



Unlocking the Future of HVAC: The Rise of VRF Systems

What Are VRF AC Systems?

The term VRF, also known as variable refrigerant flow, utilizes refrigerant for both heating and cooling purposes, providing highly adaptable solutions for a variety of applications. The technology was first developed by Daikin Industries in 1982.

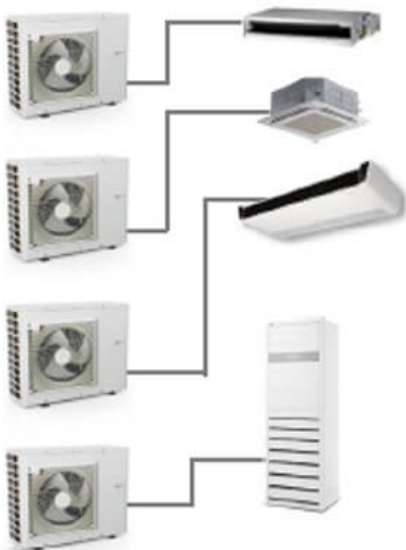
[VRF](#) is a large-scale, extremely efficient, ductless [HVAC](#) system that operates in a large-scale application. In contrast to [split ACs](#), VRF systems can support multiple indoor units that operate on a single system and can be tailored based on the end-user requirements.

VRF systems can be bifurcated into heat recovery and heat pump systems. These systems have the distinctive capability of simultaneously providing heating and cooling.

These systems have multiple air handlers that can be controlled independently. This means that VRF systems work silently even when operating at full capacity.

VRF is designed for industrial and residential use. It can work as a heat pump or a cooling system, and users can benefit from both heating and cooling simultaneously.

Single split



VRF

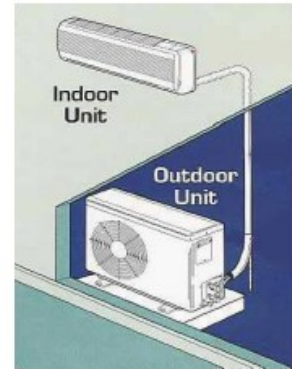


VRF Versus Other HVAC Types

Split Air-conditioning Systems

Split type air conditioning system is one-to-one systems consisting of one evaporator or the [fan coil unit](#) connected to an external condensing unit. Both the indoor and outdoor Electrical cabling and copper tubing are used to link the units.

Heat is extracted from the surrounding air by the indoor component (evaporator) and released into the environment by the outside condensing unit.

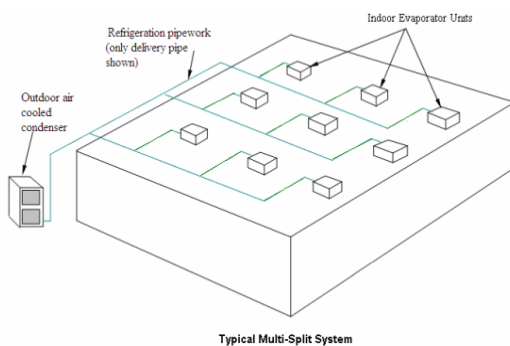


Split Air-conditioning System

Multi-Split Systems

A multi-type air conditioning system functions on the identical ideologies as a split type [air conditioning](#) system however in this case there are manifold evaporator units connected to one external condensing unit.

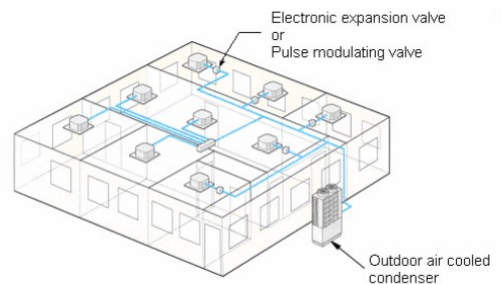
These simple systems were intended mainly for small to medium size [commercial infrastructure](#) where the installation of ductwork was either too costly, or visually unacceptable.



Typical Multi-Split System

Variable Refrigerant Flow or VRF Systems

VRF system functions similar to the multi-split system connecting one outdoor unit to several other evaporators. Conversely, multi-split systems turn ON and OFF entirely in response to single master controller, while VRF systems continually adjust the flow of refrigerant to each indoor evaporator.



VRF System with Multiple Indoor Evaporator Units

The control is attained by constantly varying the flow of refrigerant through a pulse modulating valve (PMV) whose opening is determined by the microprocessor in receipt of information from the thermistor sensors in individual indoor unit. The indoor units are connected by a control wire to the outdoor unit which responds to the request from the indoor units by varying its compressor speed to match the total cooling and/or heating requests. VRF systems has an ability to deliver a more energy-efficient strategy (ranging from 11% - 17% less energy as compared to conventional HVAC system) at a slightly higher cost.

Types of VRF AC Systems

Types	Description
Heat Pump VRF System	The heat pump VRF system works on the principle of reversing the flow of the refrigerant in the outdoor unit for both heating and cooling output.
Heat Recovery VRF System	This type of VRF system offers simultaneous heating and cooling in different areas of the infrastructure. It uses a heat exchanger to transfer heat between refrigerant circuits.
Water-Cooled VRF System	A water-cooled VRF system is predominantly used in areas with high ambient temperatures. These systems use water as a cooling medium instead of air.
Hybrid VRF System	A hybrid VRF system is a crossbreed technology that combines a traditional air-cooled system with a water-cooled system to offer better efficiency and flexibility.
Simultaneous Cooling and Heating (SCAH) VRF System	The SCAH VRF system permits both heating and cooling to occur simultaneously in different areas of the infrastructure without the requirement for a separate heat recovery system.

Source: The Insight Partners



VRF System – Market Drivers

Need for Energy Efficiency and Conservation

VRF systems reuse waste/excess heat instead of discharging it into the environment; it is directed to other parts of the building that require heating, which saves energy and contributes to further waste reduction. A VRF system network is intended to provide an appropriate amount of refrigerant to the corresponding interior units.

VRF system operates without ducts, this as a result, improve the energy efficiency of these systems. In a traditional HVAC system, the loss of cool air through ducts accounts for more than 30% of total energy usage. Whereas, in the VRF system, there is minimum energy consumption as the indoor units cools the area according to their current environmental condition, and thus, the compressor's ability get boosted or lowered to minimize the energy utilization.

Traditionally, conventional HVAC systems only allow a couple of options when it comes to temperature and operate simply by turning on and off. On the other hand, VRFs present an advanced system for heating and cooling with simultaneous heating and cooling in various zones in the building. This translates to occupants getting a more convenient and flexible environment through setting up desired temperatures.

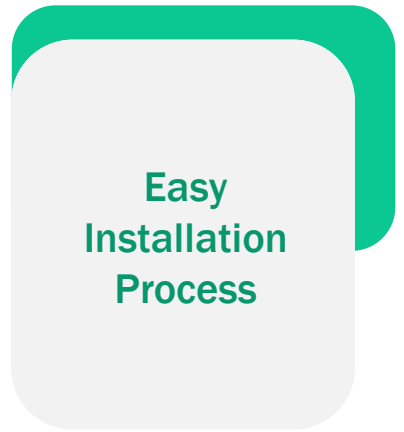
Customization Options

Flexibility in Design

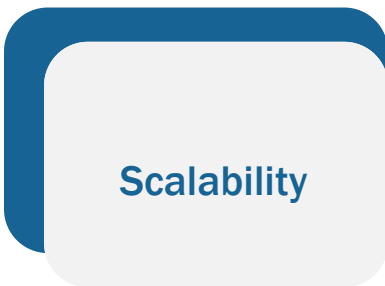
Various types of VRF system are available in different sizes, suitable for numerous applications. The user can choose the appropriate system depending on the application.

In case of space issues, VRF systems also come in sleek and compact options that are perfect for areas with limited space. These space-saving designs provide an efficient and effective heating and cooling solution without taking up valuable room.

Large-scale commercial HVAC systems can be expensive to install as these utilize large area to install the heating and cooling system. VRF systems are compact, and they do not take up much space for maintenance areas. These systems also do not use bulky equipment such as distribution fans or water pipes, making the installation of the VRF system easier and cheaper in a commercial space.

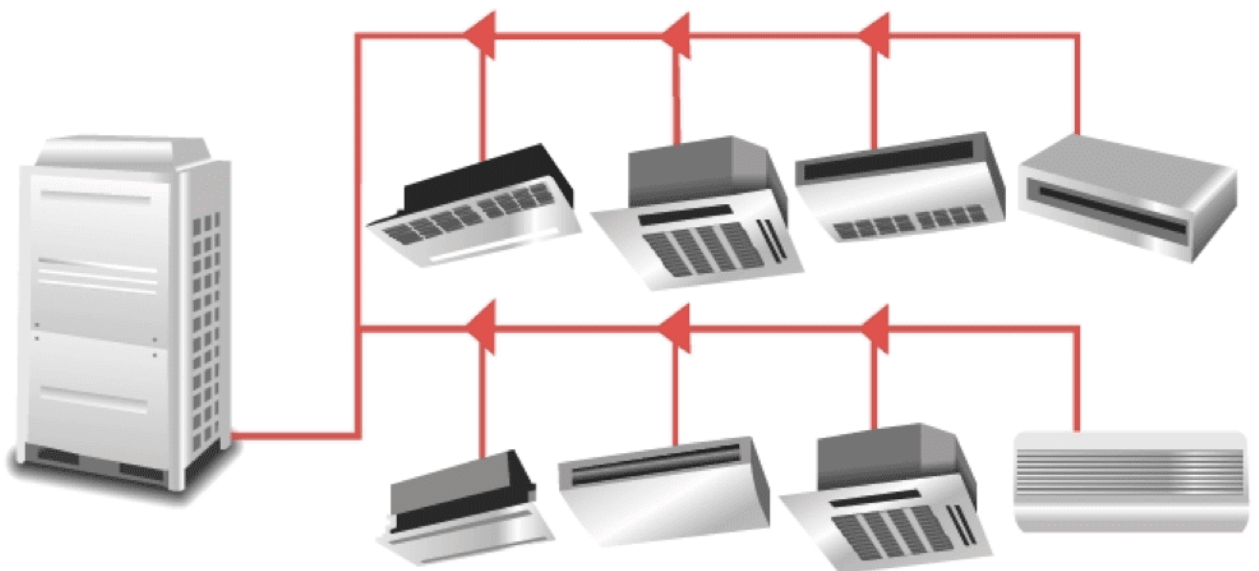
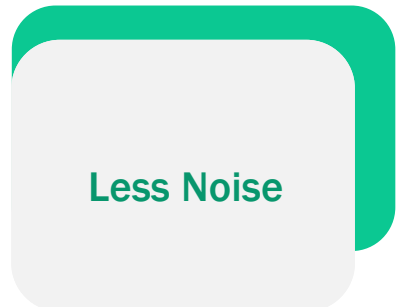


Since the VRF system is compact in size, its installation is more straightforward and not expensive compared to conventional HVAC systems.



Once VRF ACs were perceived to be best suited only for commercial buildings. However, they have evolved to be compatible with wide-ranging heating and cooling products. Now, they are capable of effectively conditioning small, single-family houses as well as big commercial skyscrapers.

One of the most important benefits of VRF systems is lower noise levels compared to traditional HVAC systems. This can be attributed to the fact that the condenser unit is outside the building, and small air handlers are installed separately and independently controlled, as discussed earlier. Therefore, VRF systems are apt for commercial or office space where noise is the problem.



VRF System – Market Challenges



High Initial CAPEX

Despite being more energy-efficient and more economical in the long run, VRF systems require a huge initial capital investment compared to conventional HVAC systems. The costs of products and installation of outdoor and indoor units, along with the requirement of specialized piping and components, puts off potential customers.

Moreover, the VRF HVAC systems can be more labor-intensive than typical HVAC systems, particularly in big or complicated buildings, which further raises the costs associated with the initial setup. These systems come with specialized maintenance standards to maintain proper operations. Many corporate and residential consumers may find VRF systems unaffordable due to the hefty upfront costs. VRF systems frequently compete with less

expensive HVAC choices such as split systems and packaged units. The increased initial cost may make VRF systems less appealing to budget-conscious users. According to a study conducted by Washington State University, the installation cost of a VRF system is approximately US\$ 18 per square foot served, compared to a code-minimum system cost of US\$ 12–15 per square foot, a price difference compounded quickly over the scale of the building. Thus, a substantial upfront cost hinders the growth of the market.

This might limit VRF adoption in the near future, particularly in budget-constrained countries or for small- to mid-scale projects where upfront cost is a big decision-making factor.

VRF System – Industry Trends



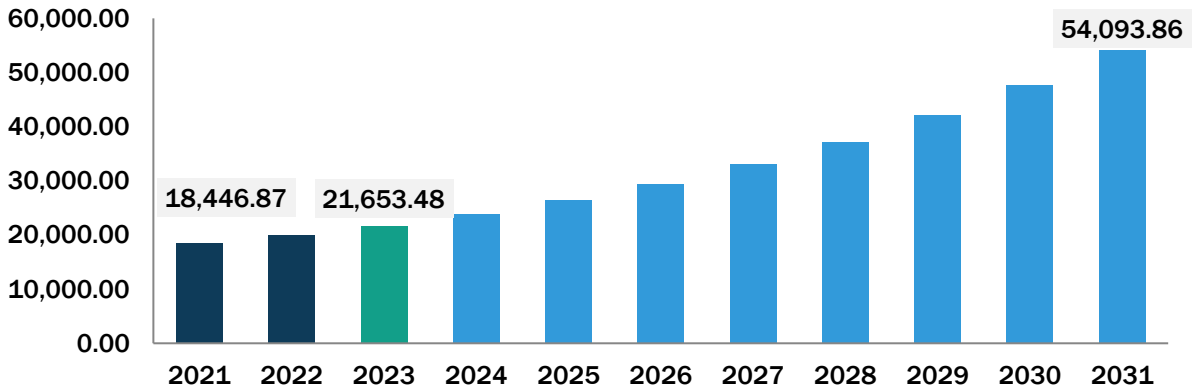
VRF System Integration with Home Automation

VRF systems are cutting-edge HVAC solutions noted for their versatility and energy efficiency. VRF systems provide better control, comfort, and energy efficiency when combined with home automation systems. Home automation systems offer centralized control interfaces, allowing customers to monitor and control their VRF systems from one location. Homeowners can use touch panels, smartphone apps, or voice assistants to alter temperature settings by regulating fan speeds and even plan HVAC operations to their liking. When VRF systems are combined with [home automation](#), energy efficiency is increased. The automation system uses occupancy sensors and sophisticated algorithms to optimize HVAC operations depending on room occupancy, natural illumination conditions, and time schedules. This ensures that energy is only used when

necessary, resulting in significant energy savings. Integrating VRF systems with home automation improves comfort and air quality control. The automation system can modify temperature and ventilation settings based on occupancy or air quality sensors, maintaining optimal indoor conditions while reducing energy waste. Integrating VRF systems with home automation provides various advantages, such as individual zone control, centralized management, energy efficiency, demand response capabilities, and increased comfort and air quality. Homeowners can use automation to optimize their HVAC operations, cut energy consumption, and experience individualized comfort in every room of their home. Thus, the integration of VRF systems with home automation can set a trend in the VRF system market.

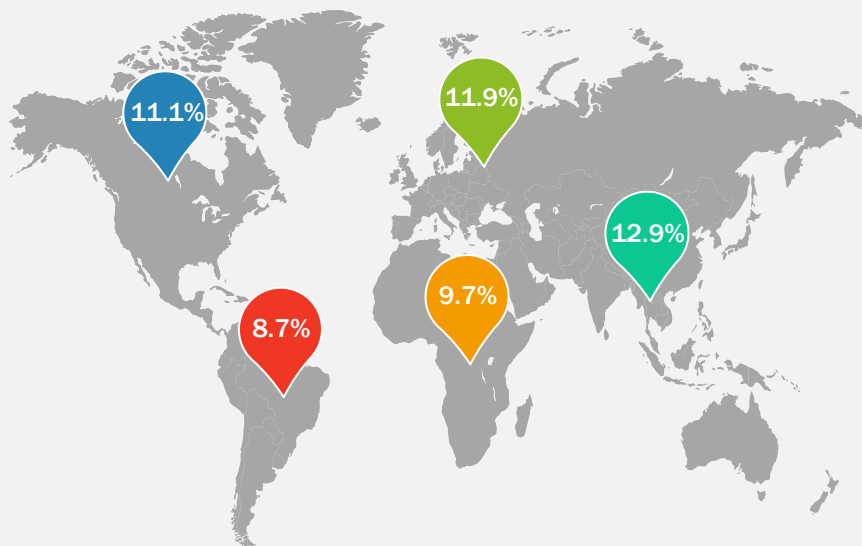
VRF System Market Revenue and Forecast

VRF System Market Revenue (US\$ Million), 2021–2031

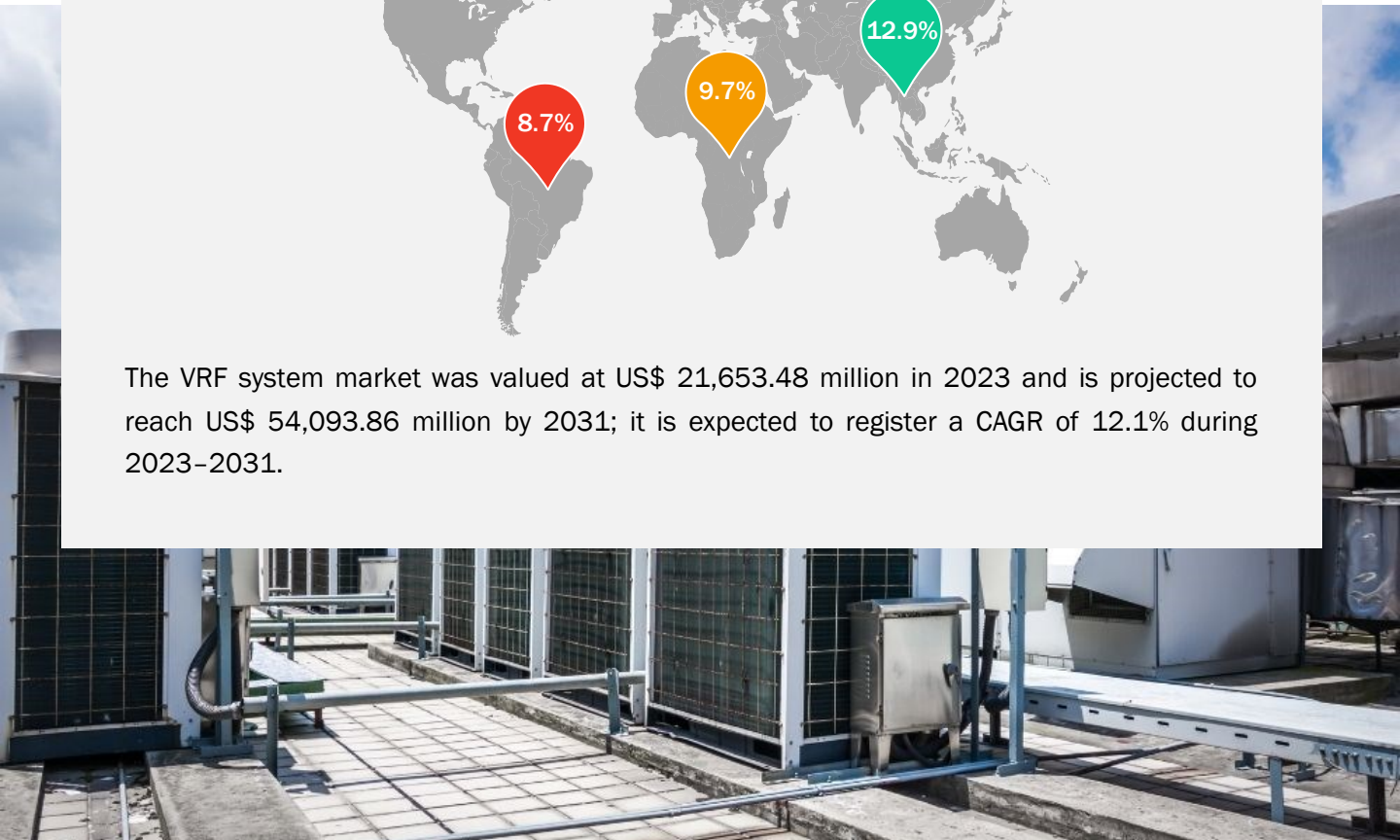


Source: The Insight Partners

VRF System Market Breakdown by Region, CAGR (2024 - 2031)



The VRF system market was valued at US\$ 21,653.48 million in 2023 and is projected to reach US\$ 54,093.86 million by 2031; it is expected to register a CAGR of 12.1% during 2023–2031.



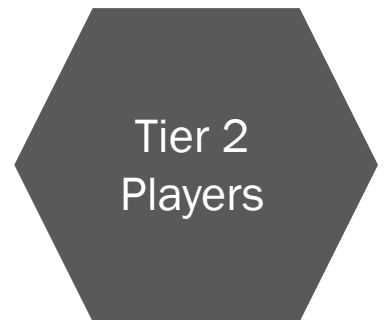
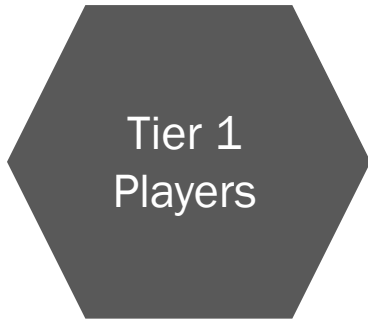
Geographic Outlook - VRF System

- **North America:** VRF systems are widely used across North America owing to their crucial role in improving energy efficiency in several operations across the HVAC industry. The market is primarily driven by increasing commercial infrastructure projects, fast urbanization, and high construction spending. The US and Canada are two of the top ten energy-consuming nations in the world, with the US registering the second position after China. Various refrigerants are used in the VRF systems which help to reduce energy consumption.
- **Europe:** The VRF system market growth in Europe is mostly driven by increased residential infrastructure projects and rising government regulations regarding energy efficiency. In European countries, such as Germany, the UK, and France, the government is highly focused on energy efficiency and the use of environment-friendly refrigerants. Several initiatives are being put forth to promote sustainable building development in Europe. A number of European businesses have committed to reducing their building's CO₂ emissions to zero with the use of VRF systems.



- **Asia Pacific:** In Asia Pacific, the rising temperatures and unpredictable weather have encouraged consumers to adopt VRF systems across numerous countries. According to the World Bank, China is implementing a revamp of its construction industry as part of China's efforts to stabilize economic growth. The plan was devised by multiple government agencies, including the Ministry of Industry and Information Technology (MIIT), smart and green building sector by tackling aspects such as supply, investment, consumption and international cooperation. The MIIT expects the country to have more than 3,000 certified green products and more than 1,500 certified green building material companies by the end of 2024.
- **Rest of the World:** Similarly, in other part of the world such as Middle-East & Africa and South & Central America, companies are developing new products and spreading awareness regarding VRF systems. Several countries in South & Central America are inclined toward developing national energy efficiency initiatives and offering them regulatory and legal support.

Key Companies - VRF System

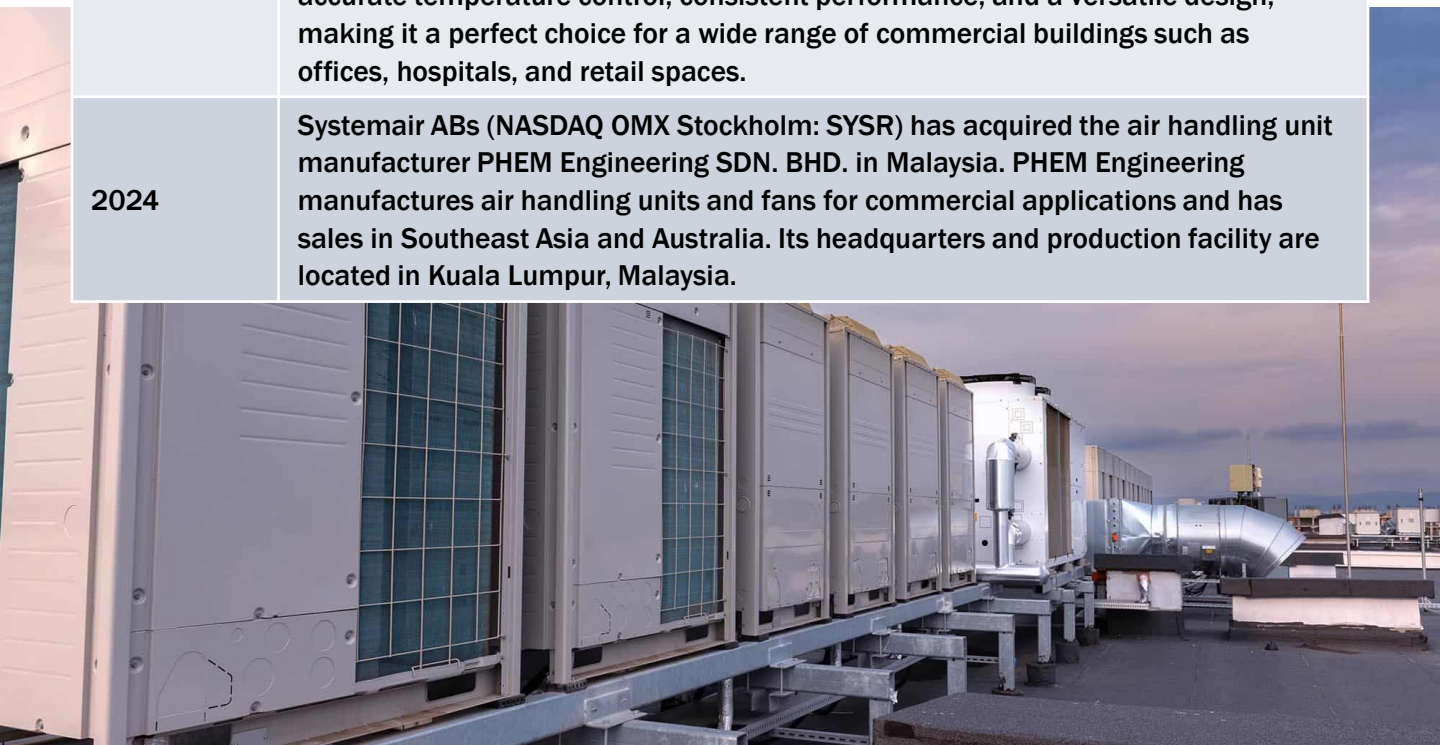


Prominent stakeholders in the VRF system market ecosystem are component providers, VRF system manufacturers, and end users. Component providers provide indoor units, outdoor units, central remote controllers, wired and wireless remote controllers, and other accessories to the VRF systems manufacturers. The timely supply of all these components is

crucial for efficient operations across VRF system manufacturing plants. Thus, any operational impact on these component providers directly impacts the VRF system market. A few of the key VRF system manufacturers in the market are Daikin Industries, Ltd.; Samsung; Panasonic Corporation; Carrier; and Mitsubishi Heavy Industries, Ltd., among others.

Industry Initiatives

Year	News
2024	Panasonic Life Solutions India (PEWIN)—a manufacturer of modular and non-modular electrical switches in India and a subsidiary of Panasonic Corporation, a Japan-based multinational electronics company—has opened a new manufacturing unit in Daman, Gujarat. This marks the company's initial foray into lighting product production in India. The company has invested US\$ 180,000 (INR 15 million) in the new facility.
2024	Lennox (NYSE:LII), a provider of innovative climate solutions in the HVACR industry, and Samsung—a trusted global brand with 40 years of innovative HVAC technology—announced that they have signed a joint venture agreement to sell ductless AC and heat pump (mini-split, multi-split, VRF) products in the US and Canada. The newly formed joint venture will be called Samsung Lennox HVAC North America.
2024	Yanmar Holdings Co., Ltd. has acquired all shares of CLAAS India, a manufacturer of agricultural machinery in India, through its group company Yanmar Coromandel Agrisolutions. The new entity is named as Yanmar Agricultural Machinery India Private Limited (YAMIN) effective November 20, 2024. The acquisition aims to accelerate the expansion of Yanmar's Agribusiness in India by bringing into its fold a company with a world-class facility and a proven track record in the production of high-quality and durable combined harvesters.
2024	Trane Technologies launched its new GEN Elite C Series VRF system, a cooling-only variable refrigerant flow (VRF) system for India, Thailand, Vietnam, and other expanding Asia Pacific markets. The innovative system provides great efficiency, accurate temperature control, consistent performance, and a versatile design, making it a perfect choice for a wide range of commercial buildings such as offices, hospitals, and retail spaces.
2024	Systemair ABs (NASDAQ OMX Stockholm: SYSR) has acquired the air handling unit manufacturer PHEM Engineering SDN. BHD. in Malaysia. PHEM Engineering manufactures air handling units and fans for commercial applications and has sales in Southeast Asia and Australia. Its headquarters and production facility are located in Kuala Lumpur, Malaysia.



Case Study 1

Overview

- Building Type: Commercial Office Complex
- Location: New York City, USA
- Size: 12 stories, approximately 250,000 square feet
- Project Duration: 2023–2024v

Challenge

The commercial office complex faced challenges related to energy efficiency, inconsistent temperature control, and the need for a flexible HVAC solution that could cater to the diverse needs of various tenants and office

spaces. Traditional HVAC systems were inefficient for the building's dynamic load demands, and the traditional HVAC system required high maintenance costs .

Solution: VRF System Implementation by Daikin

The building was retrofitted with a Daikin VRF system, which was designed to simultaneously meet the heating and cooling needs of different parts of the building.

Key Results

- **Energy Efficiency:** After the installation of the VRF system, the building saw a 30% reduction in energy consumption compared to the previous HVAC system.
- **Cost Savings:** The reduced energy consumption resulted in an estimated 25% reduction in operational costs for the building's HVAC system.

Case Study 2

Overview

- Building Type: Hotel Resort
- Location: Maldives
- Size: 120 villas, 3-story main building, 15,000 square meters
- Project Duration: 2023–2024

Challenge

The hotel resort faced challenges related to maintaining a consistent indoor climate across multiple guest rooms, villas, and public spaces in a tropical environment. Given the extreme heat and humidity of the Maldives, the hotel required a highly efficient HVAC system that could ensure consistent temperature control across various zones and provide individual control for guests' rooms. Along with this, the

resort also wanted to reduce the energy consumption while minimizing the environmental impact and move towards a low maintenance HVAC system.

The hotel management also wanted to minimize operational costs while providing a luxury experience for guests, which included ensuring a quiet, efficient, and comfortable air conditioning system throughout the property.

Solution: VRF System Installation by Mitsubishi Electric

To meet these requirements, the hotel resort opted for the installation of a VRF system. The

chosen system was supplied by Mitsubishi Electric, known for its reliability and energy efficiency in high-demand environments.

Key Results

- The VRF system's ability to modulate refrigerant flow in response to actual demand resulted in a 35% reduction in energy consumption compared to traditional systems. This was particularly valuable in the resort's tropical climate, where constant cooling is required. The heat recovery feature further enhanced energy savings by allowing the reuse of heat energy for areas that required heating.
- **Cost Savings:** The system's efficiency led to a 20% reduction in operational HVAC costs. Reduced energy consumption, coupled with low maintenance, contributed to significant savings for the hotel.

Conclusion

VRF is an energy-efficient HVAC solution that regulates the flow of refrigerant to several indoor units based on demand for precise temperature control across various zones. VRF systems have the immense capability to achieve significant energy savings and enhanced comfort and flexibility under a commercial and residential building umbrella. Although VRF systems have higher initial installation costs and require specialized maintenance, they provide long-term operational savings, reduced energy consumption, and scalable, adaptable climate control for diverse environments.

Suggested Reading

[VRF System Market](#)

[HVAC Contained Servers Market](#)

[HVAC Chillers Market Overview](#)

[Smart HVAC Controls Market](#)

[HVAC Relay Market](#)

[HVAC Insulation Market](#)

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