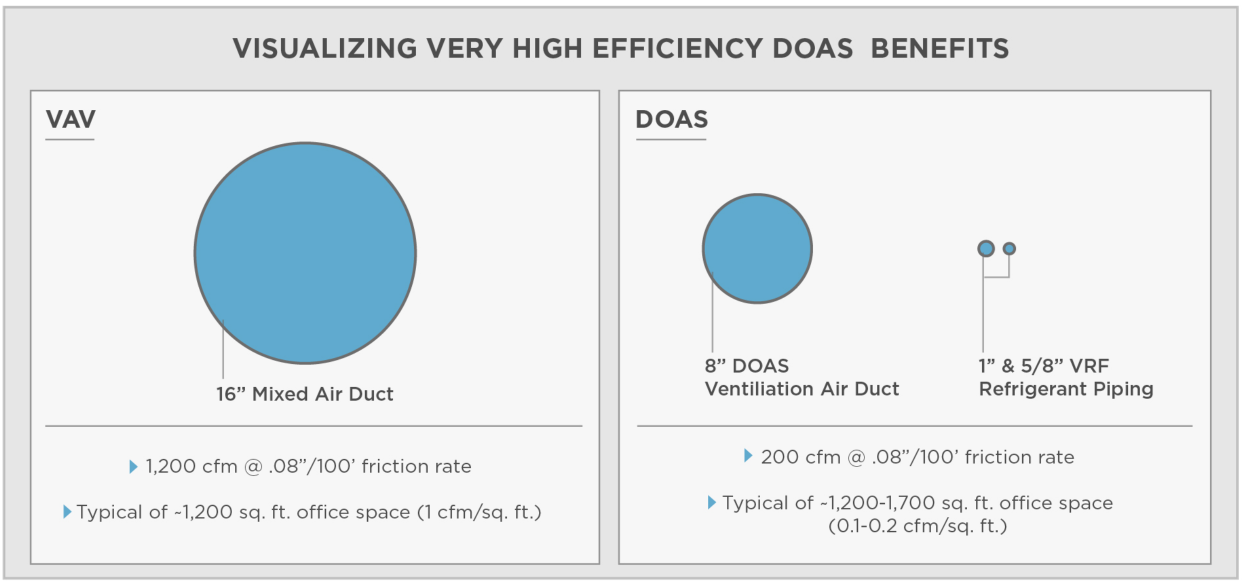
- Improves indoor air quality: The HRV delivers 100% fresh and filtered outside air when the system is running with no air recirculation. This results in improved indoor-air quality, and better occupant perceptions of comfort.
- Improves comfort: Building occupant comfort can be improved through a combination of 1) improved air quality, 2) fresh air delivered close to room temperature, 3) heating/cooling controls by zone and occupancy rates using DCV strategies, and 4) occupant acoustic comfort. Improved health and comfort can result in lower tenant turnover.

- **Simplifies or reduces system maintenance**: Depending on the system being replaced, fewer components and advanced controls can help to simplify or reduce system management, maintenance, and unnecessary operation. Additionally, very high efficiency DOAS can improve building management through simplified zone controls, self-commissioning and performance monitoring.

- **Saves space with smaller equipment**: The smaller footprint of the very high efficiency DOAS system compared to typical packaged rooftop units (RTUs) sometimes means more available roof space for other amenities (e.g., PV arrays, green roofs, skylights, etc.).

  In some cases, very high efficiency DOAS can reduce duct sizes by as much as 50% due to the ventilation air being decoupled from the heating/cooling system. Figure 3 compares the relative sizing difference of a 16-inch round duct for a 1,200 cfm VAV space to an 8-inch DOAS duct delivering 200 cfm of ventilation air only.

[Figure 3: Saving Space Through Duct Size Reduction]



[Figure 4: RTU Examples]

ECONOMIC ANALYSIS

Cost is often a barrier to the adoption of new technological approaches. While very high efficiency DOAS has been adopted widely in Europe, cost barriers have slowed adoption in the U.S. For example, the payback period of very high efficiency DOAS is currently higher in the U.S. than in Europe, even though the latter has higher energy costs. However, our analysis shows that very high efficiency DOAS is cost-effective in most applications, and, over time, costs will likely decrease due to more industry design experience, installation familiarity, and additional competing product lines.

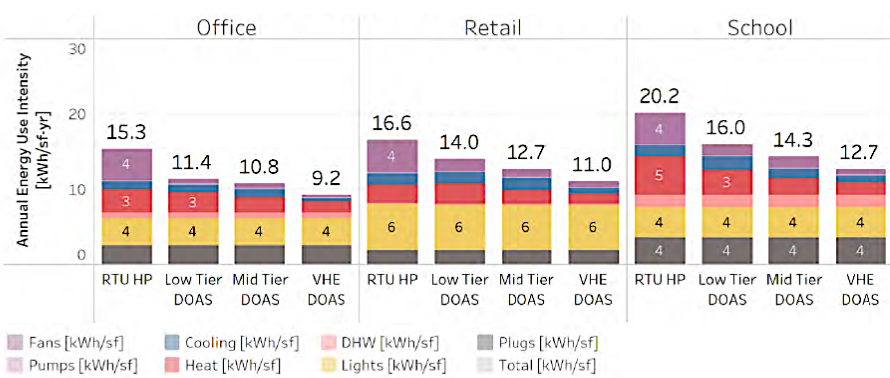
Economic analysis shows very high efficiency DOAS to have the highest net-present value across Northwest climate zones compared to two other HVAC strategies that were studied. In this study, a cost and energy analysis provides a broader understanding of the economic benefits of converting an existing commercial building's HVAC system. It examines three different HVAC configurations with varying levels of energy efficiency (very high efficiency DOAS, mid-tier DOAS, and low-tier DOAS (WSEC equivalent) in three building types (office, retail and schools) and three climate zones (4C, 5A, 5B). Working with contractors, designers, and equipment venders, costs were compared to relevant case studies to substantiate estimates and ensure they reflected construction best practices.

The analysis found the very high efficiency DOAS approach to have the highest net-present value over the 20-year estimated life of the equipment in all climate zones and building types analyzed. The mid-tier DOAS package, which was developed as part of this study, was found to be a positive net-present value in all climates and buildings, with one exception (retail in Climate Zone 4), and had a lower net-present value than the very high efficiency DOAS package. The low-tier DOAS was found to be positive in Climate Zone 6 for the office and school building only, with the retail building not paying back in 20 years. In the retail buildings, all the baseline RTU electric heat pump (RTU HP) systems include airside economizers and variable speed fans (VSFs). Baseline RTU HP systems for other building types included a mix of economizer and non-economizer systems with higher energy use.

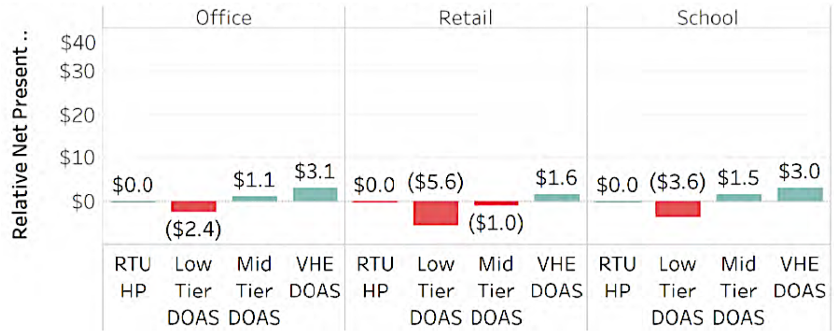
In real-world applications, higher initial cost of equipment was a key barrier encountered in the Northwest pilot projects. Most pilots, which were completed between 2016 and 2018, cost less than $25/sq. ft. to implement. However, in many cases, the initial bid submitted was significantly higher than the actual cost. The heightened bid pricing was most likely due to 1) new technology pricing, 2) lack of experience in designing and installing this system, and 3) the tendency to not downsize the heating/cooling equipment in initial bids.

Figure 4 and 5 show the energy use and net-present value of a select set of the analysis. The charts show results for a small commercial office, retail, and school building, operating west of the Cascade Mountains in ASHRAE Climate Zone 4c. The energy use is shown annually in kBtu/sq. ft. of floor, and the relative net-present value compared to the RTU HP system is shown in $USD/sq. ft. from the energy-cost savings over 20 years.

[Figure 5: Energy Use Intensity (kWh/sq. ft. per year) – (CZ4c) Mixed Marine]



[Figure 6: Relative Net Present Value ($/sq. ft.)], 20-year (CZ4c) Mixed Marine]



More information related to this study can be found in the **economic analysis** completed by Red Car Analytics at: betterbricks.com/uploads/resources/NEEA-DOAS-Analysis-Report_Red-Car_Final.pdf.

ADDITIONAL RESOURCES

The following additional resources can be found at betterbricks.com/solutions/hvac/dedicated-outside-air-system-doas:

- Pilot summary report: Technical summary of the performance and findings from eight pilot demonstration projects conducted throughout the Northwest using the very high efficiency DOAS approach.
- Case studies: High-level overview for each of the eight pilots, including building profiles and conversion performance/savings.
- System Requirements & Recommendations: Details the equipment and design requirements to achieve very high efficiency DOAS.
- Very High Efficiency DOAS Comprehensive Design Guide: An educational and reference tool for industry stakeholders, building owners and designers in the Northwest.
- Comparison of Very High Efficiency DOAS with Washington State Energy Code DOAS Requirements

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