Choosing Air Source Heat Pumps for Multifamily Buildings

Introduction

Electrifying buildings is viewed as a major pathway to reducing carbon emissions and eliminating the use of fossil fuels. Because heating is typically the highest single energy end use in multifamily buildings in New York State, and the highest user of fossil fuels, the use of heat pumps is a primary electrification strategy. The most efficient heat pumps are ground source heat pumps, but these are generally limited to suburban and rural areas, due to the need for land for wells. So, air source heat pumps are expected to be a main way to electrify multifamily buildings. This is already occurring in new multifamily buildings, with rapid growth in the use of air source heat pumps across the state, and this transition has also started in the conversion of existing buildings from fossil fuels.

Multifamily buildings use two broad types of air source heat pumps: Larger commercial systems and smaller residential systems. These heat pumps are almost exclusively split systems, in other words, systems with an outdoor unit and one or more indoor units. The nomenclature is a little confusing. Some people use “VRF” to refer to both types, because both typically use variable speed compressors, but few manufacturers refer to the smaller systems as “VRF”. Some people refer to the small systems as “multi-split ductless”, but the large systems are also multi-split systems and can be ductless. We will use an abbreviated version of the Air Conditioning, Heating, and Refrigeration’s (AHRI) nomenclature: AHRI refers to the larger systems as “Commercial Variable Refrigerant Flow (VRF) Air-Conditioners and Heat Pumps”; we will refer to these as “large VRFs”. AHRI refers to the smaller systems as “Residential Variable-Speed Mini-Split and Multi-Split Heat Pumps,”; we will refer to these as “small mini/multi-splits.”

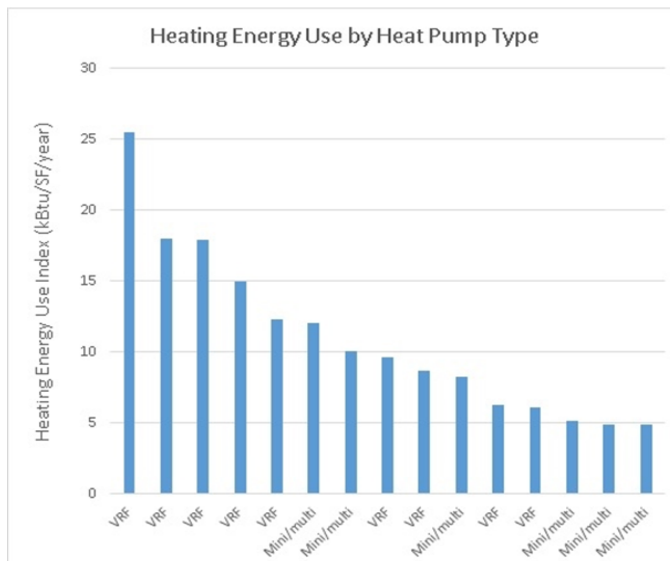
The decision whether to use large VRFs or small mini/multi-splits in multifamily buildings, either in new building or in existing buildings, is an important one. The early trend a few years ago was to use large VRFs, whereas more recently both types of systems are commonly installed. Energy and design professionals should choose the system that best suits their specific building. However, as discussed below, large VRFs cost measurably more to install, use measurably more energy, use measurably more refrigerant, and in many cases take up more space. We therefore pose the question: Should small mini/multi-splits not be given first preference in multifamily buildings?

This document is limited to split system air source heat pumps that deliver air to the indoor space (“air-to-air” heat pumps), rather than air-to-water, water-to-air, or water-to-water heat pumps. Split system air-to-air heat pumps currently comprise most of the heat pumps being used in the U.S. and overseas, and they are expected to dominate electrification efforts, at least in the near term and possibly long-term as well. Our focus on split system air-to-air heat pumps is not intended to detract from or de-emphasize other heat pumps types (ground source heat pumps, packaged rooftop heat pumps, etc.), each of which has an important place in the electrification effort. We also do not include packaged terminal heat pumps (PTHP’s, also informally referred to as “PTAC heat pumps”) in our analysis, because most of the units currently available on the market are not able to provide efficient operation in the New York climate[1], or have other limitations (such as only being approved for new construction), or have limited performance data available. We look forward to the emergence of high-efficiency, cold climate small packaged heat pumps such as PTHPs.

Energy Use

Large VRFs appear to use more energy than small mini/multi-splits, for the same building load.

A 2018 study of eight large VRFs in new multifamily buildings found the average heating usage to be 13.5 kbtu/SF/year, compared to one building with a small mini/multi-split that had a heating energy use of 5 kbtu/SF/year, lower than that of any of the large VRFs[2] . Because this study only used a single small mini/multi-split, we looked at additional buildings and expanded the study to nine large VRFs and six small mini/multi-splits, including the buildings from the earlier study. We found the average heating usage for large VRFs to be 13.3 kbtu/SF/year, compared to a 7.5 kbtu/SF/year average for small mini/multi-splits, representing a 77% higher average heating energy use for the large VRFs. The spread of the energy use of the 15 buildings is shown in the figure, below.



A literature survey of the actual annual-average heating efficiency of small mini/multis concluded that the typical operating COP in the New York State climate is about 2.5.[3] If small mini/multis indeed are 76% higher in efficiency, as found in our EUI comparison, this means that large VRFs have a typical COP of 1.4. Low COPs for large VRFs have been seen in two prior studies, both of which were done in warmer climates of the Southeast U.S., and so should be conservative (high COP) relative to efficiencies in the Northeast. One study reported COPs of 1.2-2.0.[4] The second study reported monthly heating COPs through winter in the 1.4-1.75 range.[5]

There are several reasons for the lower energy efficiency of large VRFs.[6] Field testing of the efficiency of large VRFs in cold climates is reportedly being planned, and we look forward to the results of this work. Until then, we are limited to rated data and the above performance data and conclude that large VRFs are measurably less efficient than small cold climate small mini/multis.

Multifamily building– NYC, NY

Footprint and Location of Outdoor Units

A common perception in favor of large VRFs is that they are indeed larger in capacity, so there are fewer outdoor units, so they will take up less space. This is incorrect in many cases. The large VRF outdoors units have upward airflow, and so cannot be stacked, whereas at least two manufacturers allow stacking, two-high, of the smaller mini/multi-splits. Even for small mini/multi-splits from manufacturers that cannot stack two-high, the footprint of smaller heat pumps with service clearance, is not much more than one single large VRF. The smaller depth dimension of the small mini/multi-splits work to their advantage, to offset some of the space advantage of the single large VRF.

In most cases, the difference in footprint between large VRFs and small mini/multi-splits is likely to be small, with small mini/multi-splits frequently requiring less room. The only exception might be in cases where there are many apartments and the smaller heat pumps need to be placed in more than two rows. In this case, the spacing between the second and third rows needs to be larger, to avoid air recirculation. So, if the number of apartments is very large, and if the outdoor units are all concentrated in one location rather than at the top of a column of apartments, the large VRFs might fit more capacity for a given footprint. For buildings with a smaller number of apartments, or where outdoor units are generally at the top of apartment stacks, the footprint of small systems will in many cases be smaller. In general, the difference in footprint is not expected to be significant between large VRFs and small mini/multi-splits.

The outdoor units of small mini/multi-splits can be more easily wall-mounted than large VRFs. For example, most large VRF outdoor units weigh well over 500 pounds, however typical wall-mount racks are only rated to 500 pounds. Large VRFs will also protrude farther out from the wall. Although wall-mounting of large VRFs has been done, it is rare, and requires specialty racking.

Installed Cost

Large VRFs cost more to install than mini/multi-splits.

A prior study reported large VRFs cost $15-20/SF, compared to small mini/multi-splits that cost $10-18/SF. Midpoints of these ranges would imply that large VRFs cost 25% more to install than small mini/multi-splits.[7]

A survey of several more recent quotes found that large VRFs cost $15-34/SF, with an average of $22/SF, for a sample of 13 quotes. Small mini/multi-splits cost $8-23/SF, with an average of $15/SF, for a sample of eight quotes. The average large VRF cost is 50% higher than the average small mini/multi-split cost.

Of interest in our sample is one project for which the same contractor quoted both large VRF and small mini/multi-splits, for the same building. The large VRF installed cost was 24% higher.

Refrigerant Quantity and Leak Risk

Virtually all air source heat pumps in the U.S., both large VRF and small mini/multi-splits, use refrigerant 410a, which has a relatively high global warming potential if leaked/released. With increasing concern about this impact, issues of refrigerant quantity and risk of leaks are important.

Refrigerant quantity (also referred to as refrigerant *charge*) appears to be measurably higher for large VRFs, per unit of system capacity, than for small multi-splits. This appears to be true even for similar-pipe-length systems, for example if outdoor units are located on the roof in a direct comparison. The difference grows even larger if small multi-split outdoor units are located close to their indoor units, for example on a balcony or wall-mounted close by.

We found that large VRFs use approximately 3-6 pounds per ton, depending on line lengths, and small mini/multi-splits use approximately 2.8 pounds per ton. If we take 4.5 pounds per ton as a mid-point representative of large VRFs (including both base charge and added charge), and 2.8 pounds per ton as representative of small multi-splits (2.6 pounds/ton plus 0.2 pounds/ton added charge for maximum line length), we conclude that large VRFs use 60% more refrigerant charge, typically, than small multi-splits.

The risk of larger refrigerant loss is also higher with large VRFs, due to their having more refrigerant. It has been shown that most refrigerant is lost in large, catastrophic leaks.[8]

There are also issues relating to refrigerant quantity limitations relating to requirements in ASHRAE Standard 15, that limits the pounds of refrigerant of a system, per cubic foot of the smallest space served by the system, that limits some applications of large VRFs, or requires work-arounds such as using ducted systems to serve multiple small spaces.

Cooling

In New York's cold climate, we direct our attention mostly to heating season performance. However, large VRFs also use more energy in cooling than small mini/multi-splits. As previously mentioned, rated efficiencies of large VRFs are lower. Furthermore, the impact of long refrigerant lines is even greater in cooling, due to higher refrigerant flows and so higher refrigerant flow pressure drops.

Contractors, Service, and Maintenance

There are fewer contractors available to install and service large VRFs than there are for small mini/multi-splits. In New York City, this might be less of an issue, due to the size of the city and availability of contractors. However, in upstate New York, this is more of an issue. For example, a specific medium-size upstate city was surveyed, and found to have multiple local contractors in town that can install or service multiple brands of small mini/multi-splits, whereas the closest contractors available to service any of the VRF brands are on average over 50 miles away.

As mentioned previously, finding and repairing refrigerant leaks in large VRFs is more difficult than in small mini/multi-splits, due to more joints per system and some joints being less accessible.

In the case of a major repair issue at the outdoor unit, buildings with large VRFs lose heating/cooling to more apartments, during such downtime, because they service multiple apartments, than do small mini/multi-splits, which typically serve one apartment per system. For example, a failed compressor in a 14-ton large VRF with a single compressor might result in loss of heat to 5-10 apartments in midwinter, for a period of several hours to several days. Because these apartments are typically adjacent (for example, in a single vertical stack), this situation risks substantial loss of interior temperature during the service downtown. With a single small mini/multi heat pump, loss of a compressor means loss of heat to one apartment, which can still gain heat from adjacent heated apartments, and so will lose less heat and so its interior temperature will drop less than during downtime of a large VRF heat pump.

Features

Although large VRFs use more energy and cost more to install, they come with added features that may be of interest. These include:

- Ability to heat/cool makeup air. Makeup air can be separate zones on a large VRF system.
- Submetering capability. VRF systems can allocate energy use to different zones. This is typically an indirect estimate based on control valve position and the duration for which they are open, rather than a direct measurement of energy flows. However, it can still be useful for allocating energy costs and for troubleshooting energy use and energy losses.
- Heat recovery – the ability to simultaneously heat and cool different zones on one system, and to productively use the rejected heat from cooling zones in reducing the energy use for zones in heating.
- Controls capabilities.
- More types of indoor fan coils, including recessed cassette type units, which are not typical in apartments, but could be of interest for office spaces and common areas.

Conversely, small mini/multi-splits have some advantages, in addition to using less energy and having lower installed cost. These include:

- Ability to be included on the tenant/occupant meter.
- Residential electricity rates, without demand charges.

ASHP outdoor unit

Conclusions

Large VRFs likely use measurably more energy than small mini/multi-splits, and cost approximately 25%-50% more to install. Large VRFs require more refrigerant per nominal ton of capacity. Service and maintenance are likely more costly for large VRFs. In many cases, small mini/multi-split outdoor units take up less space than large VRFs, and space differences between small mini/multis and large VRFs are not believed to be significant. For these reasons, small mini/multi-splits deserve priority as a split system air source heat pump option for multifamily buildings, over large VRFs.

Large VRFs do have some advanced features, such as ability to heat/cool makeup air, and heat recovery, that might offer benefits in some cases for common area heating/cooling loads. Where long pipe lengths are required, such as for high-rise buildings, large VRFs offer greater lengths, but at greater energy use.

ASHP indoor unit

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For more information on this topic, please see: Large VRFs Versus Small Mini/multi Split Heat Pumps: A Comparison