2019 WHITE PAPER

APPLYING VRF AND THIRD-PARTY HVAC SYSTEMS

INTRODUCTION

As modern construction requirements, sustainability and the rising cost of energy continue to drive the demand for Variable Refrigerant Flow (VRF) systems in the United States and worldwide, building owners, facility managers and project teams will be responsible for buildings where VRF systems are applied with complementary third-party HVAC equipment. This White Paper discusses how advanced controls supported by professional services from VRF system manufacturers enable facility managers to monitor and control third-party HVAC equipment while using high-performance VRF systems as the primary technology for heating and cooling.

WHAT IS VRF TECHNOLOGY?

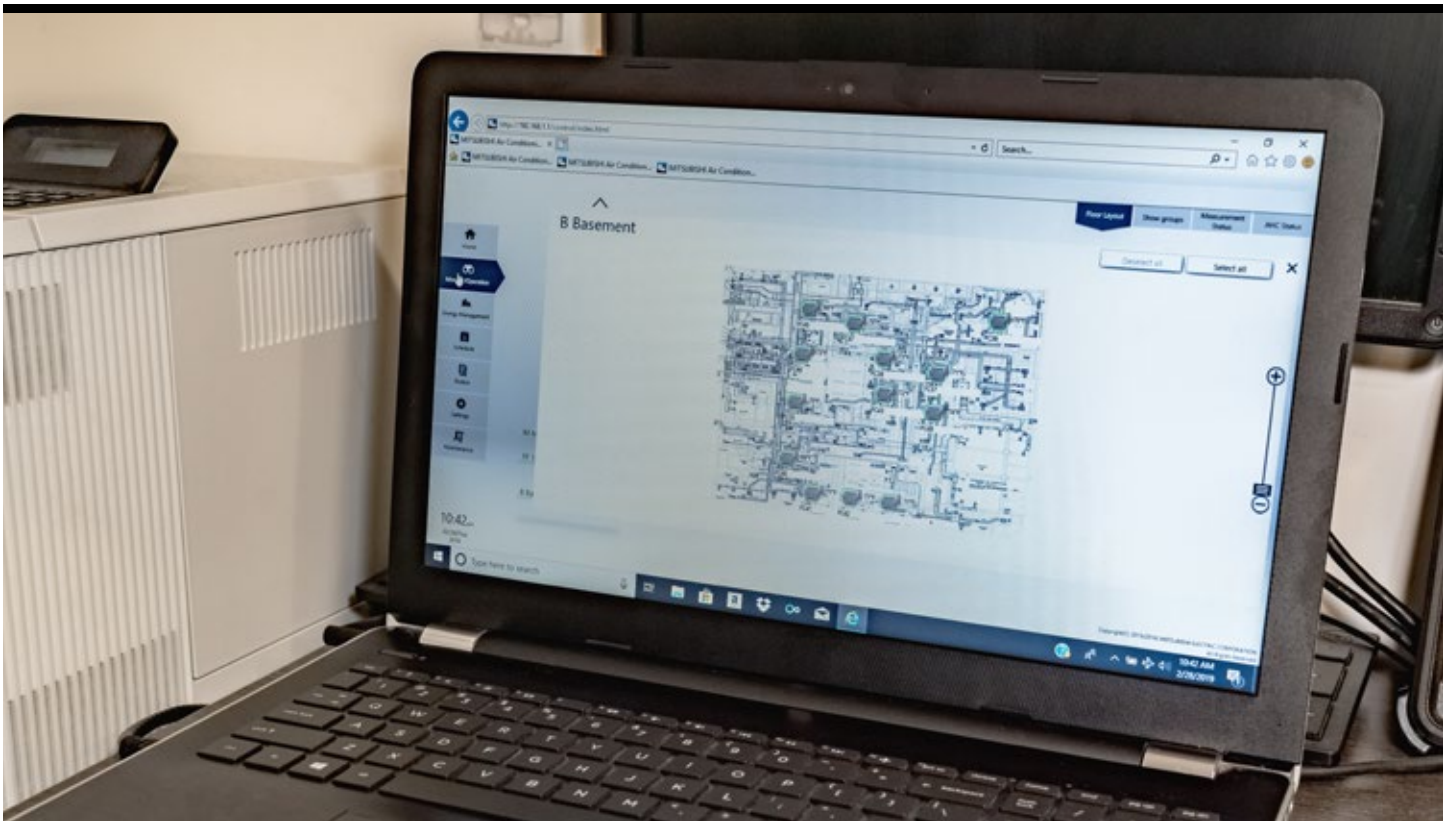
VRF is an HVAC technology designed to provide energy-efficient comfort control according to the conditioning needs of a building's zones. Each VRF system consists of an outdoor unit connected to a network of indoor units by refrigerant lines, with each zone having its own thermostat. Depending upon the application and conditioning requirements, a zone may be served by one or many indoor units of varying styles. The optimal choice for some projects is typically a hybrid application of ducted and ductless units.

Whether ducted or ductless, VRF equipment is engineered to **offer design flexibility with modularity, a smaller footprint than conventional HVAC equipment, and quiet operation that will not disturb occupants.** For example, compact VRF outdoor units can operate down to 56.5 dB(A), about the noise level of a normal conversation, allowing a building owner to provide rooftop amenities right next to the equipment.

VRF systems accomplish heating and cooling through the transfer of conditioned refrigerant between each zone's indoor unit(s) and an outdoor unit. Each outdoor unit is equipped with an INVERTER-driven compressor designed to vary its speed and capacity to match the heating or cooling load of a space at any particular point in time. While the compressors of conventional HVAC systems run at full speed and capacity regardless of the actual load, **VRF systems save money by modulating refrigerant flow and using only the precise amount of electricity required to maintain the set point**. The energy efficiency of electric-powered VRF systems make them ideal for applications that utilize renewable energy and essential for initiatives dedicated to lowering carbon-gas emissions.

VRF systems are available as heat pumps appropriate for moderate climates and single-zone applications or as heat-recovery systems, which provide simultaneous heating and cooling. VRF systems applied with heat recovery are the optimal choice for office buildings, hotels and any facility where some zones may require heating while others require cooling. A heat-recovery system incorporates a branch circuit (BC) controller that directs refrigerant based on the conditioning needs of a particular zone (heating or cooling).

While VRF is a mature technology and the preferred method of heating and cooling throughout Asia and Europe, **VRF manufacturers continue to innovate and move the technology forward.** Recent examples include greater use of **innovative sensors** and outdoor units with **four-sided heat exchangers.**



VRF MANUFACTURER CONTROLS AND SERVICES

Sensors and controls, along with mechanical components within VRF systems are fully integrated and in constant communication. The breadth of information and control made possible by a fully-integrated VRF system includes personalized local-comfort control for occupants; energy-allocation controls to calculate the energy used in tenant spaces; algorithms that direct systems to deliver more or less cool or warm air and modify directional airflow based upon the number and location of occupants; and superior centralized control for facility managers.

Given the sophistication and interconnectivity of VRF components, facility managers gain access to the most system points and obtain peak performance when they use manufacturer-provided controls to manage a VRF system. Facility managers can monitor multiple zones across multiple buildings, set operating schedules and adjust equipment remotely. Varying levels of access are possible where one facility manager might have an enterprise view allowing for reporting, status and controls for the VRF equipment in each of an organization's buildings while other staff members have access to select systems or buildings. Additionally, leading VRF system manufacturers offer controls software developed on non-proprietary platforms such as Tridium's Niagara ^{AX} Framework®. Controls using open architecture give building owners and facility managers the freedom to switch service providers if they desire, and may open opportunities for interoperability with third-party equipment that uses the same non-proprietary platform.

VRF controls can also integrate with third-party building management systems (BMS) through standard protocols like BACnet®. The VRF manufacturer's controls engineers help with mapping and identifying what points must be shared between the VRF controls and the BMS. This approach is common in hospitality applications where such integration empowers front desk staff to address comfort complaints through the guest management system without having to contact a technician.

For greater control and insight into the operation of both VRF and third-party HVAC equipment, the VRF manufacturer can provide the BMS for a facility. Building owners and facility managers can expect peak performance of VRF systems along with top-quality control, more efficient operation and a higher level of information available at greater speed due to the manufacturer's access to the largest number of VRF system points. Additionally, having a single provider for VRF controls and the BMS for all mechanical systems streamlines support and eliminates finger-pointing. Depending upon the application and client preference, the VRF manufacturer can be involved in one, or many steps of the integration process, including design, programming, installation, training and start-up.

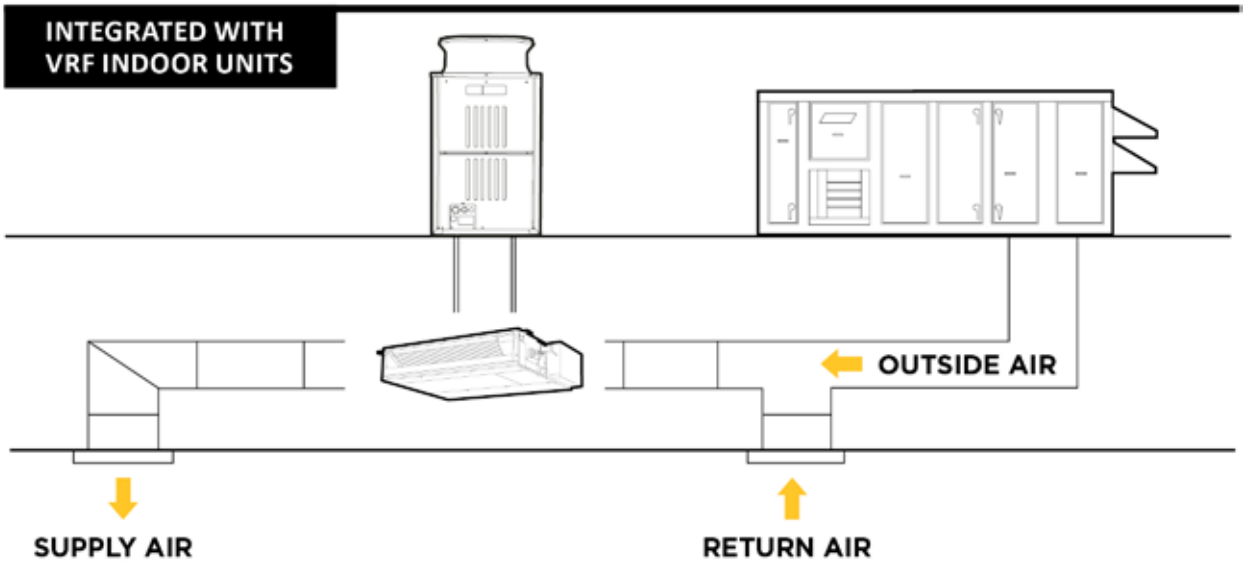
A VRF manufacturer may also offer packaged controls offerings that provide system points beyond what is available through the BACnet protocol. This standardized, factory-direct approach can lower costs related to project coordination, labor, materials and installation. For example, a VRF manufacturer may offer a pre-engineered controls panel designed for common applications such as measuring and allocating the electrical consumption of VRF equipment by zone.

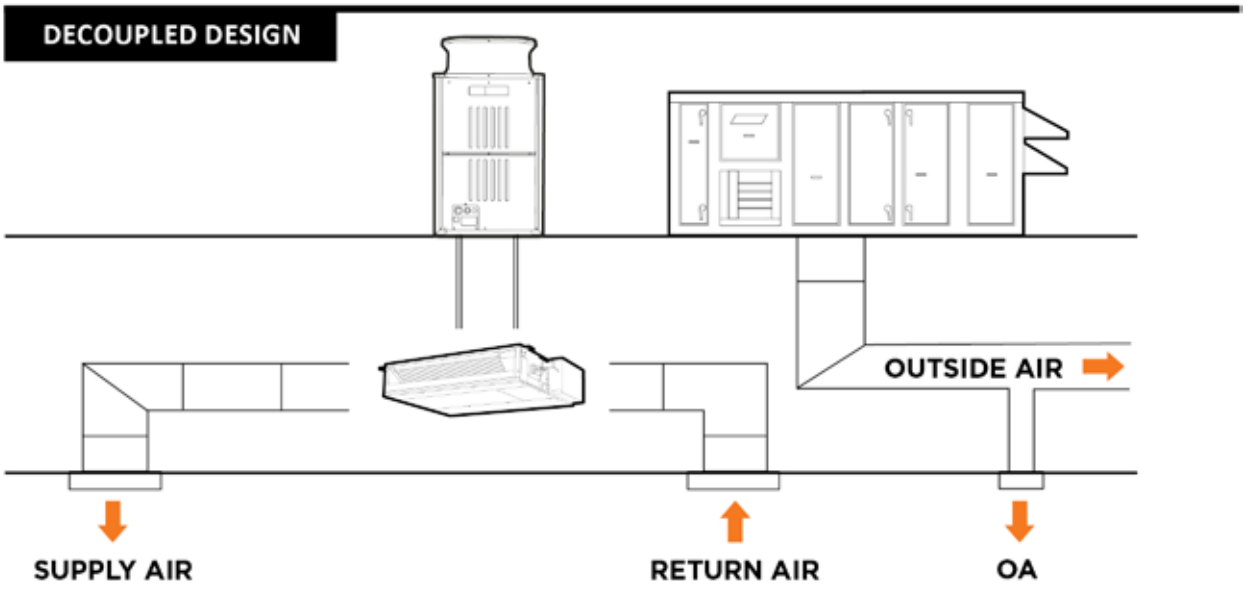
MECHANICAL VENTILATION: THE ESSENTIAL COMPLEMENT

VRF systems provide zone filtration and allow for the integration of ventilation air. Each zone has an indoor unit equipped with its own filter to reduce contaminants such as allergens, viruses and bacteria. Although VRF systems contribute to improved indoor air quality, they are not designed to provide ventilation air or dehumidify. In partial-load conditions, the compressor of a VRF system will run slower, meaning that the coil has less refrigerant and is less active. This reduction in refrigerant capacity is ideal for energy efficiency, but a warm coil in cooling mode doesn't offer much latent capacity.

The equipment most commonly applied with VRF systems are specialized mechanical ventilation systems that provide outdoor air and handle moisture. To ensure compliance with the ventilation requirements of ASHRAE Standard 62.1 and the International Mechanical Code, HVAC specifiers will typically apply VRF systems with an **Energy Recovery Ventilator (ERV) or a Dedicated Outdoor Air System (DOAS).**

DOAS may be applied with VRF systems in a design where conditioned outdoor air is ducted from the DOAS to VRF indoor units. DOAS may also be applied with VRF systems in a decoupled design where conditioned air is ducted directly from the DOAS to each zone. **In decoupled designs, the VRF systems handle heating and cooling supported by the DOAS that conditions ventilation air to room-neutral temperature before it reaches each zone.** This approach requires two duct distribution networks, but simplifies fan balancing and ventilation rate verification to prove compliance with ASHRAE 62.1.





Recognizing the importance of mechanical ventilation, some VRF manufacturers now provide DOAS designed to utilize the same communication protocol as VRF equipment. Specialized mechanical systems engineered for use with VRF systems are also equipped with INVERTER-driven compressors to increase energy efficiency and satisfy the requirements of AHRI Standard 920, which includes Moisture Removal Efficiency (MRE) as a full-load efficiency metric and Integrated Seasonal Moisture Removal Efficiency (ISMRE) as a part-load efficiency metric.

For example, VRF systems provide energy-efficient comfort in restaurants that experience fluctuating heating and cooling loads as guests transition in and out of dining spaces. However, even if the restaurant uses a DOAS to provide conditioned outdoor air to staff and guests, the amount of grease and debris produced by commercial kitchens means restaurants typically require a third-party packaged rooftop makeup-air unit.

A third-party mechanical ventilation system that natively uses a different proprietary protocol can be integrated with a VRF system via a simple input/output (I/O) connection. In that scenario, a DOAS, for example, would use its own controls to regulate functions such as discharge air temperature, but the VRF system would send signals to dictate when the DOAS would turn on or off. **Through the VRF controls, the facility manager could establish a schedule where the DOAS would turn on at 8 a.m. and turn off at 5 p.m.** The same I/O method could be used to coordinate the operation of makeup-air units and exhaust fans. Alternately, if greater levels of insight and control are needed, third-party mechanical ventilation systems can be integrated with VRF systems via BACnet.

A research and development facility may also have special requirements that necessitate the use of a third-party roof-top air-handling unit (RTU) in addition to a VRF system and DOAS. Perhaps humidity generated by a machine shop that uses a water jet to cut materials requires the application of an RTU — which packages heating, cooling and ventilation components together — to serve a particular zone. Or, like a restaurant, a research and development facility might require specialized fans and makeup air units. The VRF system would provide smart comfort control for the majority of the building — conference rooms, offices and common areas — and facility managers would manage all of the HVAC equipment through the VRF controls, possibly customized by the VRF manufacturer based on the use of each zone.

Some ventilation applications may have special requirements that necessitate the use of third-party air handlers to provide capabilities such as supply-air control as a complement to a VRF system and DOAS. In response to this need, manufacturers offer linear expansion valve (LEV) kits to connect the expansion coils of third-party air handlers to VRF condensers.

CASE STUDY: UBER ADVANCED TECHNOLOGY CENTER

In Summer 2016, **UBER Advanced Technologies Group** (ATG) officially opened its doors in downtown Pittsburgh. As the main campus for UBER's autonomous vehicle research and development labs, the building presented a unique design challenge. Vehicle testing garages sit side-by-side with state-of-the-art conference rooms and office space. This drove the need for zone control and specialized ventilation. After the engineer consulted with the local Mitsubishi Electric Trane HVAC US distributor, **Comfort Supply, Inc.**, a comprehensive solution was clear: **CITY MULTI® VRF** technology applied with **PremiSys® Fusion DOAS** managed via **Diamond Controls™ Solutions**.

"We house all the software engineers and techs who build the data and software for our autonomous cars," explained TJ Wolkiewicz, facilities lead, UBER ATG. "When we took over this building — originally a 110,000-square-foot warehouse — we needed the space to work for us."

After planning for a second floor, the project and facilities team knew the layout required advanced HVAC technology.

"We had several different parts going into this building: a garage, special research areas, office spaces, gathering areas, a café and so on," said Aaron Doubt, facilities & special projects director, UBER ATG. "We had to have a system that gave us precise control over each zone. With a traditional, forced air HVAC system you have mass conditioning. We could have never provided a comfortable atmosphere for our occupants with a centralized system."

To communicate and function properly, the indoor units, outdoor units and controllers must be addressed according to VRF manufacturer specifications. Addresses are assigned to each unit of equipment via a set of dials or rotary switches. In addition to providing necessary training on how to address systems, VRF manufacturers may provide software that automatically selects address numbers to help HVAC contractors avoid errors.

ALL-IN-ONE SUPPORT

Knowing VRF had the zoning capabilities required, one brand stood out from the competition. "Mitsubishi Electric had everything the building engineer was looking for," noted Justin Kern, senior commercial sales engineer, Comfort Supply. "They were able to provide a single source contact for the VRF system, ventilation equipment and building controls. It's not often you can have one company responsible for all three. It makes for a better overall project whenever that happens."

Combining their experience, the engineer and Comfort Supply worked directly with the Controls Solutions Team (Controls Solutions) from METUS to layout and design a cohesive system. **A feature of Controls Solutions, building automation is paired with top-notch customer service from initial design to post-installation and follow-up support**. Kern described Controls Solutions as a huge benefit — particularly for the planning stages of any project.

"Mitsubishi Electric was involved right from the construction phase, even coming out onsite several times," expressed Kern. "Controls Solutions helped us communicate to the HVAC contractor exactly what needed to occur during the install since we don't have a controls background. **Sometimes when I'm on a project, there's minor startup issues when we're dealing with a third-party controls company. Controls Solutions thoroughly understands how to control and operate VRF."** In addition to the VRF system, the team specified 4 PremiSys Fusion DOAS units for ventilation, as well as third-party electric heaters and exhaust fans throughout the building. All control systems were integrated into METUS' building management system (BMS), Diamond Controls — a feature not very common with your standard BMS.

COMPREHENSIVE CONTROLS AND SAFETY

Within the testing garages, Diamond Controls is also a major component of ventilation safety for employees.

"In our R&D showroom, we pull in cars for research and testing," noted Wolkiewicz. "Monitoring car exhaust and fumes is a priority. In addition to our DOAS systems, **Mitsubishi Electric was able to integrate CO2 sensors into the controls interface**. I can just put the system on 'auto mode' and it will alert us as well as our Pittsburgh Security Operations Center if it senses any kind of gas in the air. It's so nice that we can see everything right from one dashboard."

Diamond Controls features a full graphical interface and streamlines scheduling and HVAC management by zone, in-person or remotely — an advantage for UBER ATG's facilities team.

"The best part of the interface is that we have remote access from anywhere," said Wolkiewicz. "This job requires that we travel to our different job sites and we're able to access the controls right from our laptops. If anyone asks us about cooling or heating, we can easily adjust that on the go.

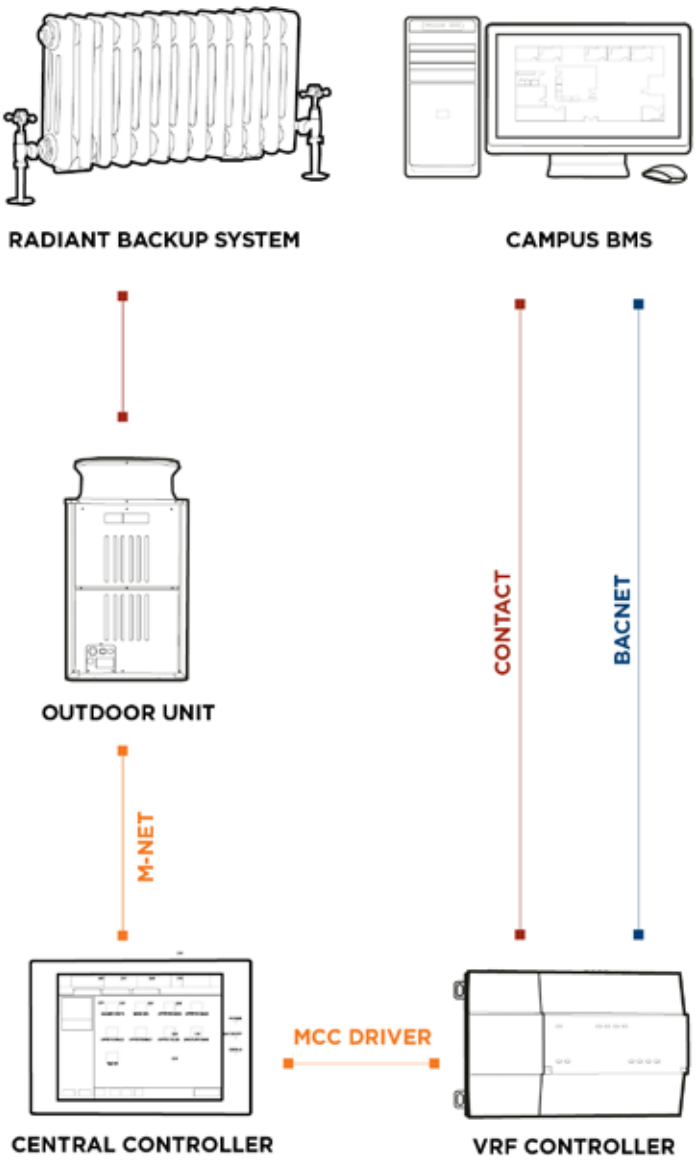
"All in all, Mitsubishi Electric provided a turnkey solution that met all of our needs," said Doubt. "At UBER, as we are a technology company, we believe in changing the way ordinary systems work to promote the betterment of humanity. Part of that is having systems that are sustainable and help us reduce waste or any emissions we produce. We hold our vendors accountable for efficiency, functionality and end-user experience. Mitsubishi Electric has clearly met that with their VRF system and equipment."

AUXILIARY HEATING SYSTEMS

VRF systems are able to provide heating in extreme temperatures with some systems able to provide up to 78% heating capacity down to -13˚F outdoor ambient conditions. For extreme temperatures below that threshold, the VRF controls system can be configured to activate a backup auxiliary heating system. As required by the application, VRF controls can manage almost any kind of auxiliary heating system including hot-water baseboard heating and electric duct heaters.

As an example, a university located in the northeastern United States retrofitted a historic campus building with a highly-efficient VRF system. **To account for extreme cold, the VRF manufacturer integrated the VRF controls with the university's existing BMS so that when the prescribed temperature threshold was reached**, the campus BMS could initiate an automatic switchover to an auxiliary radiant heating system. The campus BMS sends a signal to the VRF system via a dry contact and the VRF system signals to the VRF outdoor unit that the system capacity is now 0%, which stops the refrigerant flow to the indoor units. The room controllers indicate the use of auxiliary heat and all operational information is transmitted from the VRF system back to the campus BMS. Then, once temperatures have warmed up, the VRF system resumes its role as the primary heating system.

CUSTOM AUXILIARY HEAT CONTROL



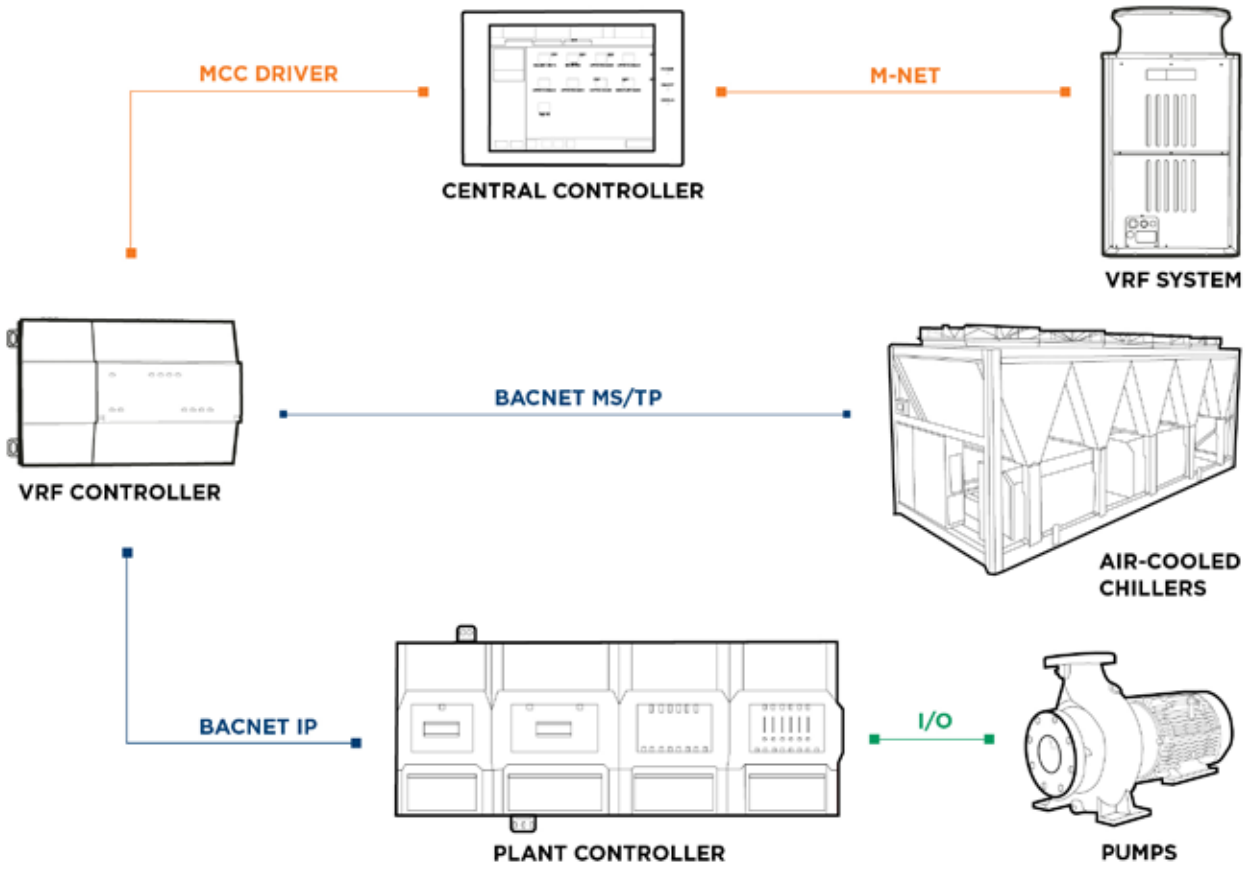
EXISTING HVAC EQUIPMENT

VRF systems are ideal for K-12 schools and universities. Schools are heavily zoned with spaces used for diverse activities and significant fluctuations in zone loads as students and staff move in and out of buildings during a day and leave some spaces unoccupied or rarely used during winter and summer breaks. Facility managers will use VRF controls to manage multiple buildings and can take advantage of remote access even during severe weather events such as snowstorms.

The history of a school is typically reflected in campus buildings of varying ages and mechanical systems. A school that purchases a VRF system to save money and increase sustainability will often still utilize third-party systems on portions of its campus. For example, a technical college in the southeastern United States installed a VRF system in a brand-new building, but retained an existing chilled water system to serve the rest of the campus. The VRF controls system — which provides control, monitoring, alarming and data management — was configured to manage the chilled water loop in addition to the VRF system. The temperature differential between the chilled water supply and the chilled water setpoint is assessed by the VRF system to determine the required water flow to meet demand and rates it from 0 to 100 percent. The primary pump and chiller have user-selectable lead/lag status. Per the calculated chilled water demand, the primary pump and associated chiller stage up and down. The secondary chilled water pump is equipped with a variable frequency drive and modulates to maintain differential pressure across the secondary loop. Temperature reset for chilled water is accomplished via BACnet MS/TP integration.

An existing boiler and cooling tower or geothermal well system can provide opportunities to apply a water-source VRF system. **A water-source VRF system uses water as the heat transfer medium, instead of air, which allows for the system's condensing unit to be installed indoors. With its condensing unit indoors and less subject to outdoor elements, water-source VRF systems experience minimal capacity loss compared to air-source systems in extremely cold weather.** Managing the repurposed boiler and cooling tower through the VRF controls simplifies operations for facility managers as they take advantage of the energy efficiency and low de-rates of a water-source VRF system.

3RD PARTY EQUIPMENT INTEGRATION



CASE STUDY: FAIRMONT STATE UNIVERSITY

When the only on-campus, apartment-living complex at **Fairmont State University** — The College Park apartments — approached the end of its lifespan, the university, based in Fairmont, West Virginia, decided to build new student housing. After several years of research, planning and design, the University Terrace project took shape in 2015 and was completed in October 2016. The new **110,000-square-foot facility is comprised of 2, 4-story buildings and 1, 3-story building housing a total of 345 students**. The promise of energy efficiency coupled with low maintenance led Fairmont State University to select a Variable Refrigerant Flow (VRF) system from Mitsubishi Electric Trane HVAC US (METUS) as the HVAC system for the new project.

Stephanie Slaubaugh, construction project manager, Fairmont State University, acted as the owner's representation and oversaw the scheduling and budget coordination on the project. She said, "We wanted a system that was energy-efficient with low ongoing maintenance costs. We also wanted a system that offered a high level of occupant comfort and control."

Michael Heath, senior mechanical designer, **McKinley & Associates**, Wheeling, West Virginia, was hired to specify the new HVAC systems. "The university originally wanted a system that was inexpensive but very energy-efficient to achieve a quick payback. They also wanted zone control and every suite within the building to have its own unit."

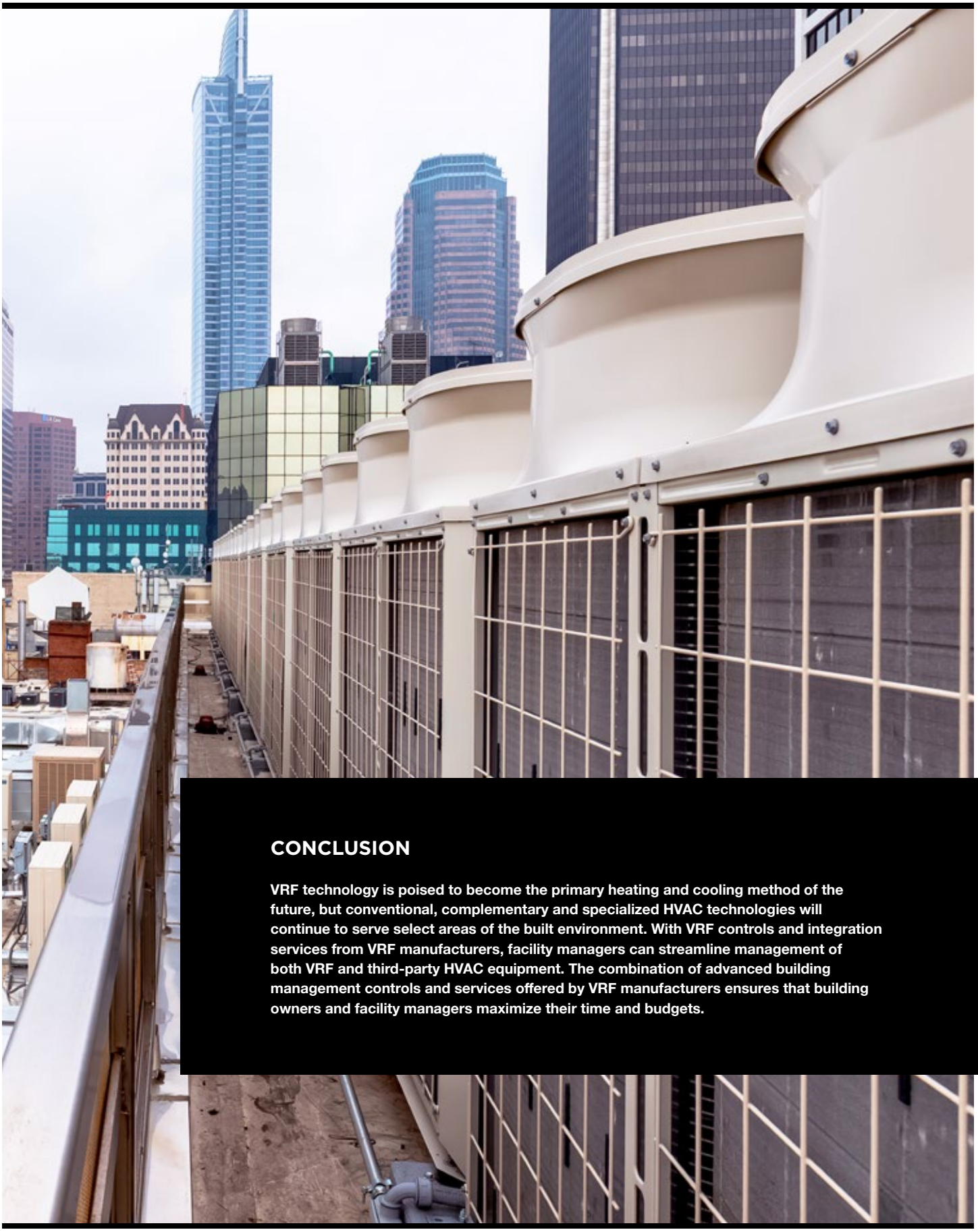
With Heath's assistance, the university considered 3 types of systems: packaged terminal air conditioners (PTACs), variable air volume (VAV) and VRF. After a deep energy analysis, Heath presented the best options for the university. He said, "If the university selected VRF, it would take 3 to 5 years to get a full payback on the system. With a PTAC, they were never going to get the savings back, and with VAV, it would be 10 to 12 years. Although VRF required a little more money to install, the school gets energy savings."

The VRF system promised substantial energy savings and easy maintenance. Heath said, "In other areas of the university, they have VAV and heat pump systems. They wanted a system that required less maintenance: where the maintenance crew didn't have to be there every day."

The university agreed with Heath's recommendation. Slaubaugh said, **"We had used ductless in several converted classroom renovations that turned out pretty well, but never on a project of this magnitude. This technology also helped us overcome our biggest concerns including comfort in below zero temperatures during winter as well as met our requirements for aesthetics and noise."**

To select a brand, the university compared METUS and another competitor. After an in-depth analysis, the project team concluded that Mitsubishi Electric VRF technology was the appropriate choice. Slaubaugh said, "Mitsubishi Electric offered a leading product and performance rating. We toured several housing projects outside of our state that utilized Mitsubishi Electric and their maintenance department had good reports on the equipment." She continued, **"We also were able to remove the need for a third-party controls contractor. Mitsubishi Electric offered controls as part of their base contract.** We went through several demonstrations, toured a mock setup and were able to interact with their controls software and it was comparable to the base controls that we wanted so we deleted the controls package and used their web-based program."

Slaubaugh said, "Mitsubishi Electric's web-based controls are a top-of-line building control system. With 3-D, interactive graphics, the system allows you to adjust temperature on an entire floor, an entire building or the whole complex. We were also able to tie in and control our Energy Recovery System from Engineered Air."



CONCLUSION

VRF technology is poised to become the primary heating and cooling method of the future, but conventional, complementary and specialized HVAC technologies will continue to serve select areas of the built environment. With VRF controls and integration services from VRF manufacturers, facility managers can streamline management of both VRF and third-party HVAC equipment. The combination of advanced building management controls and services offered by VRF manufacturers ensures that building owners and facility managers maximize their time and budgets.