

Memorandum

To: Bonnie Watson, BPA
From: Rebecca Legett, Benjamin Freas, Nicole Reed Fry, Navigant Consulting, Inc.
Date: April 25, 2016
Subject: 2016 Air Conditioning, Heating, and Refrigeration Expo Findings

Navigant staff, along with the Bonneville Power Administration (BPA) market research team and program staff, attended the 2016 Air Conditioning, Heating, and Refrigeration (AHR) Expo, an industry trade show held from January 25 to 27, 2016 in Orlando, Florida. The purpose of attending the AHR Expo was to gather information on emerging technologies, trends, and supply chain issues in the Heating, Ventilation, and Air Conditioning (HVAC) industry as well as to network with market actors to facilitate future HVAC market research. Specific research objectives for the trade show included:

- Observe and document new and emerging technologies and trends in the residential and commercial HVAC markets
- Understand how these new trends impact BPA program strategy and future market research studies
- Inform the commercial and residential supply chains and decision chains
- Understand market niches to inform the chain logic method (e.g., understand how the different distributors and other data sources are similar or different from each other)
- Network with residential and commercial Northwest market actors to better facilitate future sales data collection efforts

Navigant and BPA staff scheduled interviews with several HVAC companies at the trade show and held informal conversations with many more—18 different organizations in total. The following sections discuss key findings from the interviews and conversations.

Who's Who

Many market actors make up the HVAC supply chain. We found that most of the leading HVAC manufacturers were in attendance at the trade show and had booth space. Two major manufacturers—Carrier and Trane—did not have booths, although some representatives from Carrier did attend the event. The team found very few Northwest HVAC distributors in attendance. Table 1 provides specific companies that either attended the trade show or were mentioned by others at the trade show to provide context for the interview findings in later sections. More detailed information about several of the market actors can be found in company profiles that the team prepared before the trade show, and are provided in an appendix to this report.

Table 1: List of Key HVAC Market Actors Referenced at the AHR Show

Leading HVAC Manufacturers (Original Equipment Manufacturers)	Component Suppliers
Carrier Corporation (includes the Bryant and Payne brands)*	Danfoss (compressors)*
Daikin Industries*	Emerson Climate Technologies (compressors)*
Johnson Controls, Inc. (joint venture with Hitachi)*	Viconics (controls)*
Lennox International*	ICM Controls (controls)*
Trane	Chemours (refrigerant)*
	Honeywell (refrigerant, controls)*
Other HVAC Manufacturers	Manufacturer Representative
Bosch Thermotechnology*	Johnson Barrow
CALMAC*	
Delta Product Corporation	
Fujitsu General*	Distributors
LG Electronics*	Johnstone
Mars/Heat Controller (includes the Century and Comfort-Aire brands)*	Airefco
Mitsubishi Electric Corporation*	Thrifty
Multistack	Keller
National Comfort Products*	Ferguson
Rheem*	Mars*
Samsung Electronics*	United Refrigeration
	Gensco

*Indicates companies that the research team spoke with at the AHR Expo

New and Emerging HVAC Technologies

Manufacturers discussed the following new and emerging technologies in the HVAC market:

- Commercial variable refrigerant flow (VRF) systems
- Residential ductless heating and cooling
- Dedicated outdoor air systems (DOASs)
- Advanced controls and smart thermostats
- Two-stage and variable-speed compressors

The following sections discuss the relevant trade show findings for each of these technologies.

Commercial VRF

Commercial VRF HVAC systems are a highly efficient type of ductless HVAC technology. A typical centralized system heats or cools air in one location and then distributes the air through ductwork to different parts of a building. In contrast, VRF systems distribute refrigerant through piping to different

parts of a building, where the refrigerant heats or cools air at or near the place where it is needed. VRF systems thus avoid the significant temperature losses that ductwork typically incurs.

VRF technology is emerging into the U.S. market from elsewhere in the world. The technology was developed in Japan several decades ago and has significant market share outside of the U.S.: An Asian VRF manufacturer said that VRF systems comprise 90% of the Asian market and 60% of the European market. A leading American manufacturer mentioned that VRF is a small slice of the market in the United States, and the company tends to focus its manufacturing efforts more on traditional rooftop units. Of the original equipment manufacturers (OEMs) the research team spoke with, Asian manufacturers in particular (e.g., Daikin, Samsung, LG Electronics, and Mitsubishi) were more likely to advertise VRF products at the AHR Expo and were more optimistic about its growth. U.S. manufacturers (e.g., Carrier, Lennox, and Johnson Controls), in contrast, were less likely to say that VRF was a major growth area or even to mention VRF in their product offerings. Consistent with our previous research findings that U.S. and Asian manufacturers often enter into partnerships to market ductless technology in the United States, the research team observed that Johnson Controls, a U.S. company, merged with Hitachi, an Asian company, to sell Hitachi's VRF product line.

Most OEMs said that VRF systems are particularly suitable for certain commercial and some large residential applications. Office buildings, schools and universities, multifamily/high-rise residential, and assisted living facilities were all cited as good candidates for VRF systems. Only Daikin appeared to have a VRF system for small residential applications among their product offerings. A major Asian VRF manufacturer noted that big box stores are generally not good candidates for VRF installations; they do not have multiple temperature zones or the need for long ducts, thus negating most of the benefit of a VRF system.

VRF systems are also far easier to install in new construction than as a replacement for an existing ducted system, so most installations are in new construction (e.g., 70% of one manufacturer's VRF business is new construction). It is possible to install a VRF system as a replacement for a ducted system; one major Asian VRF manufacturer noted that they sometimes install VRF systems using the existing ducts to route the refrigerant piping. Another major Asian VRF manufacturer also mentioned that in residential applications, the company can use existing ductwork with new air handlers in separate zones of the building. However, the system still incurs efficiency losses through the ductwork. One good retrofit application is replacement of a chiller system that distributes chilled water through pipes to condition separate spaces; an American manufacturer noted that it is fairly easy to replace the water pipes with refrigerant pipes to install a VRF system.

Several non-energy benefits help encourage installation of VRF systems. According to one manufacturer, VRF equipment is smaller and lighter and less limiting for architects because the refrigerant pipes take up far less space than ductwork. VRF system installations are also being encouraged by existing utility rebates and incentives. This manufacturer said that although VRF installations are largely driven by savings, a rebate can be the tipping point, and a prescriptive incentive is preferable. Another manufacturer noted that the amount of the incentive is important: they said that Southern California Edison (SCE) has offered a flat rate incentive of \$1000 per ton for VRF, which encourages installations, but Rocky Mountain Power has offered only a \$100 per ton incentive, which is not enough to drive uptake. (Note: The research team did not verify when these utilities offered these incentives or whether they are still valid)

Barriers to VRF implementation are chiefly high cost relative to other HVAC options and little understanding of long-term benefit. One VRF manufacturer pointed out that VRF implementations are typically custom-engineered products, and thus predicting the return on investment for a given customer can be complicated. Some organizations maintain models for predicting the energy savings: LG has energy models on its website showing the benefit of VRF, while Mitsubishi referred to the Weidt Group energy savings model, an energy use intensity comparison for VRF using DOE-2 modeling.

Residential Ductless Heating and Cooling

Residential ductless heat pumps, also called mini-splits, are another product that is emerging into the U.S. HVAC market. Like VRF, mini-split technology has been in place for some time; it originated in Japan in the 1970s.¹ Also similar to VRF, primarily the Asian manufacturers (e.g., Daikin, Samsung, Fujitsu) mentioned mini-splits at the trade show. A major Korean manufacturer estimated that ductless mini-splits are about 6% of the overall U.S. residential market today, and the size of the market is approximately \$450–\$600 million. A second Asian manufacturer noted that one perceived barrier to installation is the aesthetics of the equipment when it is installed on the wall of a room. Manufacturers sometimes work with installers and even architects to mitigate this drawback, either by hiding or disguising the cassette behind a wall or in a ceiling, or redesigning the cassette to make it more attractive.

DOAS

One manufacturer discussed dedicated outside air systems (DOAS). This technology is a separate ventilation system used to provide a sufficient amount of outdoor air to indoor spaces as required by building codes and for occupant comfort and safety. Building code requires outside air ventilation in occupied spaces to remove air pollutants and carbon dioxide. This is particularly important for large commercial buildings. Traditionally, ducting outside air to the equipment that provides comfort cooling and/or heating provided mechanical ventilation. To maintain appropriate air pressure within a building, some air is exhausted to accommodate the addition of outside air.

By separating ventilation from comfort conditioning and combining outside and exhaust airflows, energy recovery technologies can transfer thermal energy to preheat or precool outside air while exhausting contaminants. This setup can reduce the overall heating or cooling load of a system. In addition, adoption of DOAS technology allows for adoption of VRF because VRF systems are typically non-ducted and cannot provide outside air. Even ducted VRF systems often lack access to outside air. This manufacturer said that Washington state code now requires DOAS for new construction and retrofits, and it is gaining ground in Europe.

Controls

The research team also spoke with control manufacturers that were offering sophisticated controls and advanced thermostats. Manufacturers of residential thermostats, such as ICM Controls and Honeywell Controls, seemed to be competing with the Nest, either implicitly or explicitly, by offering high-end, Wi-Fi-

¹ For an explanation of the history and evolution of ductless mini-split systems, see <http://www.achrnews.com/articles/102091-history-lesson-ductless-has-come-a-long-way>.

enabled, touchscreen models. Honeywell's Lyric Wi-Fi thermostat even closely resembles the Nest, as shown in Figure 1 below.

Figure 1: Competing Smart Thermostat Offerings



The Lyric

The Nest

Source: Honeywell²; Nest Labs³

Manufacturers are also introducing advanced controls for commercial buildings. Viconics, a partner of Schneider Electric, offers a password-protected control interface with occupancy sensor and learning ability. The control system can sense temperature, humidity, and CO₂, and can communicate with the building management system. Viconics claims that the control system can achieve system savings of 15% to 35%. Another advantage the company mentioned is that consumers can update firmware from the website, eliminating the need to purchase a new piece of hardware to upgrade the control system.

One benefit of controls is their compatibility with a range of HVAC equipment products at different stages of the product life cycle. For example, OEMs can integrate controls into new products as part of the manufacturing process, and building owners can integrate controls into existing products (i.e., the aftermarket⁴). In cases where controls manufacturers sell the majority of their products to OEMs, they often label these products with the OEM's brand. This can make it difficult for an observer to identify the original manufacturer of the control itself.

Two-Stage and Variable-Speed Compressors

Compressor manufacturers, such as Danfoss, Bitzer, and Emerson, are developing new compressor offerings to improve HVAC system efficiency, such as two-stage and variable-speed technology. These features allow compressors to operate at a lower capacity at times to meet part loads. This functionality

² <http://yourhome.honeywell.com/en/products/thermostat/lyric-thermostat>

³ <https://store.nest.com/product/thermostat/>

⁴ "Aftermarket" refers to HVAC system components sold separately by distributors or wholesalers to repair contractors or end-users. Distributors typically offer these products as replacements for failed components in lieu of replacing an entire HVAC system, but aftermarket products can also be used to improve existing systems, as in the case of installing improved controls in place of basic controls that were originally provided with a system.

affects system efficiency by reducing compressor energy use, improves system maintenance by reducing wear and tear due to compressor cycling, and improves occupant comfort by tailoring the system capacity more closely to the heating and cooling load. VRF systems in particular benefit from inverter-driven compressor technology that can finely tune to meet the variable load for which these systems are designed.

Compressors, like controls, are typically sold to OEMs but are also available as aftermarket applications through distributors. However, a major American compressor manufacturer noted that the efficiency of compressors sold to distributors tends to be lower than the efficiency of compressors sold to OEMs. This is because compressors sold through distributors are typically intended to replace failed compressors in existing HVAC units. If a system is old enough to need a replacement compressor, that usually means the compressor is an older model that is not as efficient as newer models being sold in new HVAC systems by the OEMs. Rather than install a newer compressor in an older system and risk incompatibility issues, this manufacturer said that repair contractors tend to install an exact like-for-like replacement. As such, we heard that distributors will stock these older, less efficient models to meet this demand.

Some compressor manufacturers, though, develop retrofit components that are specifically meant to improve efficiency. For instance, another American compressor manufacturer is developing a two-stage compressor that can replace an existing single-stage compressor. Normally, replacing a single-stage compressor with a two-stage compressor is a complex process because of the additional controls that need to be set up. However, this manufacturer designed its compressor for minimal additional complexity on the part of the installer. Part of the impetus for this product development is that the company perceives reluctance on the part of OEMs to add features that increase the bill of materials if the OEMs are unsure whether they can recoup the cost. By offering this product, this manufacturer can introduce a higher-efficiency compressor into the market even if OEMs are slow to build it into new systems.

Additional Commercial and Residential Market Insights

This section describes trends, drivers, and barriers that the research team observed in the HVAC market.

Trends

The team noted several market trends learned from talking with trade show attendees:

- Several manufacturers have developed good-better-best tiers of technology offerings to cater to customers who desire more efficient products while retaining the ability to supply the majority of the market that is still at the lowest efficiency tier.
- A major American manufacturer confirmed what we learned in our previous research, which is that the midstream model is the biggest influencer of efficiency for the failed equipment market.⁵ As the end-user usually needs a failed system to be replaced as soon as possible, the end-user is far more likely to purchase an inefficient unit that is already in stock at the distributor instead of waiting for a more efficient unit to be ordered and shipped from the manufacturer. This reality

⁵ "Midstream model" refers to the system model that is stocked at the distributor or wholesaler. In the supply chain, the distributor or wholesaler is considered "midstream" while the manufacturer is "upstream" and the customer is "downstream."

implies that if the distributor or wholesaler were to stock more efficient equipment, the replacement market could be more likely to adopt it.

- Another trend is toward increasing sophistication of controls and connectivity. Viconics mentioned that HVAC system controls increasingly incorporate wireless communication, integration with other controls, and compatibility with smart buildings.
- Recent EPA rulings disallowing the use of certain refrigerants do not appear to be affecting the HVAC market. Most HVAC manufacturers have already switched from an unacceptable refrigerant (R-22) to R-410A, which is allowed by the EPA rule, but are not moving further to adopt alternative refrigerants such as hydrocarbons (e.g. propane) and CO₂. Manufacturers we spoke with were divided on whether the industry would be likely to move towards CO₂ in the near future. One Korean manufacturer predicted that refrigerant regulations would drive the market towards CO₂ (although there are no current regulations prohibiting or reducing the use of R-410A in HVAC applications), though one refrigerant manufacturer we spoke to said that CO₂ operates at high pressures that are difficult (though not impossible) to design for. The high pressure operation also prevents CO₂ from being used as a retrofit in existing equipment that is designed to use more conventional refrigerants.

Drivers

Trade show attendees frequently cited incentives and rebates as drivers of energy efficiency. One manufacturer said that tax credits could increase the percentage of their sales above baseline efficiency from 25% to 35%. An international manufacturer said that outside of the United States, high incentives in Western Europe are driving innovation. Within the U.S. market, a large American-based manufacturer noted that end user rebates influence the residential market, while the electricity rate structure (which may consist of higher rates for higher energy use or time-of-use rates) influences the commercial market. The manufacturer said that the Cool Cash rebate program was a significant influence on residential customers.⁶ (Consumer behavior can be sensitive to the amount of the incentive; the manufacturer observed that when the federal tax credit decreased from \$1,500 to \$500, it saw a big change in consumers' willingness to purchase higher-efficiency equipment.) They also suggested that incentivizing the contractor base is just as important as financing and consumer rebates.

Codes and standards can also be efficiency drivers. A compressor manufacturer mentioned ASHRAE⁷ 90.1 and DOE, as well as California standards, as a significant influence. The company believed that OEMs typically adapt to California standards even if they are more stringent than standards elsewhere.

A leading Japanese manufacturer also mentioned that the Electric Power Research Institute (EPRI) can be a vehicle for collaboration on energy efficiency issues.⁸ This same manufacturer also predicted that EPRI could be a more effective collaboration vehicle if more utilities participated.

⁶ The Cool Cash program is a rebate program offered by certain utilities; this program provides rebates to residential customers who purchase efficient central air conditioners and then submit a rebate form. An example utility brochure can be found at <http://www.riversideca.gov/utilities/pdf/CoolCash.pdf>.

⁷ American Society of Heating, Refrigerating, and Air-Conditioning Engineers

⁸ EPRI is a non-profit scientific organization that conducts research to benefit the electric power industry. One area of research is energy efficiency in the context of an electric resource.

Barriers

Some manufacturers cited first cost as a barrier, mostly in the context of residential products where homeowners may be reluctant to incur high initial costs despite an anticipated return on investment.⁹ Another significant barrier to implementation of new technologies in HVAC equipment is longer lead time. Because of lower demand, distributors typically do not stock higher-efficiency equipment. Commercial high-efficiency equipment may also have customizations that manufacturers need to handle in the factory, so manufacturers make that equipment on an as-needed basis. One American-based manufacturer, for example, said it has a four-week lead time on high-efficiency rooftop units. VRF systems typically have to be custom-engineered as well, leading to long installation times. This scenario makes it highly difficult to install efficient equipment, especially in retrofit scenarios when unexpected failure of existing equipment requires immediate replacement.

Commercial and Residential Supply and Decision Chains

OEMs generally reinforced the assumptions about the supply chain in the HVAC Market Intelligence Booklet. Multiple manufacturers (e.g., National Comfort Products, LG, Fujitsu, and Carrier) confirmed that they stock products through wholesale distributors, and contractors purchase equipment from the distributors and install the products. This model was applicable for both the residential and commercial markets. In the commercial supply chain, LG and Fujitsu reported that they sell to consulting engineers or contractors through a manufacturer representative. Some manufacturers mentioned specific distributors or manufacturer representatives that they work with; many major distributors carry multiple manufacturers' products.

One scenario not covered by the supply chain diagrams was a national accounts pathway. One large HVAC manufacturer said that 50% of its unitary sales go directly to large commercial national accounts. If this setup is typical of major manufacturers, it could represent a significant segment of the market not influenced by distributors.

The research team also spoke with component suppliers that sell to the HVAC market. Generally, component suppliers supply their components (e.g., compressors, controls, refrigerant) both to HVAC manufacturers that build them into the equipment and to distributors for aftermarket supply. Likewise, many advanced controls are available in the aftermarket as replacements for less-sophisticated controls or as new controls for existing equipment.

Market Niches and Chain Logic Issues

Interviewees raised one issue that could inform chain logic assumptions. As equipment becomes more efficient, it can become more complex to install, which restricts the base of qualified contractors. For some equipment, such as VRF, manufacturers said it is especially important to install the equipment well for it to work properly and achieve the expected efficiency benefits. Manufacturers have taken steps to ensure that advanced equipment is installed properly, and in some cases, this requirement could serve to restrict their supply chains. For example, one Asian manufacturer requires its distributors to have technical service advisors on staff to do pre-commissioning and commissioning, and the distributors must make

⁹ By the same token, most rebates and incentives that were mentioned seemed to target residential products.

contractors go through special training to be able to install the equipment. Another Asian manufacturer provides free training for contractors and even pays for contractors to take external training.

Distributors may also self-select: One American-based manufacturer mentioned that whether distributors tend to sell higher-efficiency equipment depends on sales staff competence, education, and turnover. These factors could all lead to a division in the distributor market among those who specialize in sales of higher-efficiency equipment and those who mostly sell baseline equipment. The research team should consider these factors in future chain logic analysis for the HVAC market.

Areas for Further Research

Interviewees mentioned several technology and market issues that raised further questions and could be areas for further research on the part of BPA.

Technologies:

- What characterizes manufacturers' good, better, and best offerings, and could incentives play a role in adoption of more "better" and "best" technologies?
- What are the benefits of DOASs, and what is the relationship between this technology and other advanced technologies, such as VRF systems?
- How do upstream component manufacturers' decisions and product development affect HVAC products' efficiency?

Market:

- How large a share of the commercial market is national accounts? How does this market path work and who are the key players? In the national account market path, what influences product efficiency?
- Is there a division in the distributor market among those who specialize in sales of higher-efficiency equipment and those who mostly sell baseline equipment?

Appendix A: Detailed Profiles of Key Industry Players

Leading HVAC Equipment Manufacturers

The profiles of industry players are based on secondary research into publicly available information. Sources include company annual reports and investor presentations, industry group reports and information, marketing material, and other relevant literature.

Carrier Corporation

Carrier Corporation, based in Farmington, Connecticut, is a leading manufacturer of HVAC and refrigeration equipment worldwide, with activity in the United States, Europe, and Asia Pacific. The company is a part of UTC Building & Industrial Systems, a new group that formed after a fiscal year 2013 merging of UTC Climate, Controls & Security with Otis Elevator Company (both units of United Technologies Corporation).

UTC Climate, Controls & Security supplies Carrier, Bryant, Payne, and Totaline with commercial and residential HVAC products throughout the United States and overseas. The company's product lines are generally applicable to new construction as well as retrofit applications. In total, new construction accounted for 42% of new sales during fiscal year 2014.

In 2011, UTC Climate, Controls & Security formed a venture with Midea Group of China (Midea) for the manufacture and distribution of HVAC products in Brazil, Argentina, and Chile. As a result of this transaction, in 2011, UTC Climate, Controls & Security recognized a gain of approximately USD\$80 million. In 2012, the company announced plans to expand its presence in India through a joint venture to manufacture and distribute HVAC products in the country.

Daikin Industries

Daikin Industries, based in Osaka, Japan, is the largest manufacturer of HVAC equipment in the world, with particular strength in the Asia Pacific region. It is active in Japan, China, Australia, India, and Southeast Asia, as well as in Europe and North America. In fiscal year 2014, Daikin posted annual revenue of ¥1,783 billion (USD\$14.4 billion). Its main corporate focus is on air conditioning, which represents 89% of its total business, with the remainder in chemicals, oil hydraulics, and defense technologies. Japan represents the largest single market for Daikin (29%), though a significant portion of its revenue comes from the United States (20%), China (19%), and the rest of the world (32%). During fiscal year 2014, Daikin reported unit sales of 835,000 commercial air conditioners in the Japanese market. Daikin expects to expand its environment-related innovation business to address shifting regulations on energy efficiency and emissions.

In August 2012, Daikin acquired U.S.-based Goodman Global, a significant HVAC supplier (both residential and light commercial) in the North American market. The acquisition significantly expanded Daikin's presence in the North American market, which had been mostly limited to McQuay-branded products,

and solidified Daikin's position as the global HVAC leader. Goodman is expected to leverage energy-efficient technologies from Daikin, and Daikin has already begun leveraging Goodman's duct-based solutions and established global procurement practices.

Johnson Controls, Inc. (York)

Based in Milwaukee, Wisconsin, Johnson Controls, Inc., is a global leader in building efficiency. It also has major divisions in automotive electrical power and controls, with 170,000 employees in total. Johnson Controls has large ongoing super energy savings performance contracts with the U.S. federal government as well as contracts with state and local governments. Roughly half of its federal business involves retrofits and the other half is related to new construction. Most of the retrofit work is in performance contracts. In addition, its Institute for Building Efficiency serves as a research arm within the larger organization, highlighting important market issues regarding energy efficiency around the world.

The company's Building Efficiency business is a market leader in HVAC systems, building management systems, controls, security, and mechanical equipment. Its HVAC equipment is marketed under the York brand. Johnson Controls' total revenue was USD\$42.8 billion in 2014, with an estimated one-quarter of that amount (USD\$10.1 billion) coming from its Building Efficiency business unit.

In early 2015, Johnson Controls and Hitachi Group signed a definitive agreement to enter into a global joint venture at the World Economic Forum to offer consumers a diverse technology portfolio within the HVAC and refrigeration industry. This deal gives Johnson Controls 60% ownership stake in Hitachi Appliances' global business, excluding those sales and service operations within Japan. Meanwhile, Johnson Controls is shifting its focus to its high-margin segments by divesting business units with lower profitability. In 2014, Johnson Controls announced that it is reorganizing its Building Efficiency business to separate the North America branch from the global products business. The company will focus on high-margin HVAC product lines, notably air distribution and ventilation solutions and VRF systems. In addition, Johnson Controls has divested its Global Workplace Solutions business.

Lennox International

Lennox International, based in Richardson, Texas, is a leading manufacturer of HVAC and refrigeration equipment and components for the residential and commercial markets. It operates in four key businesses: residential heating and cooling, commercial heating and cooling, services, and refrigeration. In fiscal year 2013, the company posted annual revenue of USD\$3.2 billion. Lennox's main corporate focus is on residential air conditioning, which represents 50% of its total business, with the remainder in commercial heating and cooling (26%) and refrigeration technologies (24%). The United States represents the largest single market for its products (71%), though a significant portion of its revenue comes from Canada (8%) and the rest of the world (21%). In 2013, commercial customers generated 26% of revenue.

In the North American market, Lennox offers a variety of products, including rooftop units that span from 2 tons to 50 tons of cooling capacity and split-system/air handler combinations ranging from 1.5 tons to 20 tons of cooling capacity. Lennox Commercial Heating & Cooling Company manufactures and sells HVAC equipment for use in low-rise commercial buildings, such as shopping centers, offices, schools, and restaurants. Lennox also operates in the North American emergency replacement market, which it projects to account for 45% of the commercial unitary market. The company will also continue to target planned replacement projects as well as new construction projects.

In 2013, Lennox released its first VRF unit to serve growing U.S. demand. In addition, in 2014, Lennox's Emergence Ultra-High-Efficiency Rooftop Unit was named a Bronze Award winner in the HVAC Light Commercial Equipment Category, and its SmartAirflow System, which manages precise airflow, was the Bronze Award winner in the Commercial Control Category. Also of note, Lennox introduced the first residential and commercial HVAC systems directly integrated with solar power in 2011. These systems are sold under the company's SunSource line of products.

Trane

Trane, based in Davidson, North Carolina, offers a range of HVAC systems, dehumidifying and air cleaning products, service and parts support, and advanced building controls and financing solutions. It is a brand of Ingersoll-Rand, a global industrial company based in Dublin, Ireland. Ingersoll-Rand markets its products through four business segments: Climate Solutions (including Trane), Residential Solutions, Industrial Technologies, and Security Technologies. Ingersoll-Rand's Climate Solutions segment distributes energy-efficient refrigeration and HVAC equipment worldwide. The Climate Solutions segment generated revenue of USD\$9.9 billion in fiscal year 2014, of which an estimated USD\$6 billion was generated by commercial HVAC sales.

Trane's EarthWise CenTraVac (CTV) chillers offer a high-efficiency and low-emissions system for commercial applications. The CTV is capable of efficiencies of at least 13.5% better than competing centrifugal chillers. Notably, Trane's CTV is the only chiller in the world that has earned an Environmental Product Declaration registration following the requirements of International Organization for Standardization 14025.

In 2013, the company introduced its Trane Variable Refrigerant (TVR) II air conditioning system. The system was developed in response to customer requests for integrated and flexible HVAC solutions and was launched throughout Latin America during Trane's fourth quarter of 2012. It can be applied as the main HVAC system in a building or as a supplemental system that coordinates with existing equipment. The TVR II is recommended for applications such as office buildings, healthcare facilities, high-end residences, schools, apartment/condominium buildings, hospitality, and retail.

Other HVAC Manufacturers

Bosch Thermotechnology

Bosch Thermotechnology is a wholly owned subsidiary of the Bosch Group, a global, €46 billion engineering company with products and services for the automotive, consumer products, industrial, and buildings markets. Bosch Thermotechnology employs 13,500 people and produces a broad range of space and water heating, cooling, ventilation, and distributed thermal and electric energy generation products for the residential, commercial, and industrial buildings sectors. Of the company's total sales, 80% are in heating and hot water products. As a result of mergers and acquisitions, its residential and small commercial portfolio includes other brands, such as Worcester, Buderus, e.l.m. Leblanc, and Junkers.

The thermotechnology division has expanded into services and technologies for more intelligent management of heat and power through improved diagnostics and automation. For example, the Buderus line of products has three web-enabled boiler series available that allow for remote controllability and

automated performance and maintenance monitoring. Bosch Group's experience in industrial energy solutions offers technical experience and technology transfer in support of the thermotechnology division's entry into the distributed combined heat and power systems market suited to small residential applications.

CALMAC

CALMAC is the world's largest manufacturer of ice-based energy storage systems. The company's IceBank systems make ice at night, which is used to cool buildings during the day. This setup uses lower-cost night energy and results in reductions of peak demand charges. CALMAC positions its energy storage technology as strengthening the smart grid and enabling renewable energy.

Delta Product Corporation

Delta Product Corporation was founded in 1971 and is a market leader in switching power supply solutions and DC brushless products. The company is headquartered in Fremont, California, and operates as a subsidiary of Delta Electronics, a Taiwan-based manufacturer. Delta Product Corporation has a wide range of offerings including variable frequency drives, data center solutions, energy management platforms, fan and ventilation products, and cabinet thermal solutions.

Fujitsu General

Fujitsu General, established in 1936, is a global provider of residential and commercial air conditioning and VRF units based in Kawasaki, Japan. With almost 5,800 employees, in fiscal year 2013, Fujitsu General posted ¥241 billion (USD\$2.3 billion) in revenue. Japan is the single biggest market for the air conditioners manufactured by Fujitsu General (28%), although Europe (20%) and the Middle East (12%) represent significant portions of the company's revenue.

Since the creation of its first VRF AIRSTAGE Series in 2001, Fujitsu General has added a compact VRF model and an expandable VRF series to its lineup. In 2008, Fujitsu General finished building a new factory in Wuxi, China, specifically to increase the rate of production of its VRF units.

In addition, Fujitsu General made two advances in 2012 in its commercial air conditioning division. Fujitsu General released an expandable VRF heat recovery model into the European, American, and Australian markets, and TCFG Compressor (Thailand) Co., Ltd. was established as a merger by Toshiba Carrier Corporation and compressor manufacturing company FGA (Thailand) Co., Ltd (a Fujitsu General subsidiary).

LG Electronics

LG Electronics is a multinational electronics company headquartered in Seoul, South Korea, and the flagship subsidiary of the LG Group. The company operates its business through five divisions: Mobile Communications, Home Entertainment, Home Appliances, Air Conditioning, and Energy Solutions. In 2014, LG Electronics recorded ₩59 trillion (South Korean Won, or USD\$53.7 billion) in revenue from all its segments.

LG has engaged HVAC for commercial buildings and home air conditioning systems by emphasizing VRF technology. The company's VRF system is engineered to minimize or use no ductwork, which saves on the cost of large distribution fans, multiple water pumps, and water piping.

Meanwhile, LG has been rapidly expanding its business-to-business solutions with a focus on energy efficiency. LG offers a full range of air conditioning solutions and customizes its products to meet the specific needs of both the local environment and the building size.

In 2015, LG upgraded its lineup of residential and commercial air conditioning systems. LG also expanded its Multi V commercial line capacity range and increased its efficiency ratings and design options. In addition, LG VRF systems are more compact and lightweight compared with most competitors, and several of LG's residential systems have been awarded the ENERGY STAR Most Efficient designation.

Mitsubishi Electric Corporation

Established in 1921 in Tokyo, Japan, Mitsubishi Electric Corporation is a multinational electronics and electrical equipment manufacturing company and one of the core companies of the Mitsubishi Group. The company posted ¥4,054 billion (USD\$39 billion) in revenue in 2014. Mitsubishi Electric markets its HVAC technologies through its Home Appliances business segment, which generated 20%, or approximately USD\$8 billion, of 2014 revenue. The Home Appliances business segment also includes solar photovoltaic power generation systems, TVs, and recorders and players. Asia Pacific represents the largest single market for its products (48%), though a significant portion of its revenue comes from North America (20%), Europe (25%), and the rest of the world (7%).

Mitsubishi Electric markets and distributes its HVAC technologies in North America through its Cooling & Heating division, which is based in Suwanee, Georgia. Its cooling and heating applications and products include VRF and split-ductless systems that can be adapted to meet the needs of many commercial and residential applications. Examples of commercial applications include low-rise multi-zones, high-rise multi-zones, office buildings, mixed-use buildings, multi-tenant dwellings, historic renovations, quiet spaces, light industrial spaces, data centers, and renovations and additions. In addition, the company's building automation controls integrate building HVAC, water, and security systems by combining third-party cameras, sensors, fingerprint verification, data encryption, and real-time remote monitoring features.

In 2012 and 2013, Mitsubishi Electric was named the recipient of a Product Innovation Award from Architectural Products in the HVAC, Ventilation, & Air Conditioning category. Moreover, in 2014, The CITY MULTI H2i R2-Series VRF zoning system won the Gold Award in the HVAC Commercial Equipment category of the 2014 Dealer Design Awards in ACH&R News.

Multistack

Headquartered in Sparta, Wisconsin, Multistack is a privately owned company that designs and manufactures modular, dedicated heat recovery and magnetic bearing centrifugal water chillers as well as central station geothermal heat pump systems. The company was founded in 1989 by former Trane executives to take over the North American sales of an Australian-invented modular water chiller. In 2012, Multistack gained exclusive rights to produce, support, and sell Dais Analytics' ConsERV Energy Recovery Ventilator product line in the North and South American markets.

Rheem Manufacturing Company

Rheem Manufacturing Company is one of the largest manufacturers of water heating equipment in North America. The company, headquartered in Atlanta, Georgia, also produces gas furnaces, heat pumps, air conditioners, air handlers, and indoor air quality products. Founded in 1925 by brothers Richard and Donald Rheem, the company was acquired by Paloma Industries of Nagoya, Japan in 1988. Paloma Industries is a privately held manufacturing company that focuses on gas appliances for residential, commercial, and industrial applications.

Samsung Electronics

Samsung Electronics is a multinational electronics company headquartered in Seoul, South Korea. The company operates its business through nine divisions: Visual Display, Digital Appliances, Mobile Communications, IT Solutions, Telecommunication Systems, Digital Imaging, Memory Business, System LSI, and LED Business. In 2014, Samsung Electronics recorded ₩229 trillion (\$216 billion) in revenue.

The company markets and distributes its commercial air conditioning systems through its Digital Appliance division. Samsung Electronics has implemented HVAC for commercial buildings and home air conditioning systems by emphasizing VRF technology.