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Background

Central steam heating systems emerged as a dominant force in urban residential dwellings from the late 1800s until the 1940s, and continue to be prevalent in older building stock in the Northeast. The majority of buildings served by NYSERDA's Multifamily Performance Program for existing buildings are heated with steam boilers or by district steam, and energy use surveys have shown that steam-heated buildings have a source energy use intensity which averages 24% higher than that of non-steam-heated buildings.

Variable Refrigerant Flow (VRF) technology has been widely recognized in many countries as a highly efficient means of heating and cooling buildings. It is proven to be capable of performing effectively across New York State and presents many advantages over steam heating systems.

Understanding the Issues

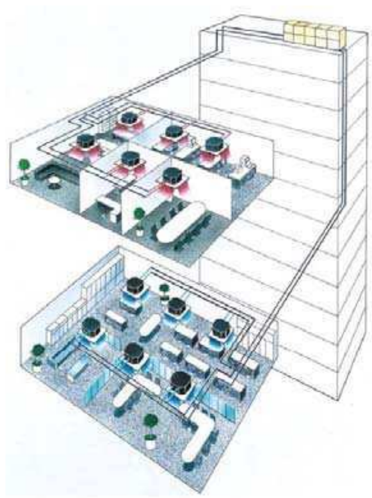
Some of the factors which contribute to the inefficiencies of heating with steam include:

- Most steam systems operate at higher temperatures than other heating systems and therefore have higher distribution system losses.
- In addition to boiler flue gas losses typical to steam and standard efficiency hydronic systems, steam systems suffer further inefficiencies from boiler blowdown, steam trap failure and condensate losses.
- There are steam losses from components that allow steam to vent to the atmosphere, such as vented condensate tanks, flash tanks, failed steam vents and deaerator vents.
- Live steam is invisible. For this reason, leakage in steam systems can easily go unnoticed over the life of a building.

High water usage has also been correlated with steam heating systems in residential buildings. Studies have indicated water use to be **79% greater** for buildings with steam heating systems than for comparable buildings heated with hydronic systems.

In addition, many buildings utilizing steam heat use window or wall air conditioning units for cooling. These have been demonstrated to be subject to significant infiltration and conductive heat loss, as well as low operating efficiency, all of which contribute to excessive energy consumption.

How do Variable Refrigerant Flow Heat Pumps Work?

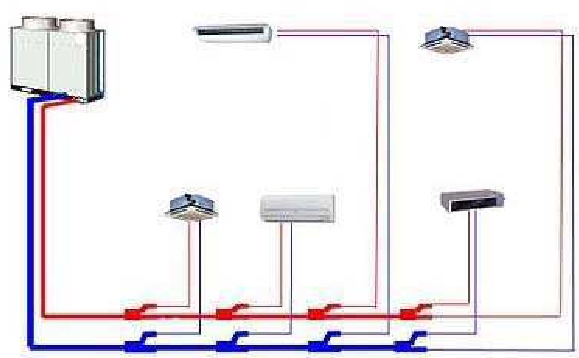


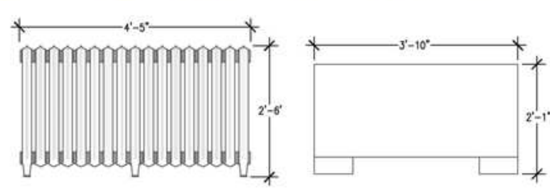
By employing variable speed compressors as part of the refrigeration cycle to transfer heat from ambient air, VRF heat pumps perform at efficiency levels well above that of most heating systems. VRF systems operate as split systems, with local fan coils ("indoor units") for distribution. Multiple indoor units can be linked to one or more outdoor condensing units, which can be cooled either with air or water. Controls provide for variation of the amount of refrigerant flowing to each indoor unit, with the indoor units all connected to their common outdoor unit by refrigerant piping. VRF systems designed with optional heat recovery capability are able to provide simultaneous and highly efficient heating and cooling to separate zones.

What makes VRF Heat Pumps Suitable for Retrofits in Steam-Heated Buildings?

Characteristics that make VRF systems suitable for retrofit in existing steam-heated buildings are:

- Outdoor units can be mounted in a variety of locations (roof, ground, balconies, etc.), offering significant flexibility to accommodate existing conditions.
- There is no need to install ductwork, and building penetrations can be limited to the size of the refrigerant lines, thereby decreasing infiltration losses.
- A variety of indoor units exist (wall-mounted, floor-mounted, ceiling-mounted, ducted, etc.) to enable distribution that can be installed to meet diverse structural and design parameters.
- In many cases indoor units require less physical space than steam radiators of comparable capacity.
- VRF systems provide highly effective zoned distribution, with independent control of temperatures in each zone.
- The VRF indoor units operate very quietly.
- One outdoor unit can serve up to 20 indoor units, which adapts well to many typical multifamily building configurations where existing steam pipe chases can be used to route refrigerant piping.
- In most cases the outdoor units are compact enough to fit in a typical building elevator, facilitating installation.





Steam Radiator vs. VRF Indoor Unit

What Benefits are Anticipated in Switching from Steam to VRF?

- The site energy consumed per Btu of heat delivered by VRF systems is much lower than that of steam systems, enabling significant conservation opportunities. (A well maintained steam system may have an Annual Fuel Utilization Efficiency of 80%, whereas a ductless VRF system is estimated to have a seasonal Coefficient of Performance of 2.5 or more in the Northeast.) The source Btus consumed by a VRF system in buildings served by the electrical grid are comparable to that of a steam system, but because the VRF losses are much lower, the efficiency gains are significant.

- The losses which typically accompany steam heating systems will be reduced significantly. Venting waste, conductive and convective pipe losses, and jacket losses from the boiler and flue losses will be eliminated with a VRF system replacing steam.

- Building infiltration and conductive losses from window and through wall air conditioners will be reduced if these are removed, the wall openings sealed, and the more efficient cooling capabilities of VRF are utilized for further savings. Infiltration related savings from taking the boiler out of service will also be realized by eliminating the need to bring combustion air into the mechanical room.

- VRF systems require very little maintenance, in contrast to steam systems, which require regular cleaning and blowdown and routine testing, maintenance and repair or replacement of steam traps. Water leaks and resultant building damage that can happen with steam systems do not occur with VRF.

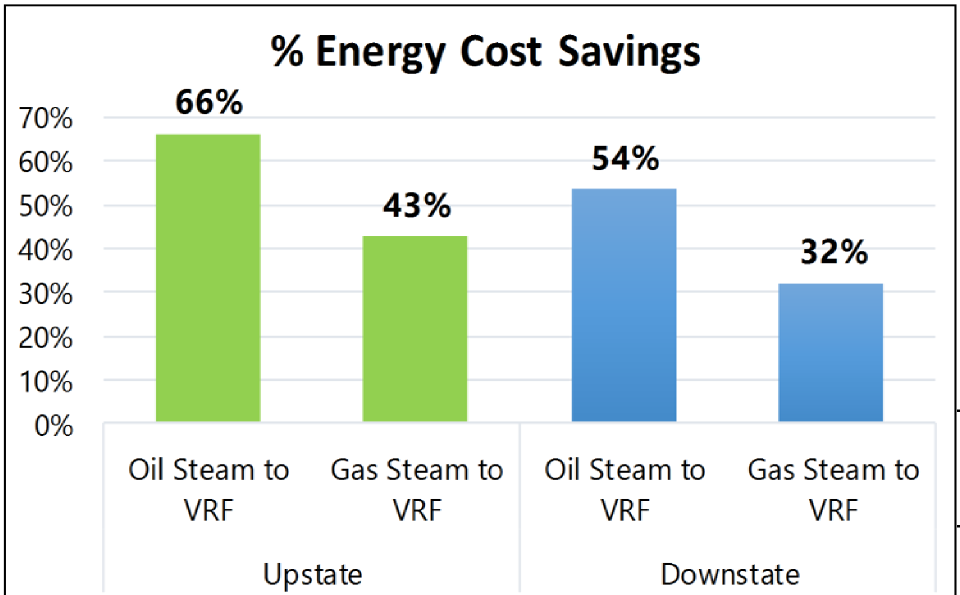
- VRF technology is safe and enjoys a greater resiliency than typical steam systems with boilers located in the basement, which are subject to flooding, an issue of growing concern as a result of climate change.

- Conditioning spaces on the zone level occurs with a much higher degree of precision and differentiation using VRF systems. Overheating and under heating of spaces, typical to steam distribution, is avoided. Building managers can enjoy greater control of schedules, setbacks and trend data, and the possibility of sub-metering is available with VRF installations.

Image References

Figures 1 and 2 illustrating a split system and multi-zone control are from Nilsonsvidal, available on the public domain. Figure 3 is from Taitem Engineering's presentation at the 2013 MPP Partner Conference, available on the Partner Portal. Figure 4 was taken of VRF outdoor units during installation at an MPP Project.

What Whole Building Energy Cost Benefits Could Be Expected?



Energy modeling in eQuest of the same typical multifamily building in the Upstate region and in the Downstate/NYC area indicates that when steam systems are retrofit with VRF, significant energy cost and source energy use intensity (SEUI) savings are likely to occur.

% Whole Building Source Energy Use Intensity Savings	Upstate	Downstate
Oil Steam to VRF	43%	42%
Gas Steam to VRF	39%	38%

What are the Average Costs of Implementation in Multifamily Buildings?

For a typical building of around 100 apartments, the cost of implementing a steam to VRF retrofit is estimated to be around $17,500 per apartment in the NYC/Downstate area (roughly $18 per square foot), whereas lower labor costs in the Upstate region would put the cost for the same conversion at roughly $14,500 per apartment ($15 per square foot).

How Cost Effective is a Typical Steam to VRF Retrofit in NY State?

The cost effectiveness of oil-fired steam to VRF conversions is very favorable in both Upstate and Downstate/NYC areas owing to the high price of fuel oil, with projected savings to investment ratios (SIRs) of 2.3 and 1.9 respectively. The total installed cost of a retrofit weighed against the relatively lower gas prices make gas-fired steam to VRF retrofits less financially attractive at present (2014) rates. With modeled SIRs of 0.9 for Upstate and 0.8 for Downstate regions, the cost benefit is below target levels, but this metric is very sensitive to energy prices and is close enough to 1.0 to merit the evaluation of conversion of gas-fired steam to VRF retrofits using contractor quotes and current fuel and electricity pricing for each location.