Turn Around, Right Size:
Efficient HVAC Approach Eclipses Standard Design Performance

While conventional practice can lead to HVAC systems that are oversized by 25% or more, the proven very high efficiency approach to DOAS design allows for the downsizing of heating and cooling systems through ventilation heat recovery and by decoupling ventilation from the primary heating and cooling equipment. In fact, when combined with accurate thermal-load calculations, the very high efficiency DOAS approach can reduce HVAC system size by an average of 32%,[1] as proven by recent real-world field studies.

Oversized HVAC systems happen for many reasons, including the constant pressure faced by designers and installers to deliver solutions at a competitive price that meet the owner's requirements (e.g., thermal comfort, indoor air quality, and resiliency). To reduce design costs and risk, designers and installers often replace existing equipment like-for-like, use industry-average metrics (e.g., sq. ft. per ton), and use conservative assumptions in load-calculation inputs.

According to an article from ASHRAE, the default inputs from load calculation software result in 20% oversizing, on average.[2] At the same time, code-driven improvements to building envelope performance and more efficient lighting and plug loads have widened the gap between oversized HVAC equipment capacities and the building loads they are required to meet.

When oversized, HVAC systems often waste energy and cost more to construct and operate, while likely decreasing thermal comfort in comparison to their right-sized counterparts.

When the most advanced commercial HVAC approaches are used, such as the very high efficiency dedicated outside air system (very high efficiency DOAS) approach, HVAC systems can become even smaller without impacting thermal comfort. With very high efficiency DOAS, commercial building energy use is reduced by an average of 48 percent while maintaining healthy and clean ventilated air throughout the building. However, when converting to very high efficiency DOAS, engineers and installers may oversize their heating and cooling system by needlessly accounting for the nearly nonexistent ventilation load.

While this oversizing is often a perceived means of improving thermal comfort, this perception can be misguided. On the contrary, right-sizing the heating and cooling system often leads to superior thermal comfort, as oversized systems are forced to operate at less-than-minimum capacity for a majority of their operation. This causes the system to overshoot its setpoints and constantly short-cycle its compressors, which increases maintenance costs and increases the likelihood that equipment must be replaced prematurely.

Designed, vetted, and tested over the last several years by the nonprofit Northwest Energy Efficiency Alliance (NEEA), in partnership with HVAC industry experts, the very high efficiency DOAS approach allows for the downsizing of heating and cooling systems by combining high-efficiency equipment with design best practices, including:

- Fully separating the ventilation function from the heating and cooling.
- 82% Using a high-efficiency heat or energy recovery ventilator (HRV/ERV) with 82% or greater sensible effectiveness.
- Pairing the HRV/ERV with an electric heat pump system that meets ENERGY STAR® performance standards.

To read more about very high efficiency DOAS, including case studies, research, and technical guides, visit **betterbricks.com/solutions/HVAC.**

Right-sizing in the real world.

In real-world very high efficiency DOAS installations in offices and schools in climate zones 4C and 5B, engineers accounted for actual building loads and successfully right-sized the heating and cooling equipment to 600–800 ft^2 per ton (15–20 Btu/hr-ft^2), while also improving thermal comfort.

As shown in Figure 1 below, the results were extraordinary. Of the 11 projects, engineers saw a 32% average reduction in system capacity from the pre-conversion system. Six of the 11 systems were downsized by 35% or more, and four systems saw an incredible 50% or greater reduction in capacity. Figure 2 shows the example pre- and post-conversion load calculation results for one of these right-sized systems. Across the board, all of the buildings maintained consistent, comfortable indoor environments, even in extreme weather conditions – including a weather event 20 degrees (F) above the 0.4% cooling dry-bulb design condition, and a 10-year minimum temperature extreme.

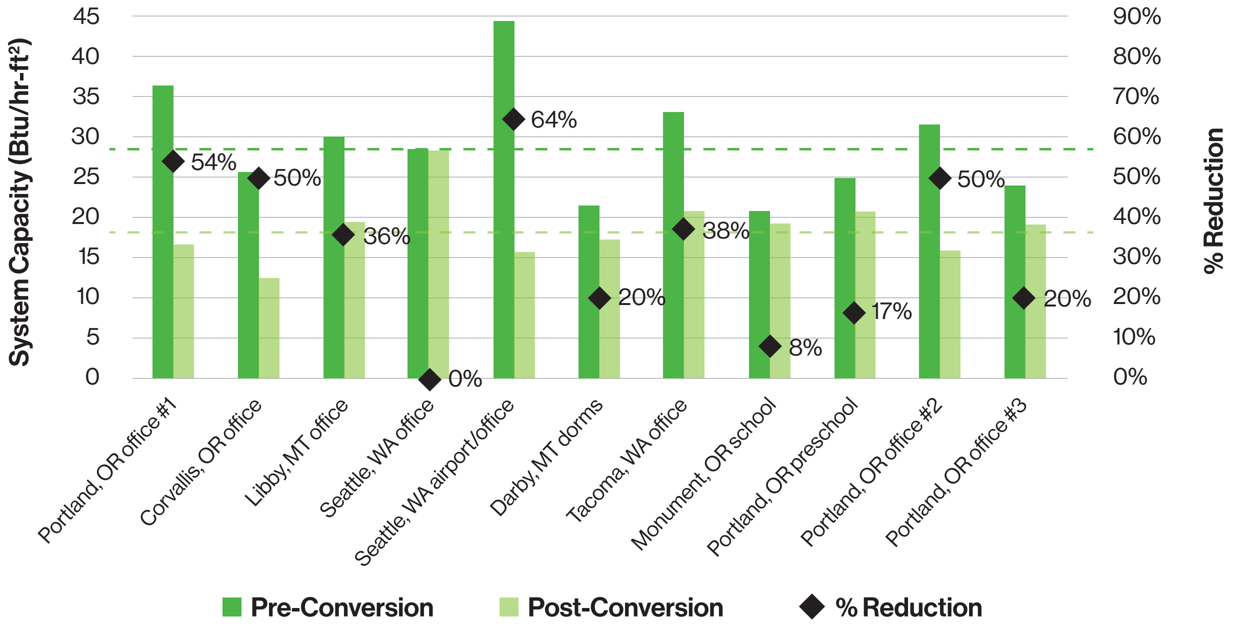

Figure 1: 6 out of 11 projects resulted in a 35% or greater reduction to system-rated cooling capacity. The text above the columns indicates the % reduction of each project's capacity. Average pre-conversion rated capacity was 29.1 Btu/hr-ft^2 (412 ft^2/ton), while post-conversion systems averaged 18.7 Btu/hr-ft^2 (642 ft^2/ton).

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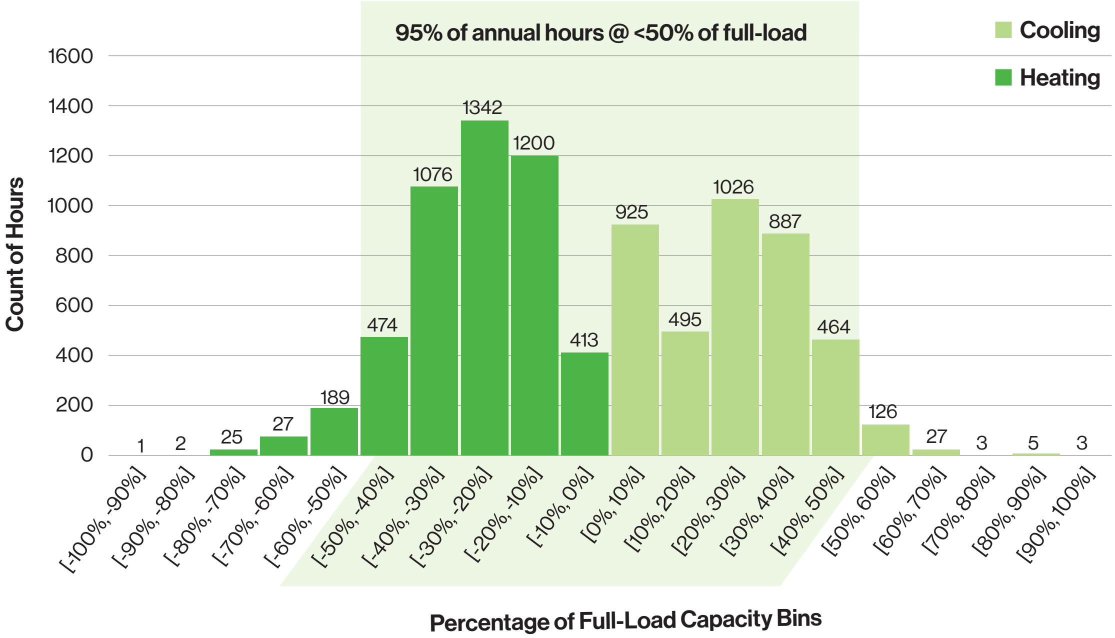

Figure 2: In one VRF project that was sized typically (~400 ft²/ton), we measured the heating and cooling load at less than 50% capacity for 95% of the year. The system operated above 90% capacity for just 4 hours out of the year (0.05%). Other systems have been found to have similar load profiles.

Break the cycle of low-load energy waste.

On top of reducing the system's first costs, right-sizing the heating and cooling equipment allows the system to operate more efficiently, due to less short-cycling in low-load conditions (which accounts for most of the year). For example, many variable refrigerant flow (VRF) systems operate at less than 50% capacity for more than 90% of the year and at less than 20% capacity for 35% of the year (see Figure 3). Even variable-speed VRF systems with excellent low-load performance are unable to operate at less than 10% capacity continuously, so they cycle on and off to meet low loads. Right-sized systems spend more operating hours above minimum capacity and can operate more efficiently throughout the year with reduced maintenance costs.

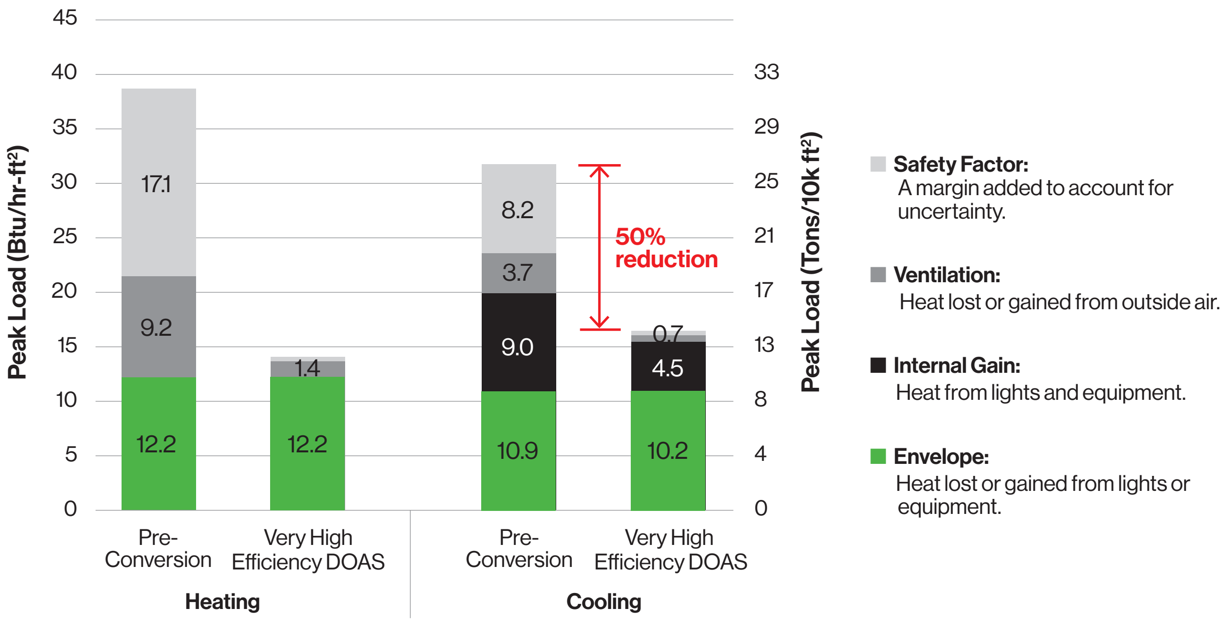

Figure 3: Example peak heating and cooling loads before and after a very high efficiency DOAS conversion. In this project, it was estimated that the existing heating system was selected with a nearly 100% safety factor.

Right-sizing recommendations.

The benefits of right-sizing are manifold. In addition to reducing equipment and energy costs, even when designing with inverter-driven technologies like VRF, right-sizing maintains comfortable space conditions in both expected and extreme weather conditions. To make the most of a building's HVAC system, including very high efficiency DOAS, we recommend following these best practices to right-size the system to match the building's actual needs:

- Perform load calculations on all new and replacement systems to avoid oversizing with traditional guidelines (e.g., 400 sq. ft. per system ton and like-for-like system capacity replacements).
- When calculating peak loads for very high efficiency DOAS, account for 82% or more reduction in ventilation load from the HRV/ERV..
- Avoid excessive safety factors.
- Use actual equipment and light power values for internal gains, as modern loads are often less than 0.8 W/ft^2.[3]
- Use realistic diversity when calculating block loads and consider seasonality (e.g., will a school's peak occupancy occur during the peak envelope and ventilation cooling load?).[4]
- Avoid upsizing to the next available size of indoor units, especially when units are located in open spaces that are served by multiple units.
- Avoid oversizing outdoor units for expected future growth, unless you are certain that indoor units will be added.
- Avoid an excessively low combination ratio (i.e., the sum of indoor unit capacity vs. outdoor unit capacity). Size indoor equipment on zone loads and outdoor equipment on block loads. See Figures 4 and 5 for more information.

How to calculate

$$\text{Combination Ratio} = \frac{\text{Total capacity of indoor units}}{\text{Capacity of outdoor unit}} \text{ X 100 } = ?\%$$

※ Typical manufacturer recommendation: ~50–130%

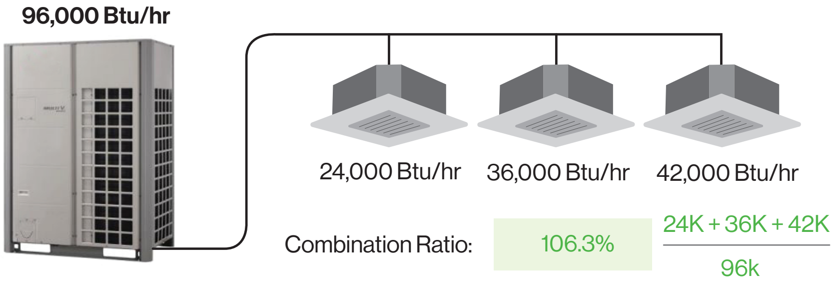

Figure 4: Combination ratio represents the ratio of the connected indoor unit capacity to the outdoor unit capacity. A system with a high level of peak cooling diversity will often have a combination ratio higher than 100%.

Cooling Loads (BTU/hour)

Time	Zone A	Zone B	Zone C	Zone D	Block Load
8:00 AM	12,000	8,750	10,000	4,500	32,250
10:00 AM	6,000	15,000	14,000	6,000	41,000
12:00 PM	10,000	24,000	14,000	8,000	56,000
2:00 PM	10,000	18,000	22,500	8,000	58,000
4:00 PM	9,000	18,000	24,000	9,000	60,000

Selection	12,000	24,000	24,000	9,000	69,000
Block Load:					60,000
Combination Ratio (69,000 / 60,000):					115%

🟩 Peak Zone Load ⬜ Peak Block Load

Figure 5: Example load calculation on peak cooling day. The peak cooling load of each zone should determine the selection of the indoor unit, while the block load (peak sum of all indoor unit loads that occur simultaneously) should determine the size of the outdoor unit. In this example, Zones A–D would select 12,000, 24,000, 24,000, and 9,000 Btu/hr. indoor units, respectively, and the block load of 60,000 Btu/hr. would determine the outdoor unit capacity.

While manufacturers often allow a ratio between 50% and 130%, indoor units should be sized based on the zone loads, while outdoor units should be sized based on the block load (i.e., highest coincident sum of all zone loads). As shown in Figures 4 and 5 above, although it is common to size the outdoor unit at or above the sum of the nominal capacity of all indoor units (resulting in a combination ratio of less than 100%), it is unlikely that all correctly sized indoor units will operate at full capacity at the same time.

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[1] As compared to the pre-conversion system capacity.

[2] ASHRAE, AT-19-C003 - *Challenges of Creating Verifiable Building Energy Model*, 2019.

[3] ASHRAE, Research Project Report 1742-RP, *Update to Measurements of Office Equipment Heat Gain Data,* March 2018.

[4] The ASHRAE paper cited in the second footnote shows that average office buildings use 0.8 W/ft² of plug-load power, while low-density spaces are often as low 0.34 W/ft².