Customer Innovation

Cold Climate Variable Refrigerant Flow Pilot

Release Date
September 30, 2023

Prepared For
Commonwealth Edison Company

Prepared By
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Acknowledgements

This project was developed as part of the Emerging Technologies initiative within the ComEd Energy Efficiency Program under internal project number P-0472. Slipstream produced this report for the Emerging Technologies Team with overall guidance and management from Illume and CLEAResult. For more information on this project, contact EmergingTech@ComEd.com.

Legal Notice

The ComEd Energy Efficiency Program is funded in compliance with state law.

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1.0 EXECUTIVE SUMMARY

Background and Objective

Commercial and industrial (C&I) building space conditioning is a significant building end use in cold climates like Illinois, where approximately 55% of total building energy use is the result of space conditioning and 40% results from space heating. As such, ComEd has identified C&I HVAC in two of its R&D focus areas: efficiency and electrification. Traditionally, buildings in ComEd's service territory have primarily relied on natural gas for meeting space heating needs, which have efficiency limitations of 96 to 97%. Variable Refrigerant Flow (VRF) systems have the potential achieve seasonal heating efficiencies above 200% but have had historic challenges operating during the coldest hours of the year. Recent technological advancements with VRF have made it more viable for cold climates, as units that used to be limited to operating to -5°F can now operate down to -22°F.

Slipstream has completed a market analysis and field demonstration of VRF systems to demonstrate the energy savings potential from this technology. In addition, the team also quantified the ability for these systems to maintain setpoints throughout the year, including the coldest and warmest hours. The team used its findings to develop actions that utilities and program staff can take to overcome market adoption barriers.

Market Analysis

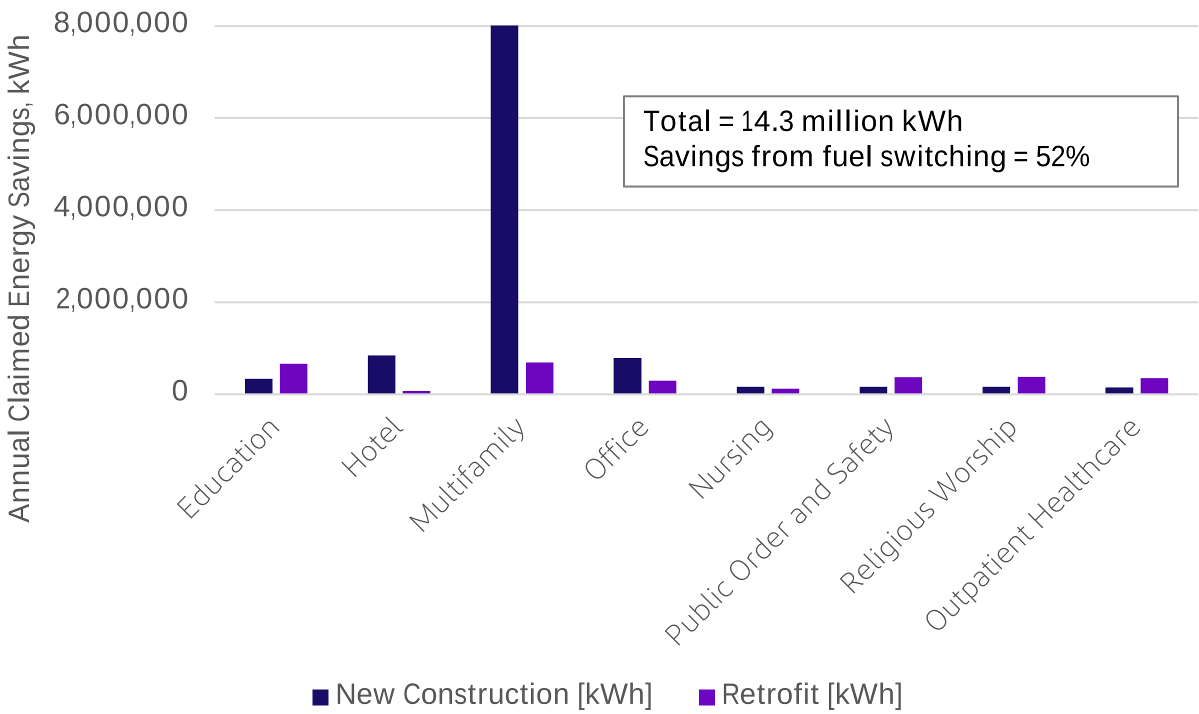
Phase One of this project involved assessing the VRF market in ComEd territory. This included product review, interviews with stakeholders at each level, reviewing energy efficiency programs in ComEd's service territory and nationwide, and estimating the size, energy savings and cost effectiveness of VRF.

The VRF market in ComEd's service territory is more mature than that in some areas of the Upper Midwest. Results suggest 100 to 120 buildings are installed with VRF each year in ComEd's service territory; the market has recently passed the "early adopter" stage. People choose VRF for a combination of energy and non-energy benefits. Energy benefits include energy reduction but also meeting sustainability and electrification/carbon targets. Non-energy benefits include quiet operation, superior zone control and smaller space requirements for new ductwork or equipment. The most common applications include multifamily buildings, offices, schools, lodging such as hotels, dormitories, and senior living, and retrofits of older buildings, particularly those not originally designed with air conditioning.

Manufacturers and distributors suggest the Chicago market is growing; designers and owners cite increasing trust of the VRF technology. Rural areas are lagging behind the Chicago market in terms of awareness and adoption. Owners interviewed generally had no issues with the system beyond post-installation issues, which are generally worked out during warranty period. Unfortunately, some of these early installation issues were quite severe and required equipment replacement. This was generally due to lack of installer familiarity, and some electrical quality issues. Aside from these issues, owners and operators found the system worked year-round, was easy to operate, and had fewer or similar complaints compared with buildings with more traditional HVAC systems.

We also conducted a market analysis and estimated energy savings compared with a variety of HVAC systems. Savings potential in the territory is large; Figure 1 shows the results of the analysis.

Figure 1. Annual achievable potential for air-source VRF systems in ComEd territory by building type and new construction versus retrofit. Fuel switching, per CEJA, enables 52% of the savings.



Other outcomes from market analysis include:

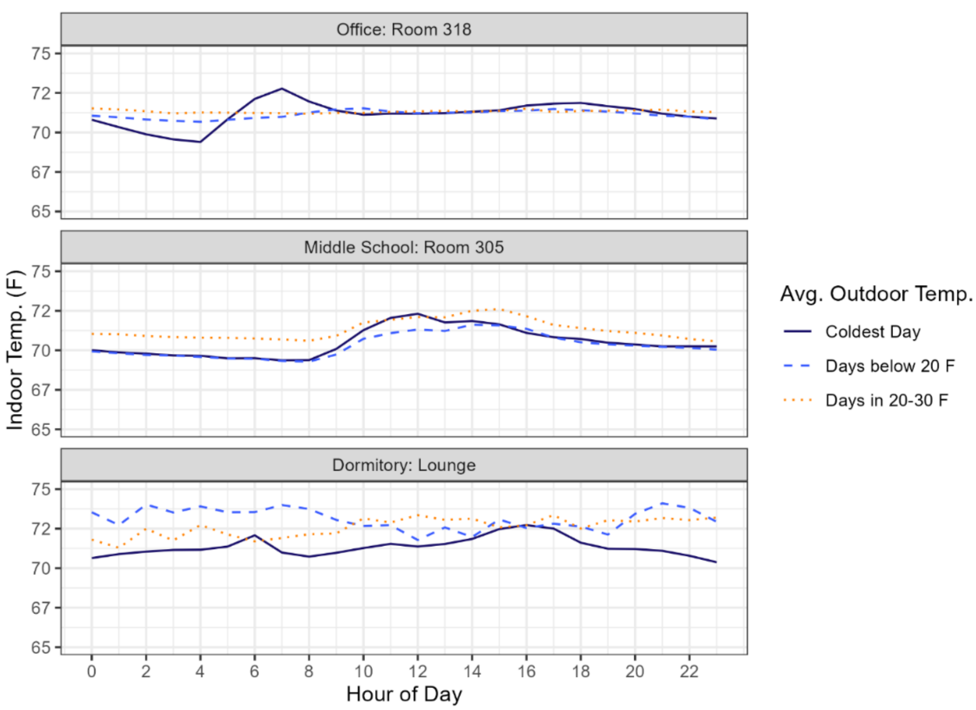
- Knowledge of VRF as a reliable cold-climate system is still lacking among key market actors in the territory. Case studies and knowledge sharing will be important.
- Non-energy benefits that add to system adoption include compact form factor, ease of use, improved ventilation, and quiet operation.

Field Research Outcomes

Phase Two of this project was a field demonstration of three sites, which included a middle school, an office, and a dormitory, all in ComEd's service territory. The middle school and office were newly constructed buildings built in 2019, while the dormitory was a retrofit of an old dormitory from the 1950s. At each of these sites, the team monitored energy usage, space temperatures and VRF supply temperatures. In addition, the team also interviewed key personnel at the sites to understand their experiences with the VRF system including quantifying occupant comfort, system operation, maintenance and overall satisfaction. At each site, the team monitored the VRF system for at least eight months to ensure that it captured seasonal performance in the summer and winter. In addition to using this data to understand the energy usage of the VRF system, the team also used calibrated energy models to calculate energy savings in a variety of scenarios.

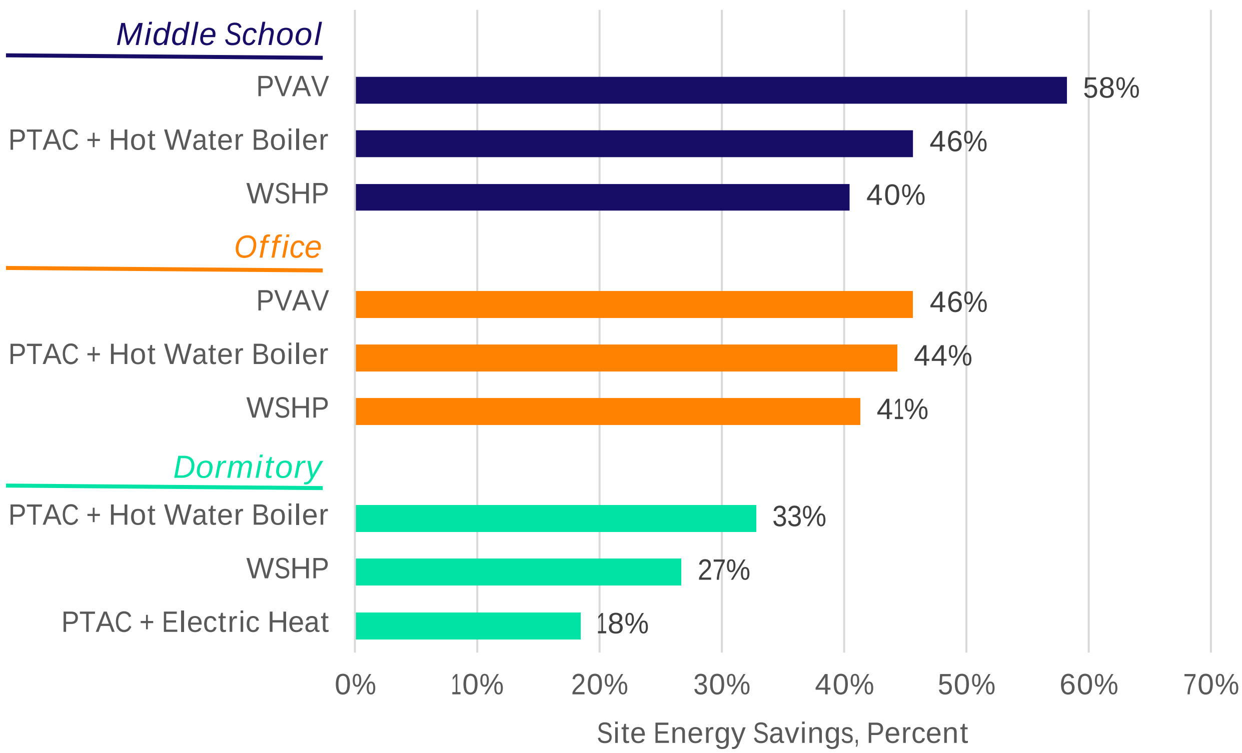
In considering comfort, the team observed that temperature was maintained in comfort ranges throughout the year. Figure 2 shows the monitored indoor temperatures of typical spaces throughout the winter, and shows limited variation throughout the year, and that most spaces on the coldest day only dropped slightly below 70°F. This aligned with the operators interviews that the system generally performed well throughout the year.

Figure 2. 24-hour room temperature on the coldest days of the monitoring period of a typical room in each building.



After collecting data on energy performance and calibrating energy models, the team calculated energy savings for different VRF systems. As baseline systems, it looked at packaged terminal air conditioners (PTAC) with either hot water boiler heating or electric heating, water source heat pumps (WSHP) and packaged variable air volume (PVAV) systems. Site energy savings for a VRF system compared with each baseline model are shown in Figure 3. Savings versus PVAV site are the highest out of all baseline systems; savings are slightly less for the decentralized systems.

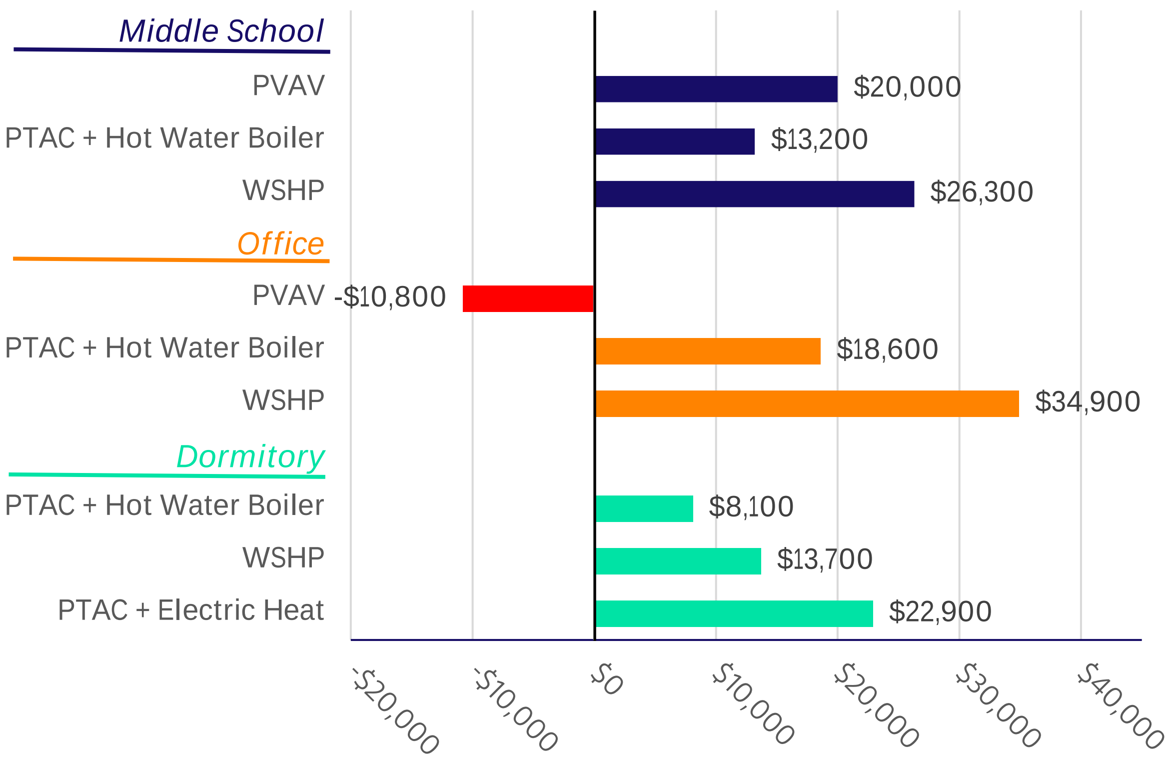
Figure 3. HVAC site energy savings percentage of VRF system compared to listed Baseline System.



Most of the savings are due to reduced gas usage, and most systems have slight electric penalties as energy is shifted to heat. VRF saves the most energy at part load, where it can take advantage of its highest efficiency. This eliminates much of the simultaneous heating and cooling penalties associated with the PVAV system. One side effect is that peak demands increased and shifted to the winter. This was reflected in the building's utility bill as well.

Cost savings were less than the energy savings, mostly due to the low cost of natural gas compared with electricity. Figure 4 shows the annual cost savings for each building and each baseline system. The office has negative cost savings for the PVAV because it is the only building using all electric heat; it uses electric resistance heat at the Dedicated Outdoor Air System (DOAS). The other two buildings use natural gas for heating. The PVAV system also had very high outdoor air intake at the DOAS, so to properly estimate a PVAV system outdoor air intake, the DOAS airflow was reduced to ASHRAE Standard 62.1-2019 *Ventilation for Acceptable Indoor Air Quality* ventilation air requirements. This reduced the energy required in the baseline system resulting in negative savings. Savings are positive if either of these were changed. If the ventilation rate for the baseline PVAV system was increased to match the VRF DOAS airflow rate, the savings would be more than $160,000 per year.

Figure 4. Estimated annual utility savings for the field monitoring sites based on energy modeled savings.



Payback for cold-climate VRF system installation is high in many cases and is highly variable. First cost for mechanical installation was found by the project team to be around $40 to $44 per square foot, while PTAC systems were close to $20 per square foot and PVAV systems close to $32 per square foot. This resulted in 20+ year payback compared with these other systems. WSHPs were found to be more expensive than VRF, offering immediate payback.

Other outcomes and conclusions from market analysis include:

- Adoption of VRF is driven by a combination of both energy and non-energy benefits; both are significant and work together to drive projects.

- Quality of installation has significant implications for avoiding significant operational problems in VRF systems; both training and program requirements should be employed within program offerings to address this issue and avoid poor customer experience.
- Peak demand for VRF buildings is higher than other systems and the peak demand shifts to winter.

There are also high greenhouse gas emission savings with VRF compared to other HVAC systems. Emissions impacts vary in the same proportion to the utility cost savings. These will increase significantly as more renewable energy is added to the grid serving ComEd customers. Note that some of the emissions savings will be offset by refrigerant leakage, where even low levels of leakage can increase global warming potential by significant amounts. This will be reduced as the EPA limits the global warming potential of refrigerants used in VRF systems starting in 2026 and is an important element of VRF installations to manage as they are scaled up.

Program Recommendations

To help capture and claim more electricity savings, the project team recommends the ComEd Energy Efficiency Program adopts the following interventions:

Increasing the penetration of the ComEd Energy Efficiency Programs into the existing VRF market. The project team believes ComEd programs are capturing 5-10% of the current VRF installations. Currently, many ComEd customers are implementing VRF and not taking advantage of ComEd incentives. Previously this was due to limitations on fuel switching, however the Clean Energy Jobs Act (CEJA) now allows energy efficiency incentives for fuel switching. One way to capture more savings from VRF projects in ComEd territory would be to offer a simple and clear standard offering. As one contractor interviewed said, "I know I can get $200 per ton for an efficient RTU, but I don't know what I get for using an even more efficient VRF system."

Bring more market awareness to VRF as a viable HVAC and electrification solution in cold climate. ComEd can further accelerate VRF awareness and confidence through marketing and outreach. These efforts should be targeted both at building owners and the design community. ComEd could create case studies, host webinars and provide other marketing materials to help bring the success of VRF to their customer's attention.

Partner with VRF manufacturers and local distributors. ComEd will want to ensure that program personnel are able to connect potential VRF users to sources of information or local industry contacts, such as manufacturers sales representatives or qualified contractors. For building sectors that are prime candidates for VRF, program outreach staff can be trained to understand typical market concerns about VRF and the top strategies for ensuring a successful project.

Streamlining and increasing incentive offerings to customers and EESPs to reduce VRF first costs. VRF systems are premium HVAC systems, which carry higher first costs when compared with basic HVAC alternatives. When additional program offerings are added to ComEd programs, the project team recommends focusing on reducing customer first costs and simplifying the VRF customer's experience. These should be an easy-to-calculate metric such as dollars per foot or dollars per ton, which has been successfully implemented in Mass Save utility programs, which offer $3,500 per ton.[1] To help facilitate a standard measure, the project team developed a measure for the Illinois Technical Reference Manual.

Ensure quality installations by incorporating some criteria into incentive. Interviews with building owners showed a surprising number of VRF units that required replacement due to issues with installation. To ensure stakeholder satisfaction and program savings, a set of eligibility criteria should be developed for projects that pursue incentives for VRF systems. The criteria should be focused on creating successful outcomes for projects installing VRF systems. The criteria should avoid being overly onerous for the customer, while ensuring projects that are incentivized have quality outcomes.

Ensure service providers in the territory are being properly trained and achieve high quality. VRF installations are dependent on quality installation more than other HVAC systems. Installer training plays a big part in ensuring that quality. There are several strategies ComEd might deploy including incentives for training, a utility bonus or spiff for contractors completing their first few systems or by requiring training to obtain incentives.

Providing education for building operators with VRF systems; connect them with service providers. While most owners, operators and occupants are familiar with gas-fired heating systems, few are familiar with VRF technology and the differences in its operation compared with traditional systems. ComEd could promote awareness and knowledge by developing webinars or materials to outline steps to overcome the most common learning/adjustment challenges when transitioning from a traditional system to VRF.

Integrate VRF into the different parts of the ComEd portfolio

By incorporating the recommended intervention in "Potential Program Implications," VRF could directly apply to the following ComEd Programs:

[1] Mass Save. 2023.

Standard Program. Create a new prescriptive measure for VRF systems. Use the new TRM measure for VRF to develop savings calculation and inform incentive rates. Consider installer qualifications for the new measure. The project team feels that creating a prescriptive measure will have the largest impact on adaption.

New Construction Program. Continue to incorporate VRF savings into the program. Leverage this research for more robust modeling or the TRM calculation to offer higher incentives for VRF through the Best Practices offering.

Multifamily Program. VRF should be considered as one other system option for multifamily buildings of appropriate size, alongside heat pumps and dual-fuel systems.

Go Electric. Details are still in development on this new program. VRF should likely be considered in this program as an HVAC system for multifamily buildings of appropriate size.

Affordable Housing Program Include a standard offering for VRF units based on the TRM measure. Provide educational materials for developers on how to avoid installation issues.

Installer Training. Expand heat pump installer training to have modules for VRF. Partner with manufacturer training.

Marketing. Develop materials about the success of VRF systems in ComEd's service territory.

Midstream. VRF is not suitable for a midstream offering due to project delivery type.