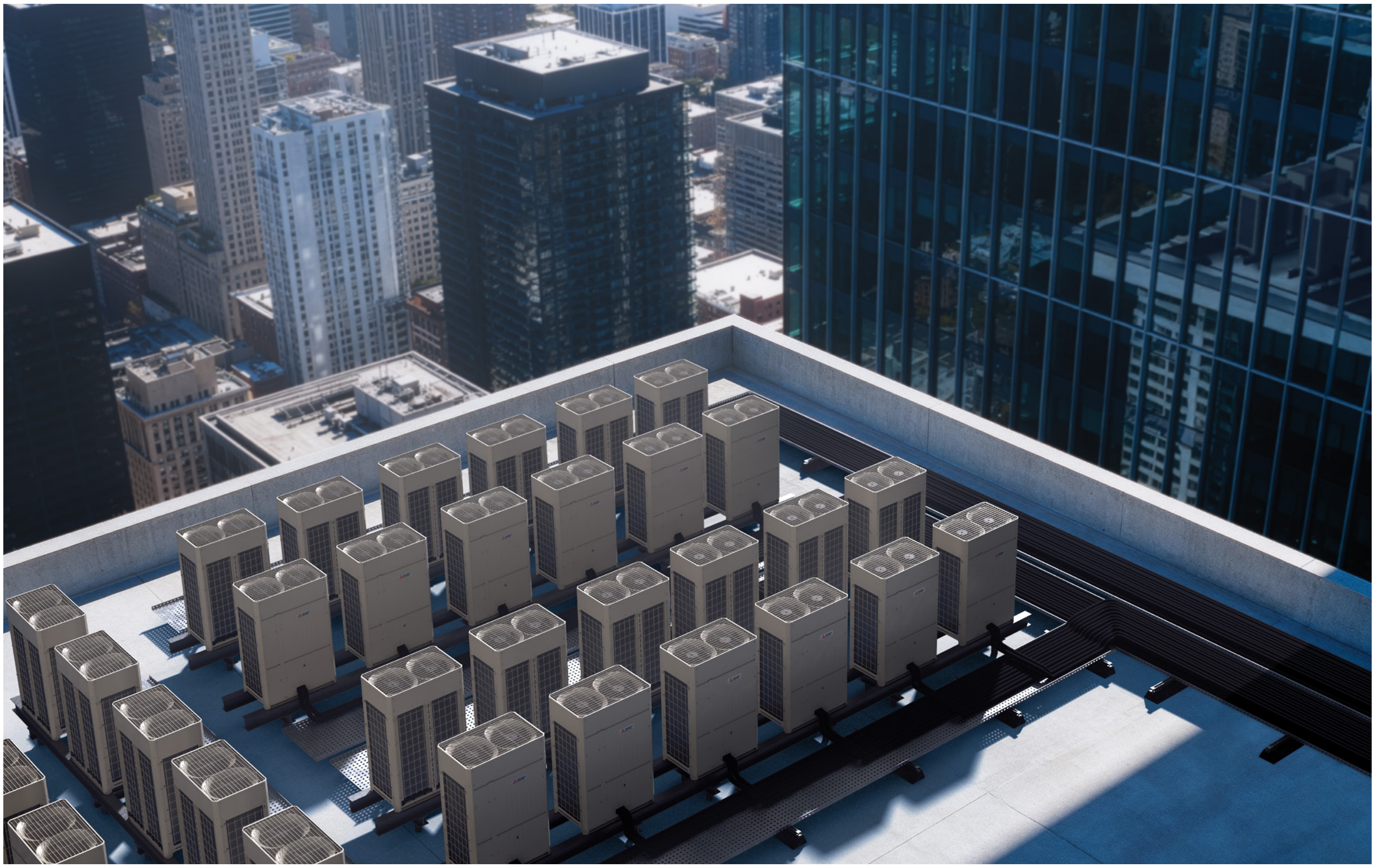

WHITE PAPER

VRF

VRF System Design Guide by Building Type

- Commercial Buildings & Classrooms
- Dormitories & Multi-Family Housing
- Institutional Spaces

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Introduction

Variable refrigerant flow (VRF) systems are widely used in commercial, educational and institutional settings for their energy efficiency, zoning flexibility and design adaptability. They are a strong option for both new construction and retrofit projects, including those requiring long vertical piping runs.

While VRF can be applied across many industries, this guide focuses on three primary application areas: commercial spaces and classrooms, dormitories and multi-family housing, and institutional spaces where codes more strictly limit refrigerant use in occupied spaces. Within these categories, we outline key considerations for selecting and designing traditional VRF and Hybrid VRF (HVRF) systems, explain their differences and highlight best practices for enhancing performance and compliance.

VRF vs. HVRF at a Glance

Both traditional VRF and Hybrid VRF (HVRF) systems deliver energy-efficient comfort and precise zoning, but they do so using different approaches. Understanding how each system manages refrigerant and distributes heat is essential for choosing the right design.

Traditional VRF systems circulate refrigerant throughout the building to serve all occupied spaces. By modulating refrigerant flow based on real-time load conditions, VRF systems provide highly responsive temperature control and allow multiple indoor units to operate efficiently within the same system.

HVRF significantly reduces refrigerant volume by confining it to mechanical spaces by using water as the distribution medium in occupied areas. This design eliminates refrigerant in zones where codes restrict its use, simplifies compliance with ASHRAE 15 and local regulations, and makes future refrigerant transitions easier — all while supporting simultaneous heating and cooling.

Understanding the differences between traditional VRF and HVRF systems is essential for selecting the right solution for your application. This comparison summarizes key characteristics, compliance considerations and best-fit scenarios for each system type.

Which Fits Best?

- ✓ **VRF:** Suited for use in commercial and educational spaces where building codes allow refrigerant piping to be routed without constraints.
- ✓ **HVRF:** Ideal when projects require reducing or removing refrigerant from occupied spaces.

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Feature	Traditional VRF	HVRF (Hybrid VRF)
Distribution Method	Refrigerant in occupied spaces	Water in occupied spaces; refrigerant stays in mechanical spaces
Code Compliance	Must meet ASHRAE 15 and local refrigerant charge limits	Simplifies compliance where refrigerant is prohibited in occupied spaces
Primary Advantages	Flexible design, wide application, lowest first cost for many projects	Eliminates refrigerant in occupied spaces, future-proofs for refrigerant changes
Best For	Commercial spaces, classrooms, most high-rise applications	Institutional buildings, dormitories, apartments with refrigerant restrictions
Simultaneous Heating/Cooling	Yes, with Branch Circuit Controller (BCC)	Yes, with Hybrid Branch Controller (HBC)
Installation Complexity	Requires refrigerant piping throughout building	Requires water piping in occupied spaces plus HBC
Future Proofing	Limited if refrigerant regulations change	High — water-based distribution allows refrigerant changes with minimal disruption

BCC vs. HBC: What's the Difference?

The Branch Circuit Controller (BCC) suits projects where refrigerant piping is acceptable in occupied spaces. The Hybrid Branch Controller (HBC) is ideal for meeting code requirements and future proofing against refrigerant changes.

Both controllers serve as the core component that enables simultaneous heating and cooling, but they operate differently based on system type. This comparison summarizes their key differences.

Feature	Branch Circuit Controller (BCC)	Hybrid Branch Controller (HBC)
System Type	Traditional VRF	Hybrid VRF (HVRF)
Primary Function	Routes refrigerant to indoor units for simultaneous heating and cooling	Transfers heat from refrigerant to hot/chilled water for distribution in occupied spaces
Distribution Medium	Refrigerant only	Refrigerant (to HBC) + water (to indoor units)
Ports	Available in multiple configurations (4-12 ports)	Available in 8- or 16-port configurations; requires water balancing
Additional Components	No pumps; refrigerant-only system	Includes pumps and modulating six-way valves for water flow control

VRF Controls and LEV Kit

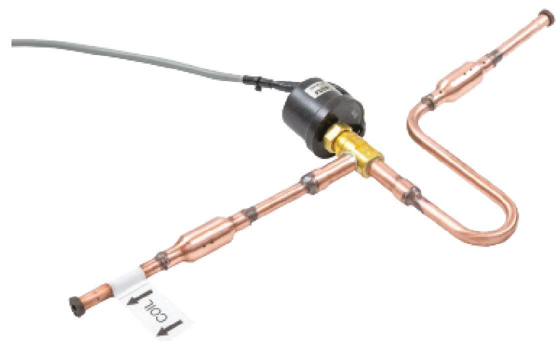
VRF Systems

Trane VRF systems deliver a robust portfolio of control options. At the foundation are the dedicated VRF controls — a pre-engineered, easy-to-install solution that manages VRF operations with dedicated wall-mounted controllers, indoor/outdoor unit controls, branch controllers and optional central controllers. These controllers enable building operators and tenants to adjust heating and cooling setpoints, monitor zones and even leverage occupancy sensors to implement energy-saving setback strategies automatically. For buildings seeking enhanced performance, Trane offers demand-controlled ventilation integration. This equips each zone with independent air valves and occupancy or CO_2 sensors, allowing the dedicated outdoor air system (DOAS) to deliver the right amount of fresh air based on real-time demand, further optimizing comfort and energy use.

Business Operating System (BAS)

Trane delivers powerful integrated system control that brings VRF systems into the broader building automation ecosystem, seamlessly synchronizing HVAC, lighting, ventilation, and other critical systems under one intuitive interface. This unified approach empowers VRF operators with modern building automation system (BAS) tools like advanced graphical interfaces, remote access, real-time monitoring, data collection, and automated scheduling—simplifying building management while uncovering new opportunities to reduce operational costs. With support for Air-Fi Wireless sensors and the full suite of Trane cloud solutions, customers gain a smarter, more connected, and more efficient building experience.

LEV Kit



Trane® / Mitsubishi Electric Linear Expansion Valve (LEV) Kits enhance the operational efficiency, comfort and adaptability of VRF systems. By providing precise refrigerant flow control and system integration, the LEV Kit enables seamless compatibility between Trane® / Mitsubishi Electric VRF outdoor units and Trane air handlers and coils.

The LEV Kit bridges the gap where conventional HVAC and VRF systems have fallen short. Examples include split DOAS systems, long piping runs between condensers and air handlers, replacements of old inefficient split systems, unit ventilators, high duct-static/filtration applications and more. While the controls for the LEV Kit itself are simple, integration to Trane controls for complex system-level controls unlocks enhanced temperature control and system adaptability, ensuring peak performance for building owners.

LEV Kits support flexible design applications, easier retrofit options and reliable performance — delivering a more sustainable and scalable solution for commercial HVAC projects. This results in enhanced energy usage, improved temperature consistency, and greater zone control for building occupants.

Design Considerations by Building Type

Every building type brings its own challenges and priorities — from piping routes in high-traffic spaces to ventilation strategies that support comfort and code compliance. Because no two projects are alike, it's essential to work with a provider who understands both the technology and the unique requirements of your application.

At Trane, our design, installation and support specialists work alongside customers from early planning through commissioning to ensure VRF and HVRF systems perform as intended. That expertise helps uncover details that drive long-term success, from selecting the right equipment to optimizing layout for safety, efficiency and occupant comfort.

The following examples illustrate how design priorities differ by application:

1. **Commercial Buildings & Classrooms**
2. **Dormitories & Multi-Family Housing**
3. **Institutional**

1. Commercial Buildings & Classrooms

Commercial buildings often require VRF systems that balance flexibility and scalability. Office layouts can range from private offices to large open-plan environments, requiring zoning strategies that adapt to changing occupancy patterns. Interior aesthetics also play a role — many designs favor ceiling cassettes or ducted units that integrate seamlessly with architectural finishes.

Efficiency remains a top priority, particularly when multiple floors or tenant spaces share a system. Proper load calculations and thoughtful placement of outdoor units ensure consistent comfort and energy performance without sacrificing usable space.

Classroom design introduces considerations that go beyond comfort. Sound performance is critical in learning environments, making indoor unit selection and placement key decisions. Ceiling cassettes and low-sound ducted units help maintain acoustic quality while delivering targeted conditioning.

Ventilation is another priority. Classrooms often require integration with dedicated outdoor air systems (DOAS) to meet fresh air requirements. Combining HVRF or traditional VRF with a well-designed ventilation strategy ensures both indoor air quality and energy efficiency. Occupancy schedules also influence system setup, with controls enhanced for rapid recovery at the start of each school day.

OVERALL CONSIDERATIONS	Commercial and classroom spaces tend to be larger spaces with all refrigerant piping accessible via lay-in ceilings — making traditional VRF — such as Trane® / Mitsubishi Electric CITY MULTI® VRF systems likely the best value for owners. It's always important to leverage the strengths of any given system type in proposing a design. In the same way vertical stack units would always be considered for four-pipe fan coil systems or water source heat pump (WSHP) systems in a tall building, VRF designs should leverage approaches to indoor unit styles and outdoor unit placement that enhance VRF design.
INDOOR UNIT CONSIDERATIONS	By far, the most cost-effective indoor unit styles for commercial spaces are ductless ceiling cassettes. Up to 16 indoor units — such as multiple ceiling cassettes in an open area — can be grouped as a single control zone sharing a set point and schedule. Alternatively, the system can be designed where individual units operate independently to maintain comfort in their respective areas. Each 33-by-33-inch ceiling cassette includes a duct knockout that allows up to 53 cfm of ventilation air. An optional multifunction casement adds additional knockouts that can increase the amount of ventilation air up to 247 cfm. If spaces require more fresh air, as in the case of conference rooms for example, ducted indoor units may be better suited because of the higher occupancy and ventilation needs. Wall-mounted units offer the lowest equipment and installed cost of any indoor unit style, but they lack a condensate lift mechanism and ventilation air inlet, which limits their use in commercial and classroom spaces.
OUTDOOR UNIT CONSIDERATIONS	School administrative areas are ideal for simultaneous heating/cooling VRF because they often include many small offices with varying schedules and temperature preferences. The main benefit of simultaneous VRF is improved comfort when all classrooms have outside exposures. Energy models typically show only a 3% to 5% penalty when heat recovery is not included. High cooling density areas, such as server closets, risk reduced capacity during simultaneous operation outside the published range. Cooling-only P-Series one-to-one systems with advanced wind baffles can operate down to -40 °F and restart within 60 seconds after a power failure. In comparison, VRF systems require 15 to 20 minutes to restart after a power outage. P-series may be better for high cooling density areas.
ADDITIONAL CONSIDERATIONS	Using CITY MULTI® in commercial structures and selected educational spaces can reduce overall construction costs — even when it is not the lowest-cost HVAC option. Eliminating large duct mains can reduce the required distance between ceilings and joists to only 18 inches, allowing higher ceilings or a lower building height, which can save up to $50 per square foot in exterior wall costs. Even when paired with curb-mounted DOAS, small, lightweight outdoor units on the roof can also reduce structural steel costs.

2. Dormitories & Multi-Family Housing

OVERALL CONSIDERATIONS	Dormitory and multi-family housing spaces tend to be small, with most piping concealed behind drywall — making hybrid systems such as the Trane® / Mitsubishi Electric HVRF a great value for owners. HVRF uses hot and chilled water within occupied spaces to help future-proof the system for refrigerant and code updates.
INDOOR UNIT CONSIDERATIONS	Dormitories are most cost effectively served by wall-mounted units. Equipment cost often ranges 30% to 40% less per ton compared to ducted or other ductless styles, and they require less labor. Installation costs are lowest because no ductwork or service access panels are required. Wall-mounted units have no provision for ventilation so neutral ventilation air must be provided directly to the space. Traditionally, dormitories are often served by ducted units, but consider zoning each room with wall-mounted units. Traditional CITY MULTI® VRF and HVRF allow up to three indoor units connected to each BCC or HBC port all function in the same mode and operate in unison. Equipment cost savings and reductions in ductwork and soffits can make zoning bedrooms cost-neutral, while zoned comfort can increase lease rates and tenant retention. Branch ducting from ceiling cassettes is also possible but limited in airflow and duct static capabilities. Horizontal ducted units cost less than same-capacity vertical ducted units. If supplemental or emergency electric heat is required, horizontal ducted indoor units need three to four feet of straight duct between the unit and a field-installed duct-mounted electric heater. Avoid this issue by using multi-position ducted units with accessory electric heat certified for mounting directly on the cabinet.
OUTDOOR UNIT CONSIDERATIONS	Heat pump systems can offer a lower installed cost than simultaneous systems for low-rent apartments but always caution owners about changeover expectations (see Additional Considerations). Simultaneous systems provide the best comfort, which can translate to higher lease rates and better tenant retention. Smaller, single-module systems are recommended over twinned systems for higher efficiency and more responsive thermo-on activation during shoulder seasons. Ensure the operating range includes 20-year winter extreme temperatures; designing for future polar vortexes or bomb cyclones is better than relying on standard winter design temperatures. Water-source VRF can make financial sense in extreme cold climates or tall buildings, especially if only one or two water risers are needed — instead of many line sets for air-cooled modules or multiple risers as typical with conventional water-source heat pumps (WSHPs). Electrical feeds for water-source VRF are often stacked per floor, reducing electrical costs compared to conventional WSHPs. For heat rejection in northern climates, dry coolers may be better suited as they can operate efficiently on dry bulb temperatures alone using 100 °F to 105 °F entering water temperature. Adiabatic coolers, which use water to increase heat rejection capacity during the warmest days of the year, can also be a cost-effective alternative to improve heat rejection efficiency.
ADDITIONAL CONSIDERATIONS	While basic interlocking with ventilation equipment provides on/off control based on occupancy, operational efficiency can often be improved at little to no additional cost by utilizing the advanced integrated controls available on Trane Horizon® Outdoor Air Units (OAU). The Horizon OAU's factory-mounted and programmed BACnet® controls enable coordination with VRF or other terminal units to enhance ventilation and dehumidification sequences. For enhanced efficiency, the Trane Horizon OAU's microprocessor-based controls allow the reheat (hot gas reheat or supplemental electric/hydronic heat) to be disabled whenever all VRF indoor units serving the same zone are actively cooling (thermo-on/cool mode). This prevents simultaneous reheat and space cooling, reducing redundant or conflicting operation, and ensuring the DOAS supplies ventilation air at the correct dew point while minimizing unnecessary energy use. The Horizon OAU control system provides configurable options for interlocking sequences via BACnet objects or field contacts, so that any time all coupled terminal units (fan coils/VRF indoor units) are in cooling mode, the OAU can automatically lock out reheat operation until a call for reheat is appropriate. This coordinated control maintains occupant comfort and humidity targets while maximizing overall system efficiency. Energy apportionment panels allow owners to accurately assign plant-level energy costs to tenants. The system records expansion valve positions at 10-minute intervals to build a mathematical model showing what percentage of refrigerant flow passed through each indoor unit at a given time. Data is compiled over the course of a month to apportion energy consumption to individual units. Assigning actual costs requires third-party watt-hour meters. The optimal approach is to feed all outdoor units — and nothing else — through a single electrical panel equipped with a watt-hour meter. Pricing varies based on the number of controllers, indoor units and site-specific electrical feeds. Consult your local Trane Account Manager for additional guidance.

3. Institutional

OVERALL CONSIDERATIONS	Institutional facilities have code requirements that provide stricter limitations on the refrigerant in occupied spaces. These environments prioritize safety, compliance and operational reliability. Examples include correctional facilities, skilled nursing and long-term care facilities, laboratories, inpatient mental health centers and certain government buildings.
INDOOR UNIT CONSIDERATIONS	Horizontal ducted indoor units installed within soffits near bathrooms are a common approach. Placement requires care because units are offered in only one configuration. High-static models have connections and a control box on the opposite side compared with low- and mid-static models. Condensate lift mechanisms are included in all horizontal ducted indoor units up to size 54. These are not pumps; rather, they silently "flick" condensate upward like a cool-mist humidifier and provide more than 20 inches of lift. Use with a filter return grill or accessory filter boxes with MERV 13 filters provided. Ceiling cassettes can improve comfort, enhance efficiency, reduce noise and lower installed costs. With 33-by-33-inch cassettes, future service can be completed by removing the grill — no costly access panels required. These units also have an optional filter casement accessory that allows for over 200 cfm of ventilation air or the addition of a MERV 10 filter.
OUTDOOR UNIT CONSIDERATIONS	Apply simultaneous systems to better satisfy individual and varying comfort needs for each space. Design winter indoor temperature for skilled care facilities should be greater than the usual 70 °F to keep these special tenants comfortable; consider sizing these systems to maintain at least 75 °F and be aware Hyper Heat systems can excel at maintaining heat output even with higher indoor temperatures.

Conclusion

Designing traditional VRF and HVRF systems requires careful consideration of building layout, load profiles and regulatory requirements. Both system types offer flexibility and energy efficiency, but selecting the right approach depends on application-specific factors such as space constraints, future refrigerant regulations and comfort priorities.

By understanding key differences engineers can enhance performance while meeting compliance and cost objectives. That's why Trane provides expertise and solutions that enable engineers to match system capabilities to project goals. A thorough evaluation during the design phase helps ensure reliable performance, long-term efficiency and adaptability for evolving building needs.

We are dedicated to supporting design engineers by ensuring their concepts are seamlessly translated from paper to the field. Our local Ductless Technical Specialists, who are highly experienced, factory-trained subject matter experts, provide on-site support for every Trane VRF installation, overseeing the process to help guarantee successful outcomes. In addition to pre-installation, installation and start-up support, our technical experts address post-start-up concerns, ensuring continued performance and reliability.

Trane is committed to professional development, offering comprehensive VRF and ductless technical training at many locations across the country. This dedication ensures that every project is supported by expertly trained and fully certified installers and service technicians, providing design engineers with confidence that their designs will be executed reliably and effectively in the field.

For more information, please visit Trane.com/VRF

Trane – by Trane Technologies (NYSE: TT), a global climate innovator – creates comfortable, energy efficient indoor environments through a broad portfolio of heating, ventilating and air conditioning systems and controls, services, parts and supply. For more information, please visit *trane.com or tranetechnologies.com.*