Variable Refrigerant Flow:

Maximizing Usable Square Footage and Occupant Comfort

White Paper

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MITSUBISHI ELECTRIC
COOLING & HEATING

Comfort trumps everything. We all recognize that no one wants to be in a building that's uncomfortable. It doesn't matter how beautiful or innovative the building is; if people don't want to be in it, it's ultimately not a successful project. This is a difficult truth for designers in a world of tantalizing projects and details. A further complication is that architects are responsible for multiple kinds of comfort: feeling, seeing and hearing. A building must feel, look and sound good in order for occupants to enjoy its statement.

When it comes to commercial buildings, architects face two main challenges in incorporating HVAC systems that bolster occupant comfort. The first is space. HVAC systems have traditionally been quite large, with outdoor units requiring ample square footage on rooftops or grounds. Indoor units and ductwork consumed plenty of interior space in ceilings and plenums. This is bad news in a business focused on usable square footage. Ultimately an HVAC system should maximize an area's usability, enabling architects to create more useable space for their clients.

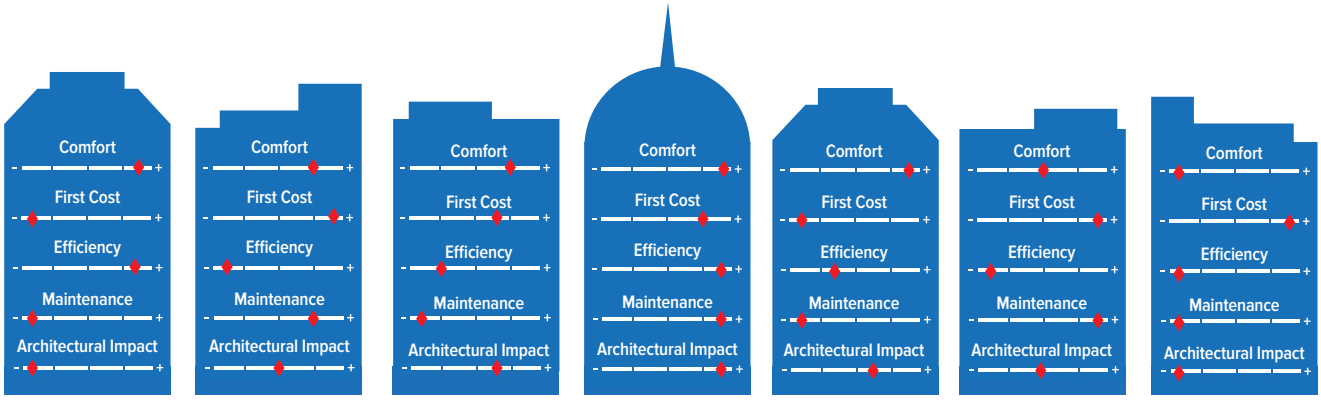
The other main challenge in designing an HVAC system for comfort is acoustics. Architects will avoid using a system that the client – or the client's tenants – will complain about. Loud outdoor units, noisy indoor units and a vibrating structure are all problematic, and best avoided.

The challenge is on for architects to turn this design obstacle into an opportunity. Architects can influence their clients and improve project performance, making a significant difference to the end user, which matters to their clients; and provide a differentiator to their clients that may increase rental rates and decrease vacancy rates. It all starts with knowing your options.

The Best Option: VRF

As much as 40 percent of a building's operating costs are tied to HVAC and other mechanical systems. It's important to minimize operating costs while achieving other goals like reliable performance, a modern aesthetic and personalized comfort. Variable Refrigerant Flow (VRF) is an HVAC technology that minimizes operating costs. It makes the most of square footage and budget while offering energy-efficient technology that provides outstanding comfort.

Compared to other systems – such as Variable Air Volume, Rooftop Units and Water-Source Heat Pumps – VRF is highly favorable in every category:



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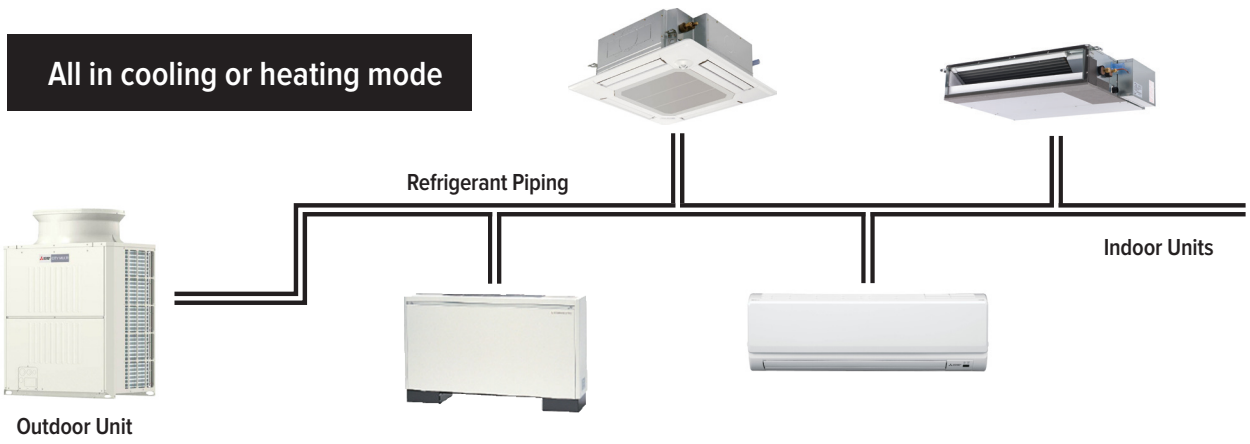
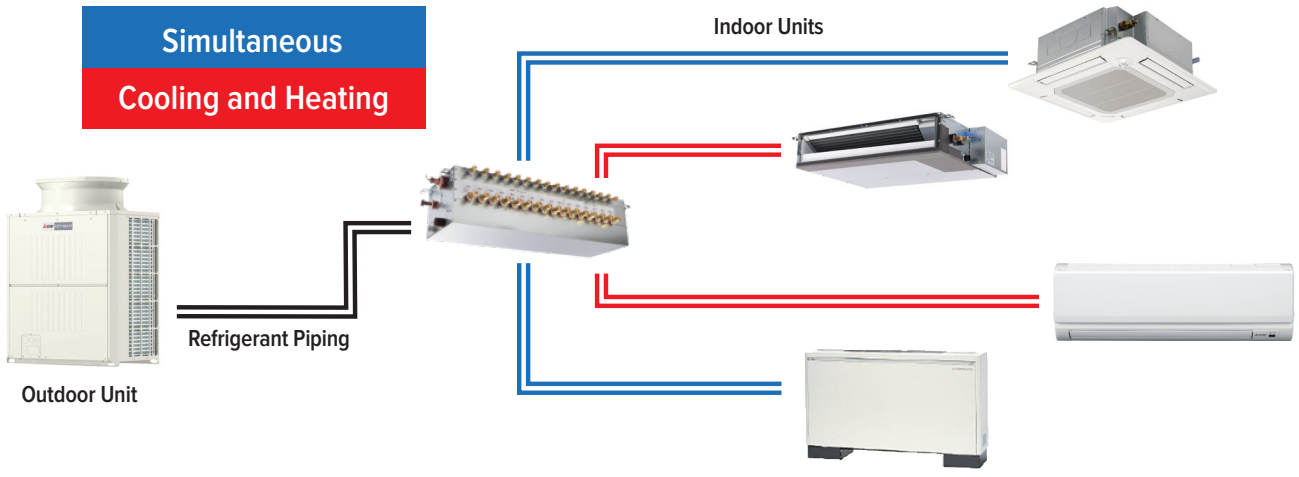
How does VRF achieve such high marks? A building's interior is broken into zones, each of which can be operated separately; one room can be cooled while another is simultaneously heated. This is possible because of the outdoor units' INVERTER-driven compressor that varies the motor rotation speed, allowing it to precisely meet each zone's conditioning requirement while reducing overall power consumption. The system's total capacity is distributed to each indoor unit via the branch circuit controller. The result is a facility where each zone can be customized.

Single-zone Basic System

Multi-zone Commercial Systems (Heat Pump)



Multi-zone Commercial Systems (Heat Recovery)



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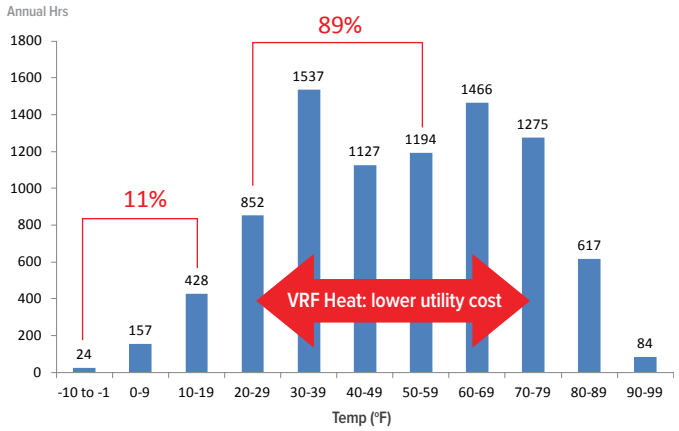
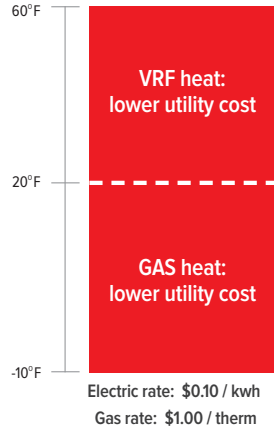
This is not a new technology. VRF has been used throughout the world since the 1980s. In many countries, it is the most-used HVAC technology: for example in Japan VRF represents 90 percent of installed systems within Commercial buildings, Europe 81 percent and China 86 percent. Architects have favored VRF systems for many reasons, among them longer line lengths for more flexible design and more affordable cold-climate heating.

These charts provide an example, demonstrating Chicago's heat economics. For 89 percent of Chicago's heating season, it is cheaper to heat with VRF than any other kind of HVAC system.

Chicago Heating Season



Heat Economics



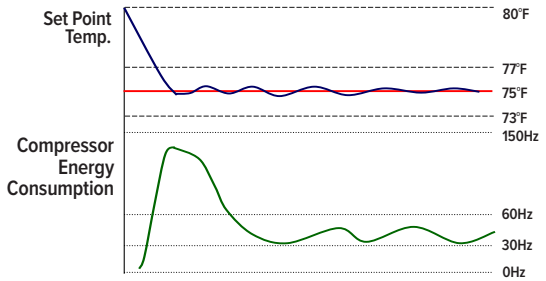
Electric rate: $0.10 / kwh
Gas rate: $1.00 / therm

VRF has also been well-received because of its variety of indoor unit styles that let architects design around their vision without the traditional constraints of an HVAC or mechanical system.

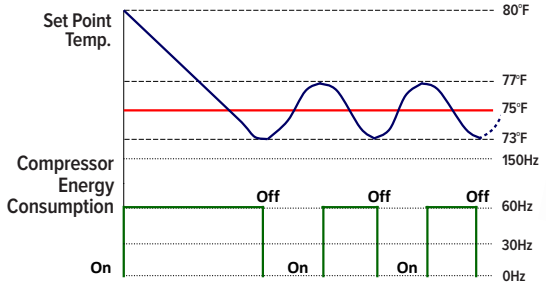
The result for the end user includes:

1 Precise temperature control

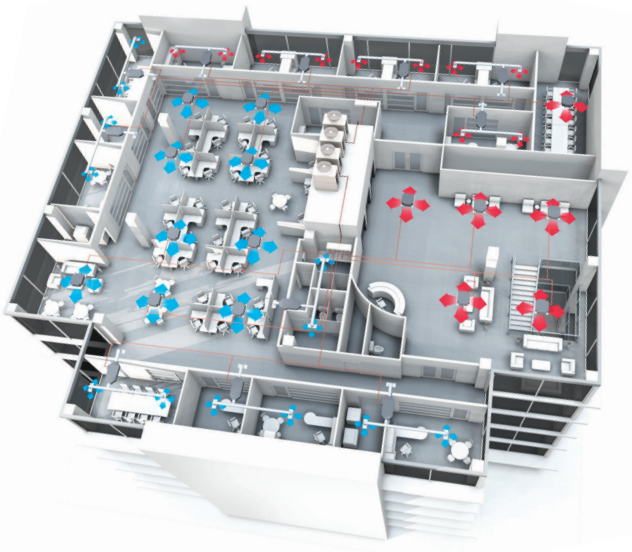
Inverter-driven Compressor



Traditional Compressor



2 Elimination of hot and cold spots.



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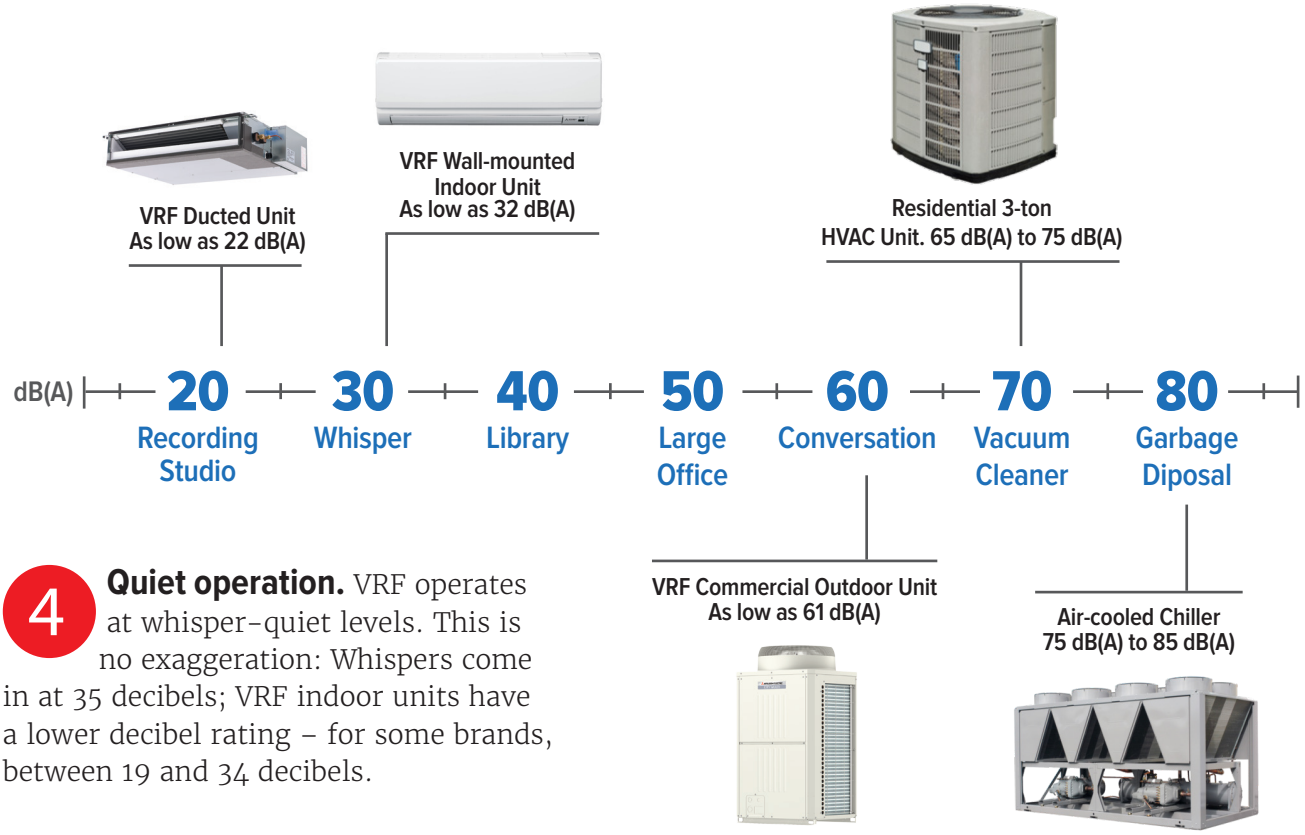
3 **Reduced utility bills.** With less energy used to operate the system, utility bills with VRF are low throughout the year.



4 **Quiet operation.** VRF operates at whisper-quiet levels. This is no exaggeration: Whispers come in at 35 decibels; VRF indoor units have a lower decibel rating – for some brands, between 19 and 34 decibels.

5 **More awe factor because of more space.** All of the space saved with VRF's smaller footprint means more room for the architect to play. Picture being able to offer higher ceilings, smaller or no mechanical rooms, more rooftop space and more garden space, among many other options.

About This Building

VRF offered residents of one of San Diego's tallest towers four to six additional inches of ceiling height, providing more visibility and an even roomier feel.

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VRF and Architects: an Ideal Pairing

Designers turn to VRF for a multitude of reasons. From a building's exterior to interior, from an architect's clients to the end user, VRF has the features and benefits that let architects' design shine.

The exterior of a commercial building is still a space of usable square footage. VRF's modular and compact design eliminates the bulky condensing units of traditional HVAC systems. This enables flexible design; outdoor units can be spread around a property or located together, placed inside or outside, placed in a mechanical room or in an alleyway.

About This Building

The David Whitney Building, a class A skyscraper in Detroit, used VRF's flexibility to split outdoor units across three areas: on the roof, in an alley and in the basement.

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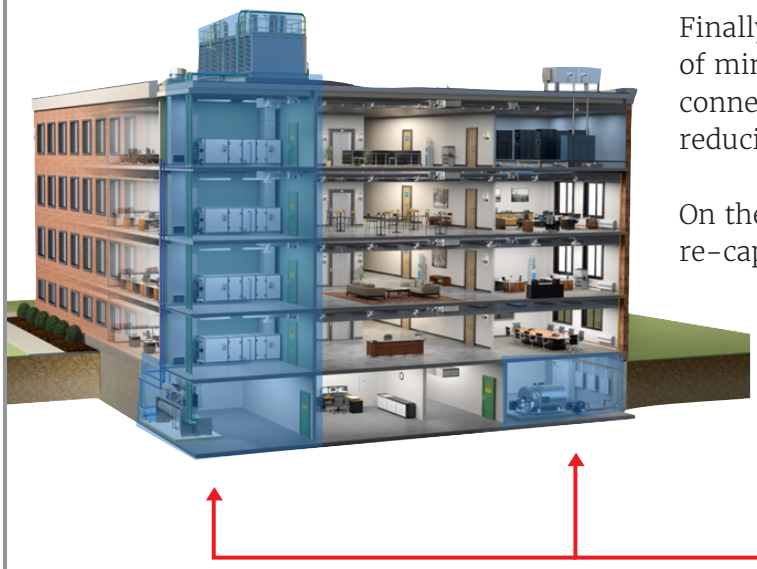
VRF's smaller footprint also means a lighter weight. For example, VRF is 31 percent lighter than chilled-water systems. The implications are profound: ultimately, lower construction costs. This is possible because installations of lighter systems require less structural support, reducing the amount of physical materials and labor required.

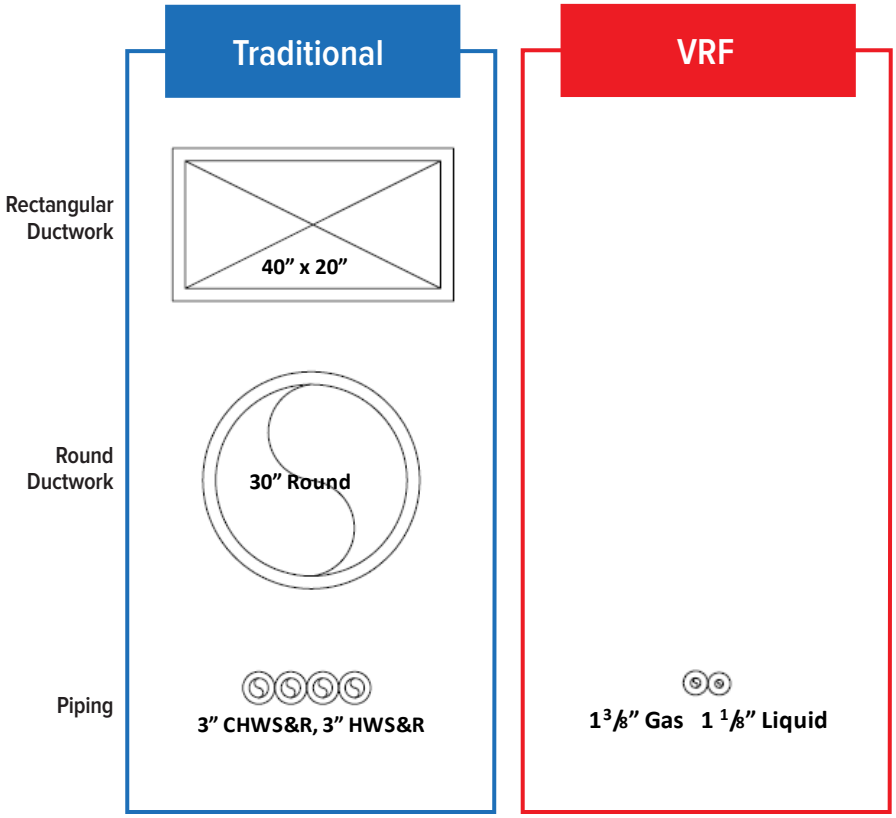


Finally, the smaller footprint also takes the form of minimized wall penetrations. Two small pipes connect the outdoor units to the interior system, reducing installation costs and impact.

On the inside of a building, VRF is all about re-capturing usable square footage.

VRF enables architects to reclaim usable square footage – for example spaces that otherwise would go to mechanical rooms, like the highlighted areas.

VRF also means reduced or no ductwork:



By reducing the plenum size, designers can raise their ceiling heights. The benefits are threefold:

1. a more spacious, modern feel
2. lower construction costs due to the possibility of designing shorter buildings
3. the option to add an additional floor for more leaseable space

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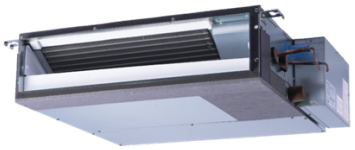
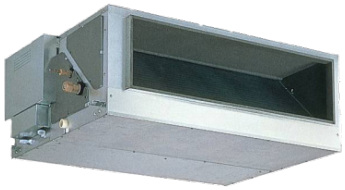
With 11 indoor unit styles and the ability to mix and match ductless and ducted options, architects can design to their vision. Some of these indoor unit choices are as follows –

Wall-mounted



Low Profile
Ceiling-concealed Ducted



High Static Ducted

1-Way
Ceiling-recessed Cassette

Multi-position

Floor-standing

4-Way Ceiling-recessed Cassette

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The owner's perspective

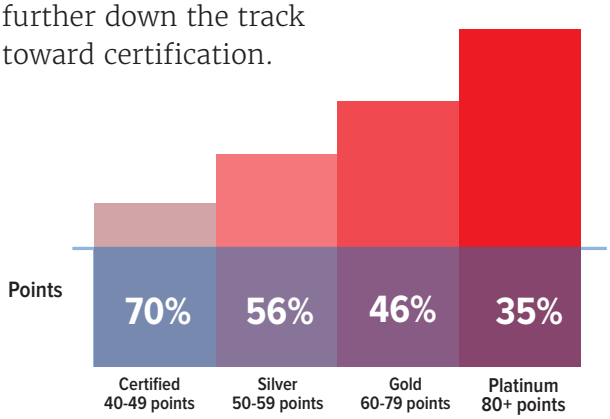
Building owners have repeatedly demonstrated a preference for VRF. It's not hard to understand why:

1 **Controls.** From simple remote controls to whole building controllers that tie in multiple automated systems, VRF works on management platforms that are user-friendly and highly effective. Facility managers can access and operate their systems from any place, at any time of day or night. Current controller options empower owners and managers to make the most of their systems – from adjusting set points, to enjoying the convenience of energy allocation and after-hours usage billing.

3 **Maintenance.** VRF has fewer components than traditional systems, and in the case of maintenance that means many fewer to-dos.

Item	Traditional	VRF
Water treatment	X	
Cooling tower	X	
Pump seals	X	
10-year overhaul	X	
Boiler overhaul	X	
Chiller maintenance	X	
Tube brushing	X	
Belt changes	X	
Strainer cleaning	X	
Filter changes	X	X
Condenser cleaning	X	X

2 **Energy efficiency.** VRF consistently performs at 25 percent higher efficiency than conventional systems. Such efficiencies are a big help in achieving certification through LEED® and other green rating programs. As an example, VRF consistently earns 28 points across two LEED categories (Energy and Atmosphere and Indoor Environment) – advancing a project further down the track toward certification.



4 **Lifetime cost savings.** VRF's initial cost is generally comparable to that of traditional systems, however when you factor in maintenance and energy usage, VRF is the clear choice. This is due to a reduced cost of installation (fewer connections needed, less demanding labor), reduced structural work needed to the building and reduced operational cost due to VRF's high efficiencies.

5 **Expandability.** VRF's modular nature enables phased projects. There is virtually no limit to how large a VRF system can be. This helps owners better budget and know what to expect. Additionally, VRF's lack of heavy infrastructure as compared to chiller plants, boiler systems and cooling towers, among other HVAC systems, means there is simply more room and weight allowance.

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Knowing when to use VRF. To say that VRF is always the ideal system is inaccurate. In some applications, VRF's added features are unnecessary. A cooling-only climate, for example, doesn't need VRF's additional heating capabilities such as hyper-heating technology. A large, open space like a warehouse doesn't need VRF's zoning capabilities.

When does VRF make sense as a comfort solution?

- When individual occupant comfort is important (health and wellness facilities, multifamily buildings, hospitality facilities).
- When lack of operational noise is important (theaters, recording studios, educational facilities).
- When there's limited/no space for ductwork (historic retrofits, cinderblock walls).
- When an owner has needs relating to cost, energy usage and square footage.

About This Building
VRF offered Teatro Angela Peralta, Mazatlán, Mexico, near-silent operation, and also enabled an easy installation that did not damage the 134-year-old structure.

Applications

Suites on Paseo

San Diego, California

Scope: 98,000 ft² **multifamily** facility housing 287 residents.

Challenge, Results: An HVAC system for a new multifamily building had to meet both high occupant expectations and strict energy standards. VRF offered easy installation and an advanced controls network across 300 separate zones, and enabled LEED Silver certification.

"This foundation allowed our all-in design to beat the baseline by 46 percent, which got us 11 out of 10 LEED points in the v2.2 system. Yes, there's a bonus point in there."

– Michael Bigelow, LEED certification specialist, California Center for Sustainable Energy

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Sacramento Drill Tower

Sacramento, California

Scope: 9,476 ft² concrete facility – two-thirds of which is a water tower, one-third of which is **offices**.

Challenge, Results: The facility's old, failing mechanical systems cost too much money to operate and required substantial maintenance. VRF drastically cut maintenance calls and led to a total energy savings (kBtu usage) of 50 percent and a total cost savings of 19 percent – in the range of $5,000 a year.

Change in Energy Usage and Energy Bill
Between pre-installation and post-installation years

Month	kBtu Usage	Energy Bill
January	-48%	-6%
February	-47%	-1%
March	-33%	-4%
April	-53%	-9%
May	-57%	-28%
June	-47%	-26%
July	-55%	-33%
August	-57%	-38%
September	-29%	-10%
October	-61%	-31%
November	-44%	-8%
December	-58%	-24%

Towson City Center

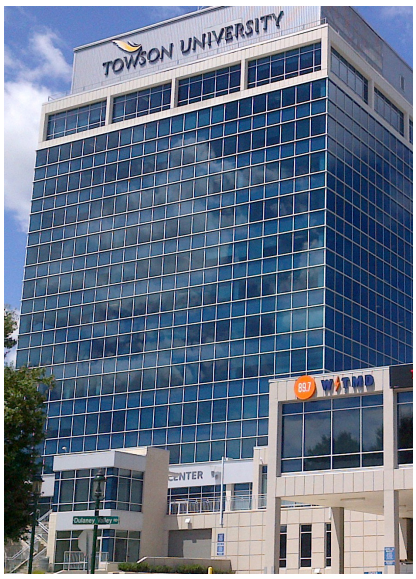
Towson, Maryland

Scope: 170,000 ft², 15-story **high-rise** building.

Challenge, Results: Renovating a 1960s high-rise with low deck height meant any HVAC system with ductwork was off the table. VRF offered a solution that was not just possible, but that won a $421,999 utility rebate and helped earn LEED Silver certification.

"In many ways, that has been the most satisfying [project of my career] because, as a team, we made [the project] work. We turned a long-standing eye-sore in the middle of town into a LEED Silver landmark of great value."

– D. Ronald Brasher, AIA, president, Brasher Architects



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Screven Elementary School

Screven, Georgia

Scope: 143,000 ft² **educational** facility.

Challenge, Results: Replacing a dated and inefficient HVAC system with VRF offered a quick installation that didn't disrupt operations, cost-saving centralized controls and a 25 percent average annual energy savings.

Average Energy Savings: 25%
Average Yearly Savings: $16,226

	Average Monthly Cost	Energy Use
Pre-Renovation	$12,375	115,833 kWh
Post-Renovation	$11,023	87,313 kWh

Grand Lake Mental Health Center

Nowata, Oklahoma

Scope: 20,000 ft² **health and wellness** facility.

Challenge, Results: The sensitive nature of patient-doctor conversations required an HVAC system that could maintain privacy while also guaranteeing physical comfort. VRF created a safe, functional environment, and was flexible enough to serve the facility's many spaces – patient rooms, gym, pharmacy, etc.

That risk of voices carrying is not happening with the [VRF] system. The design of the system allows for privacy."

– Larry Smith, chief operations officer, Grand Lake Mental Health Center

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The Hotel Wilshire

Los Angeles, California

Scope: 74-room boutique **hotel**.

Challenge, Results: Renovating a 1950s medical office building into a luxury hotel meant starting from scratch on design – including HVAC design. VRF offered the whisper-quiet operation discerning guests demand, and created space for a rooftop pool. A bonus: LEED Silver certification.

"One of the most common complaints at hotels is the noisy, uncomfortable HVAC system forever turning off and on in your room. In contrast, The Hotel Wilshire indoor units are so quiet and the room is so comfortable that the sleeping experience here is unlike any other."

– Debra Matsumoto, general manager, The Hotel Wilshire

Union Mill

Baltimore, Maryland

Scope: 86,000 ft² **mixed-use** development of residences, offices and a restaurant.

Challenge, Results: Retrofitting a 140-year-old canvas mill into a mixed-use facility involved working around two-foot-thick stone walls, zoning and noise restrictions, and equipment sitelines. VRF's configuration flexibility and multi-zone design delivered a cash rebate of $164,258 and LEED Silver equivalency.

"Thanks to the ingenious engineering of INVERTER-driven compressors and heat exchangers, my average apartment energy usage is only $50 a month."

– Evan Morville, partner, Seawall Development Company

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Leaders in the Field

For decades now, VRF has enabled architects to push the envelope. VRF is a proven technology but it still feels cutting edge. Visually, it looks modern and sleek. In terms of benefits, it's continually leading the pack. VRF lets architects confidently use the highest-efficiency mechanical system on the market while seeming ahead-of-the-curve. Ultimately, VRF enables architects to be leaders in their field and provide an efficient (both energy and operationally) solution to their clients.

Learn more about VRF while earning AIA Continuing Education Learning Units. Visit Architect, Architectural Record and The Continuing Architect to find courses on achieving LEED points, trends in retail and hospitality design, and more.

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