Welcome

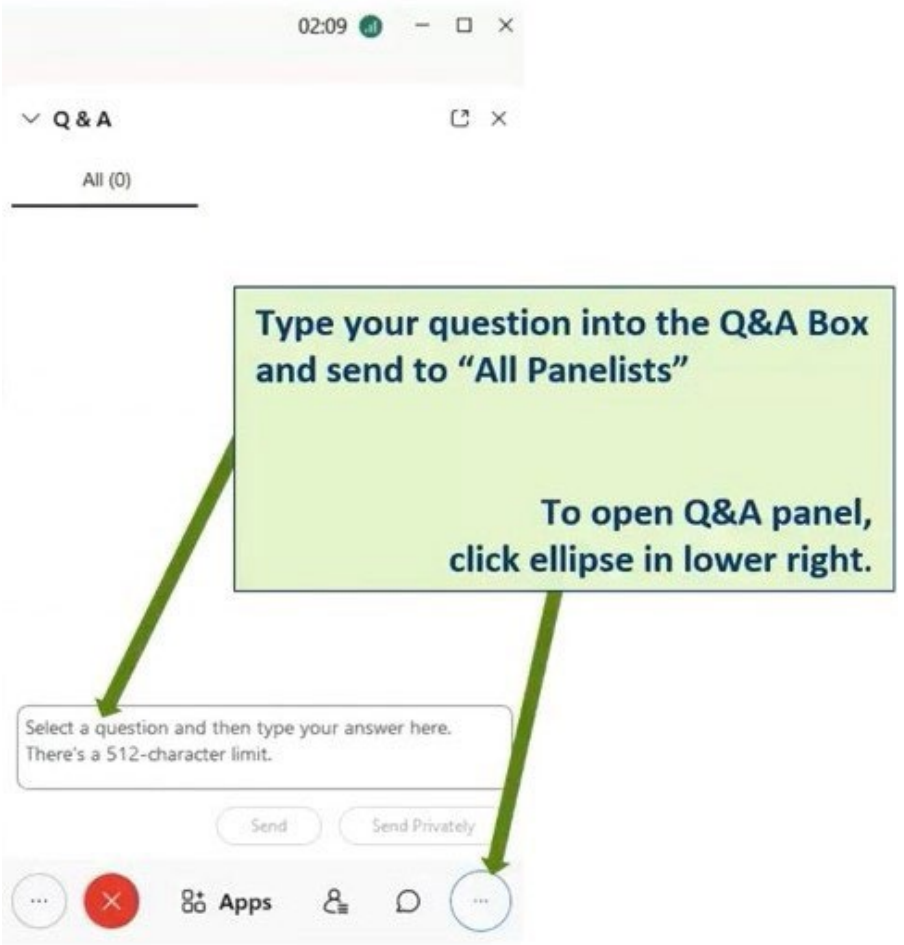
Conservation Applied Research & Development (CARD) Webinar

December 11, 2024

Cold Climate Variable Refrigerant Flow (ccVRF) System Demonstration and Market Research

Webinar Basics

- Attendees in listen-only mode
- Questions will be addressed at the end of the webinar
- Type questions into Q&A box
- Send to “All Panelists”
- Webinars are recorded and archived, slide set will be available
- For closed captions, click the “cc” bubble



Cold Climate Variable Refrigerant Flow (ccVRF) System Demonstration and Market Research



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Minnesota's Applied Research & Development Fund

Purpose is to help Minnesota utilities achieve energy savings goal by:

Identifying new technologies or strategies to maximize energy savings

Improving effectiveness of energy conservation programs

Documenting CO_2 reductions from energy conservation programs.

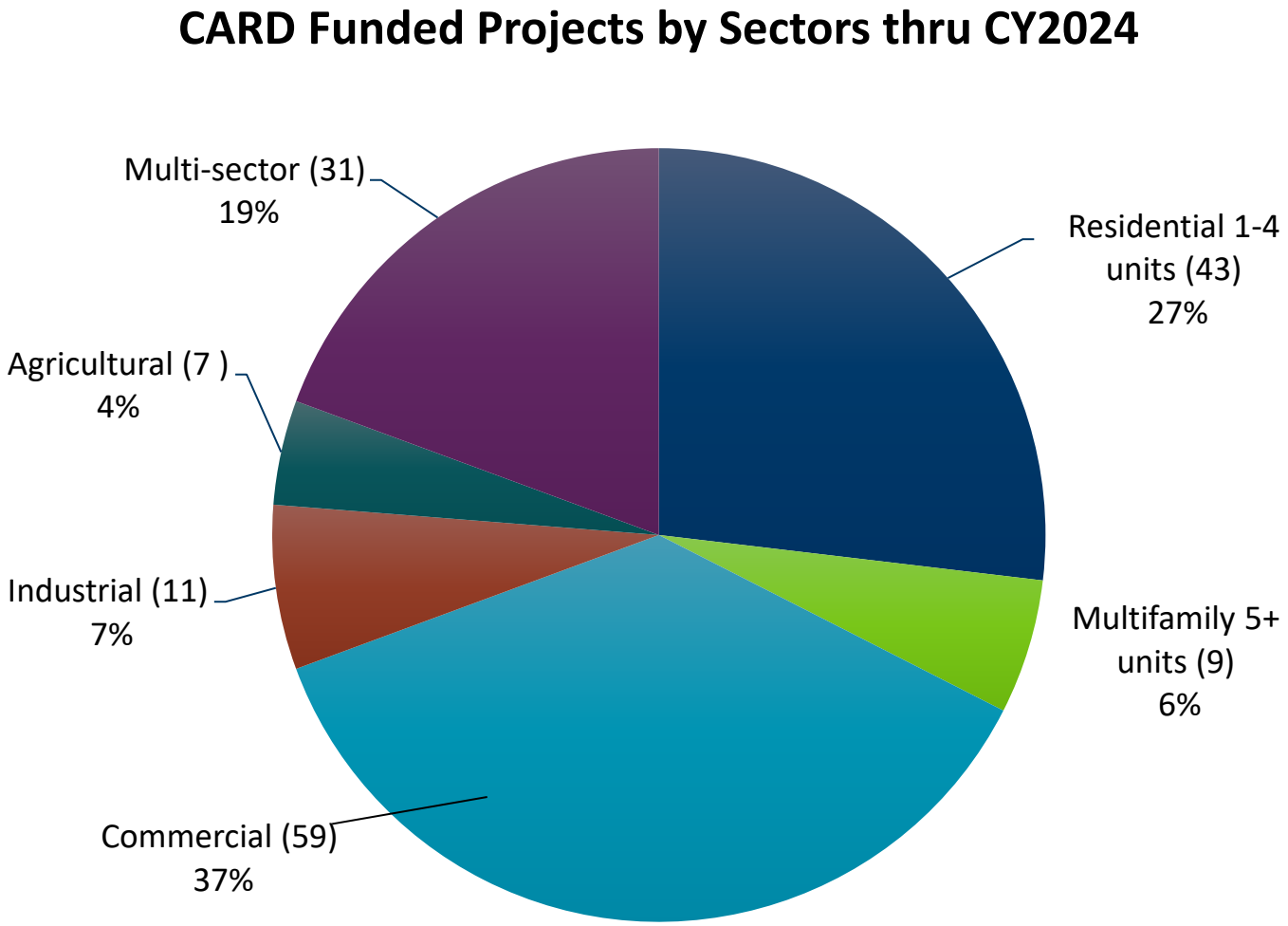
Minnesota Statutes §216B.241, Subd. 1e

Utility may reach its energy savings goal

1) Directly through its Energy Conservation & Optimization (ECO) Plan or

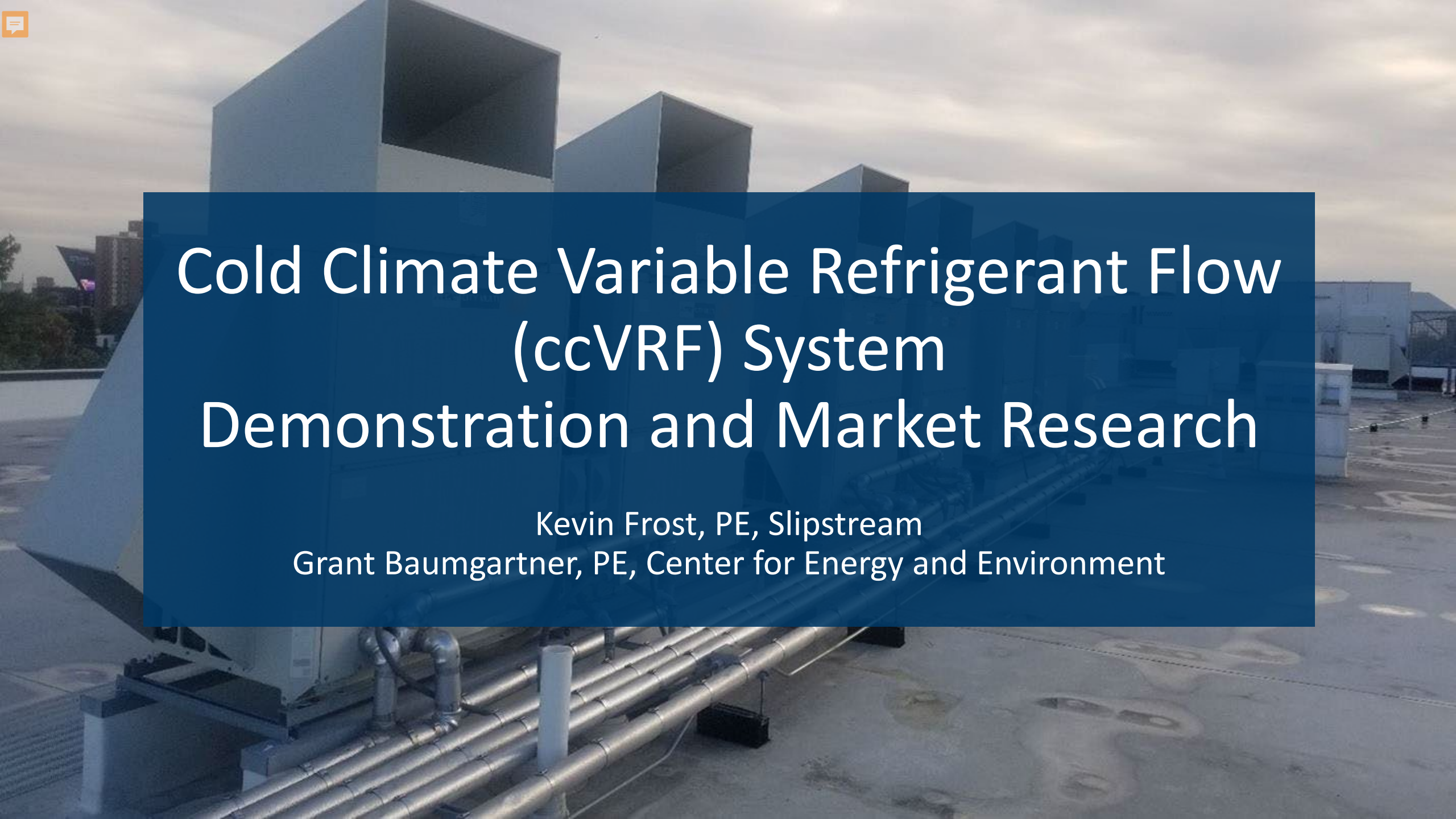
2) Indirectly through energy codes, appliance standards, behavior and other market transformation programs

CARD Funded Projects by Sector through CY2024



CARD RFP Summary

- 13 Funding Cycles
- 554 proposals
- 160 projects funded
- $36.8 million in research



Cold Climate Variable Refrigerant Flow (ccVRF) System Demonstration and Market Research

Kevin Frost, PE, Slipstream
Grant Baumgartner, PE, Center for Energy and Environment

Project Team and Acknowledgements







Agenda

Agenda:

- Variable Refrigerant Flow (VRF) Technology
- Cold-climate Variable Refrigerant Flow (ccVRF) in Minnesota
- Field Demonstration Methodology
- Results
- Key Outcomes
- Minnesota Utility Program Interventions

Study Findings

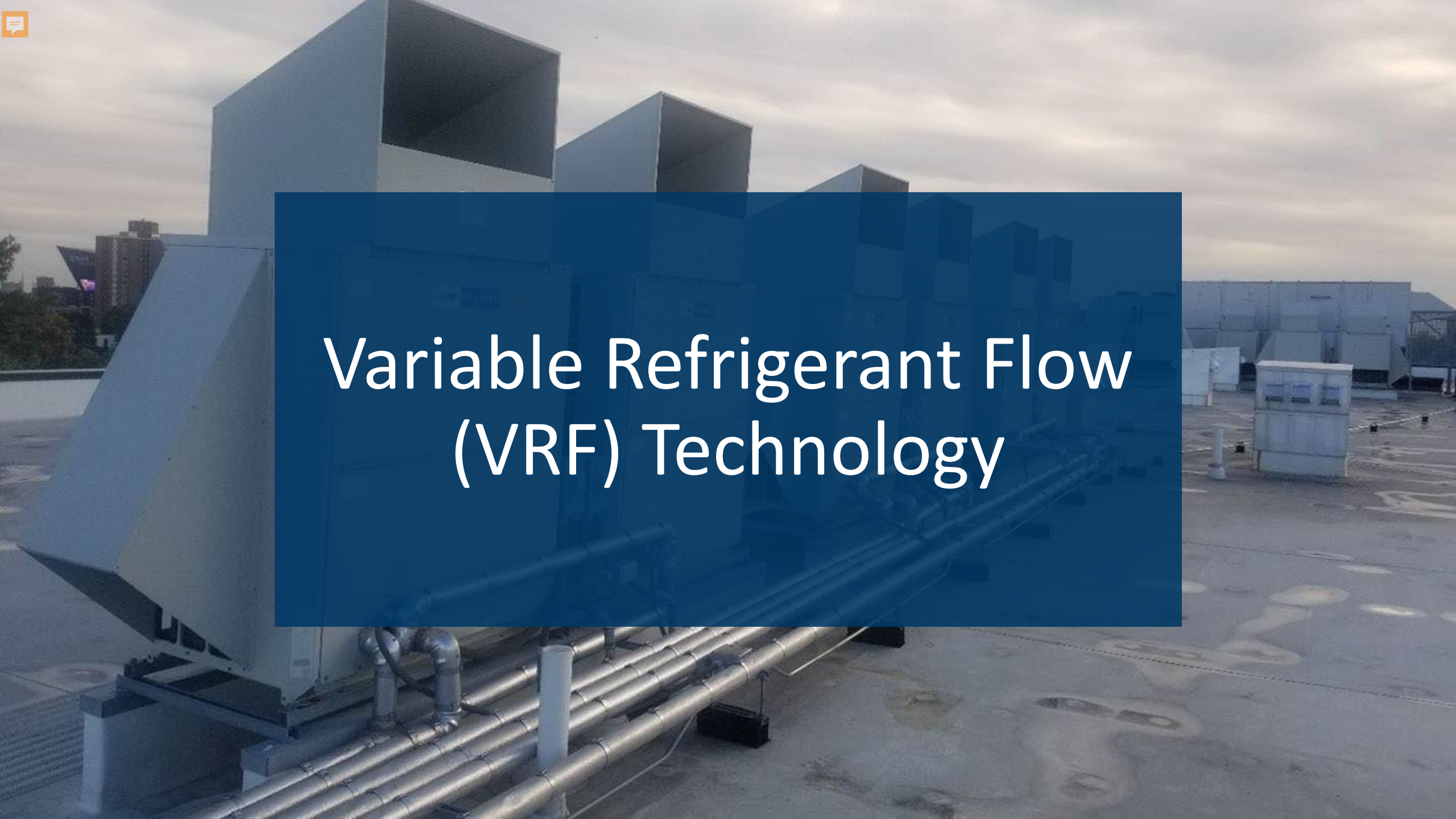
The good

- Energy Savings
- Emissions Savings
- Cold-climate performance

The not as good

- Cold-climate performance?
- High first cost and limited payback
- Installation issues
- EPA refrigerant phasedown

Should we design, install, and incentivize VRF in Minnesota?



Variable Refrigerant Flow (VRF) Technology

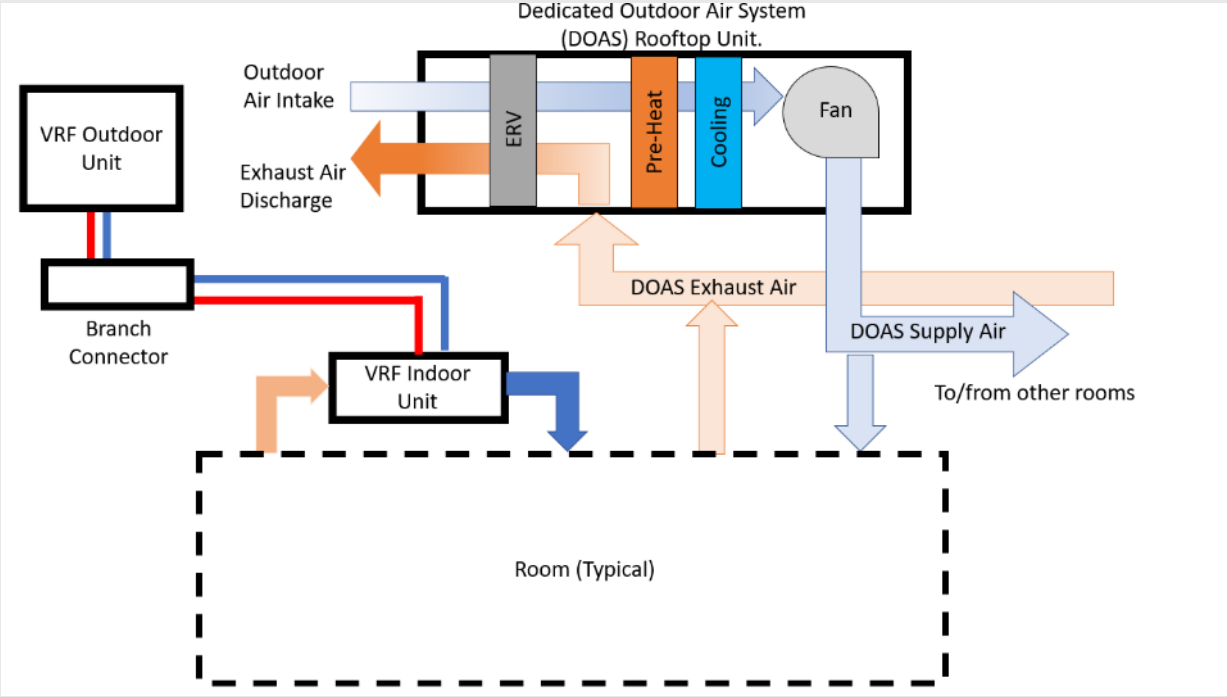
Variable Refrigerant Flow (VRF)

- Variable refrigerant flow (VRF) heat pumps
- Vary flow of refrigerant to match load of the space
- Serve multiple spaces
- Air-source
  - Water source and ground source available too, but not the subject of this study



VRF and Dedicated Outdoor Air Systems

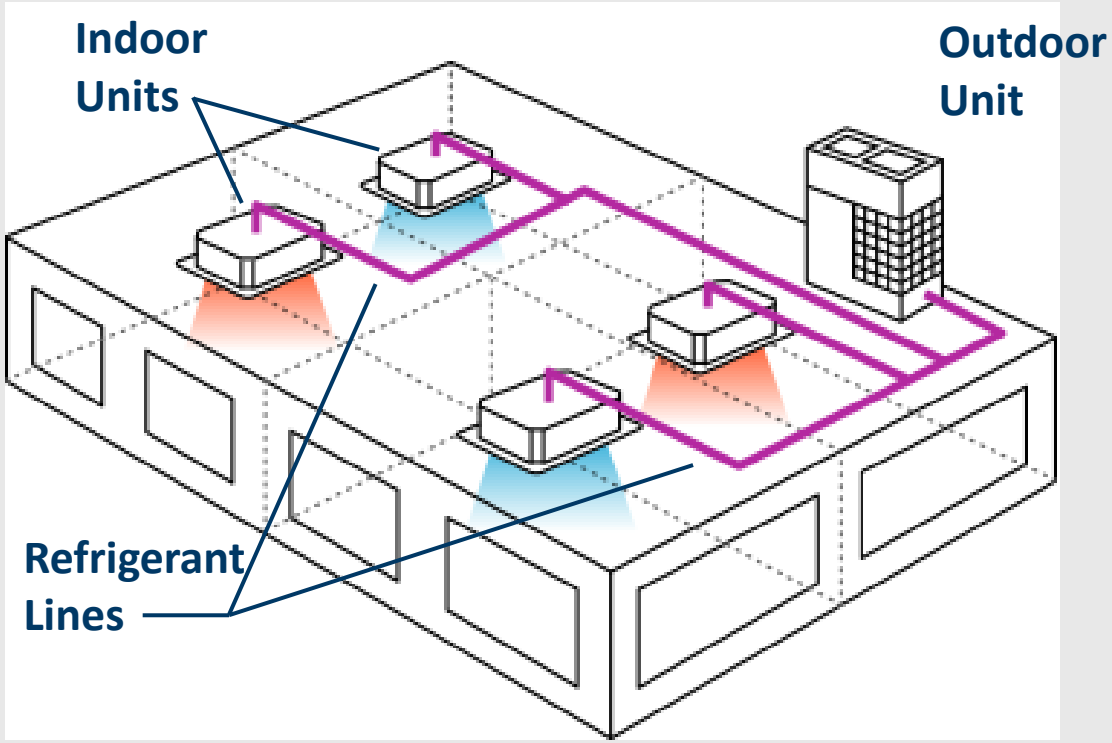
VRF is often paired with a separate ventilation system, usually a **Dedicated Outdoor Air System (DOAS)** or individual **Energy Recovery Ventilators (ERV)**.



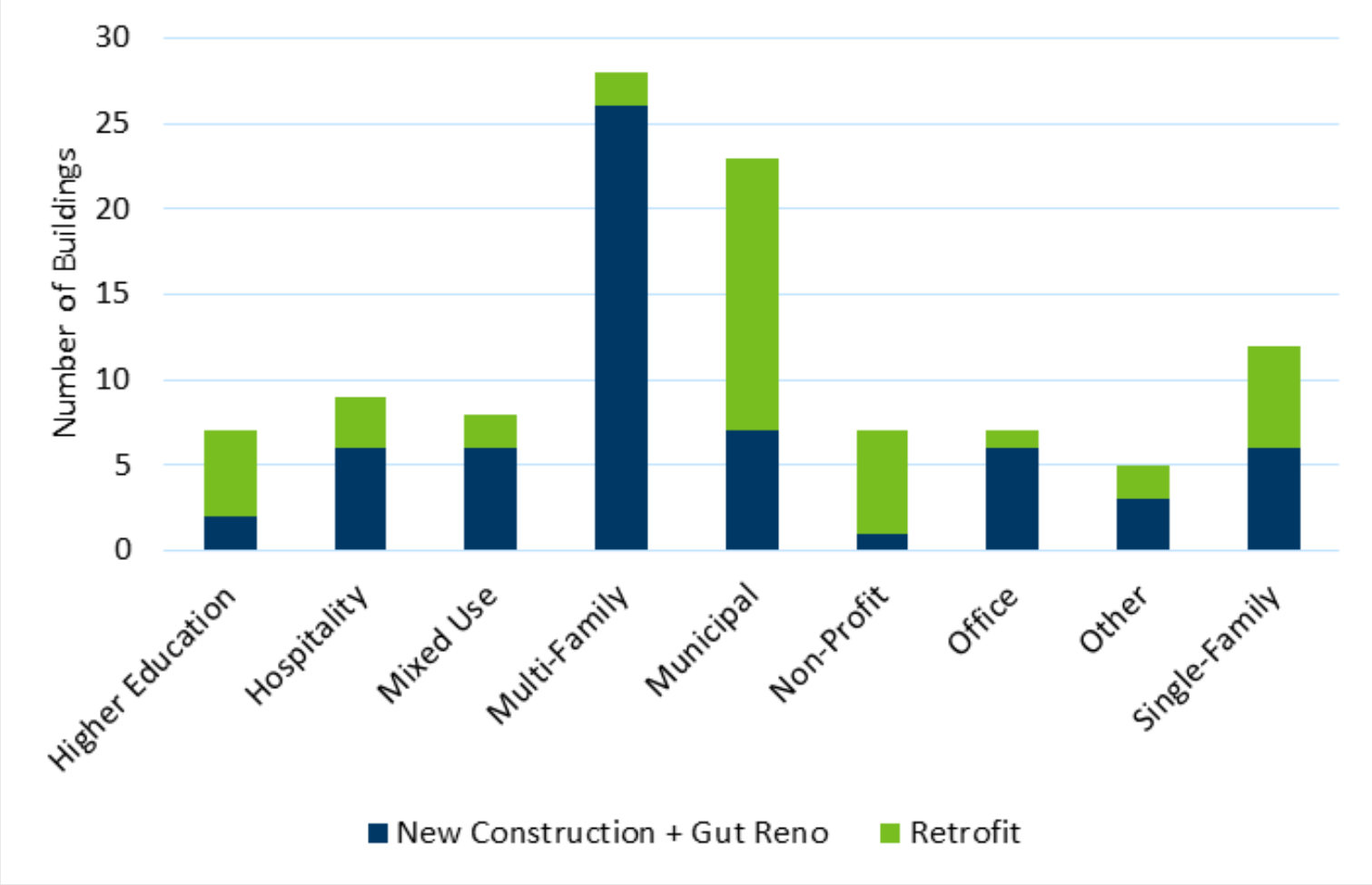


Where and when to use VRF

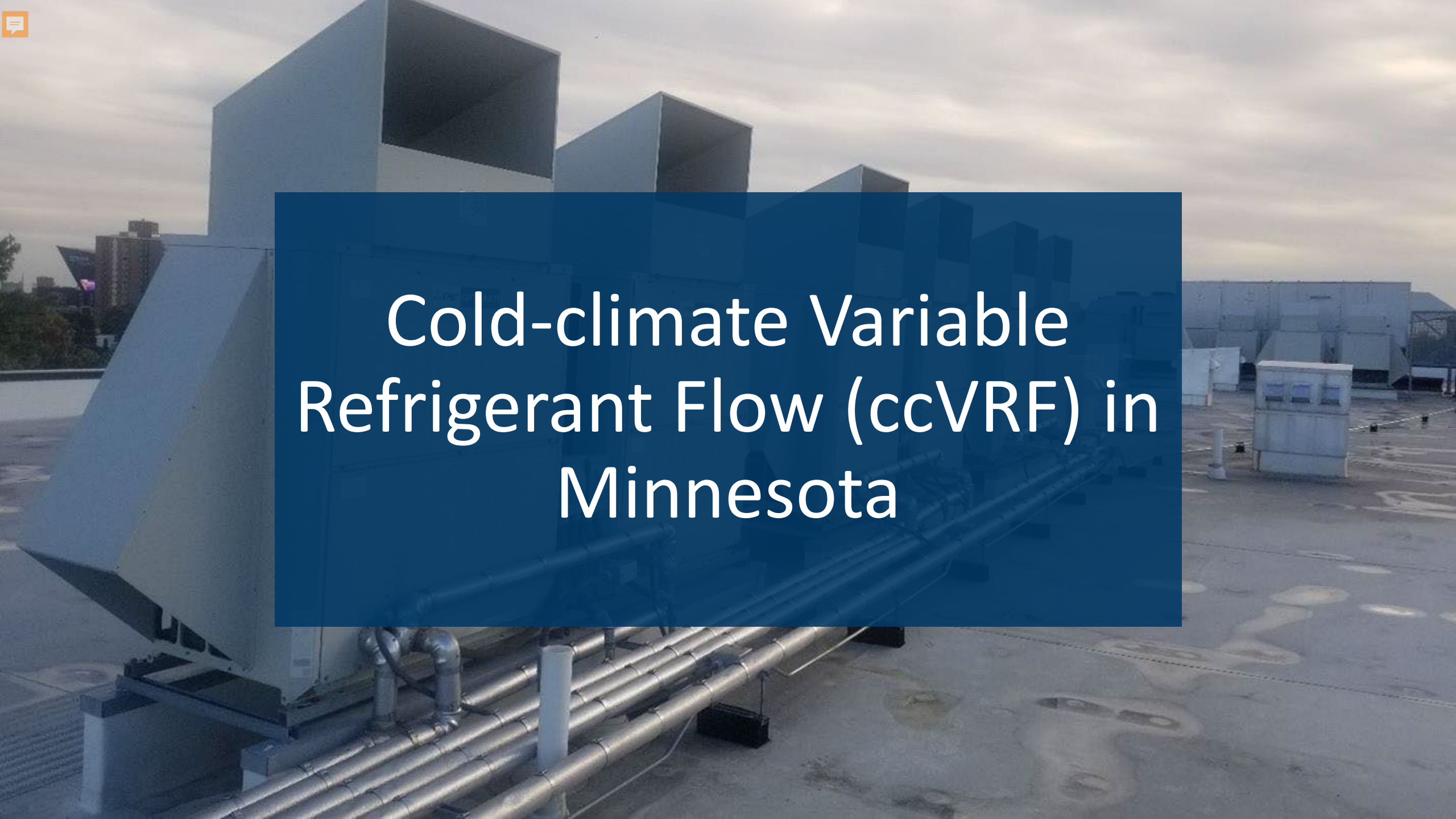
- Best for buildings with multiple zones or limited space
- Heat and cool different spaces at the same time
- Limits to height and length of refrigerant pipe
- Important light-to-mid commercial and residential heat pump option



VRF Market Applications



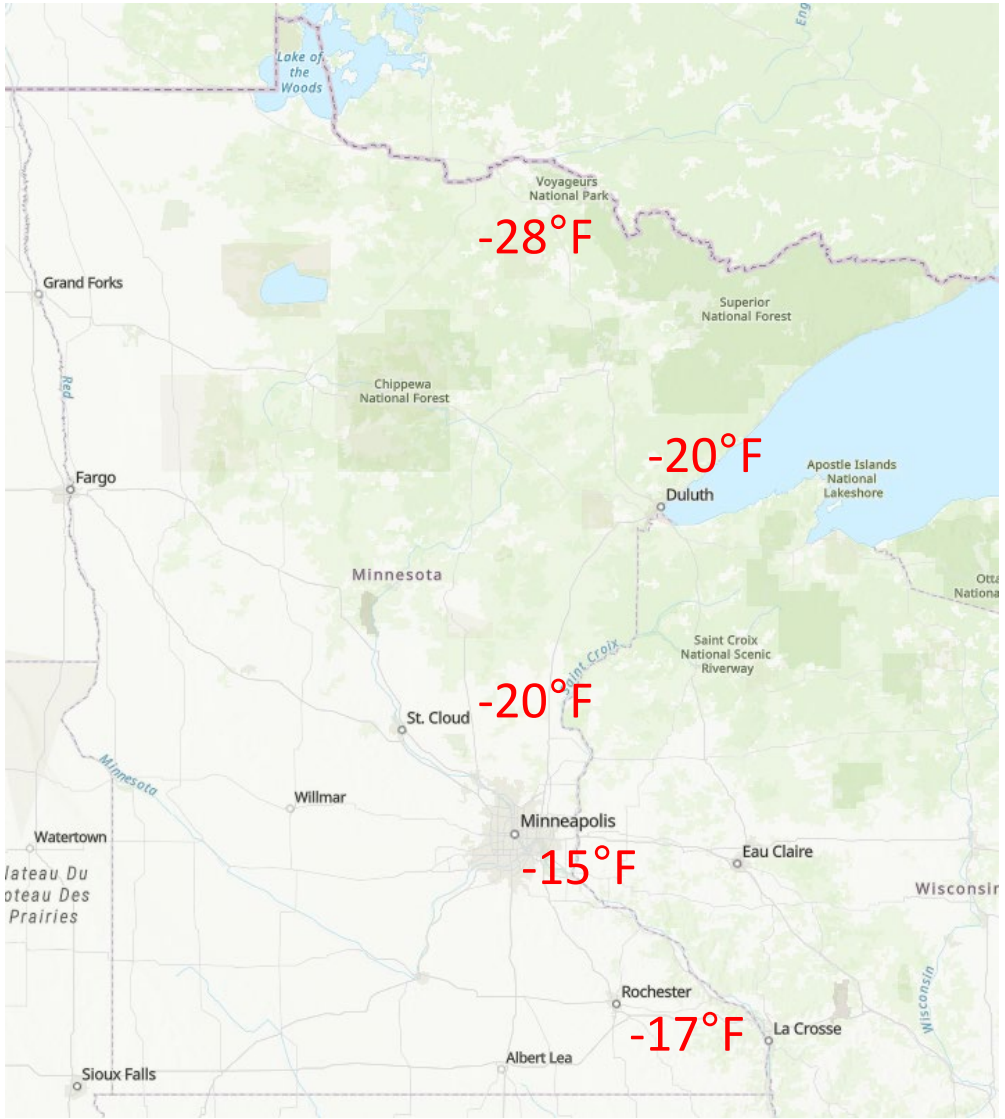




Cold-climate Variable Refrigerant Flow (ccVRF) in Minnesota

Minnesota is cold

Winter design temperature requirements are between -13°F to -28°F.



VRF with Supplemental Heat



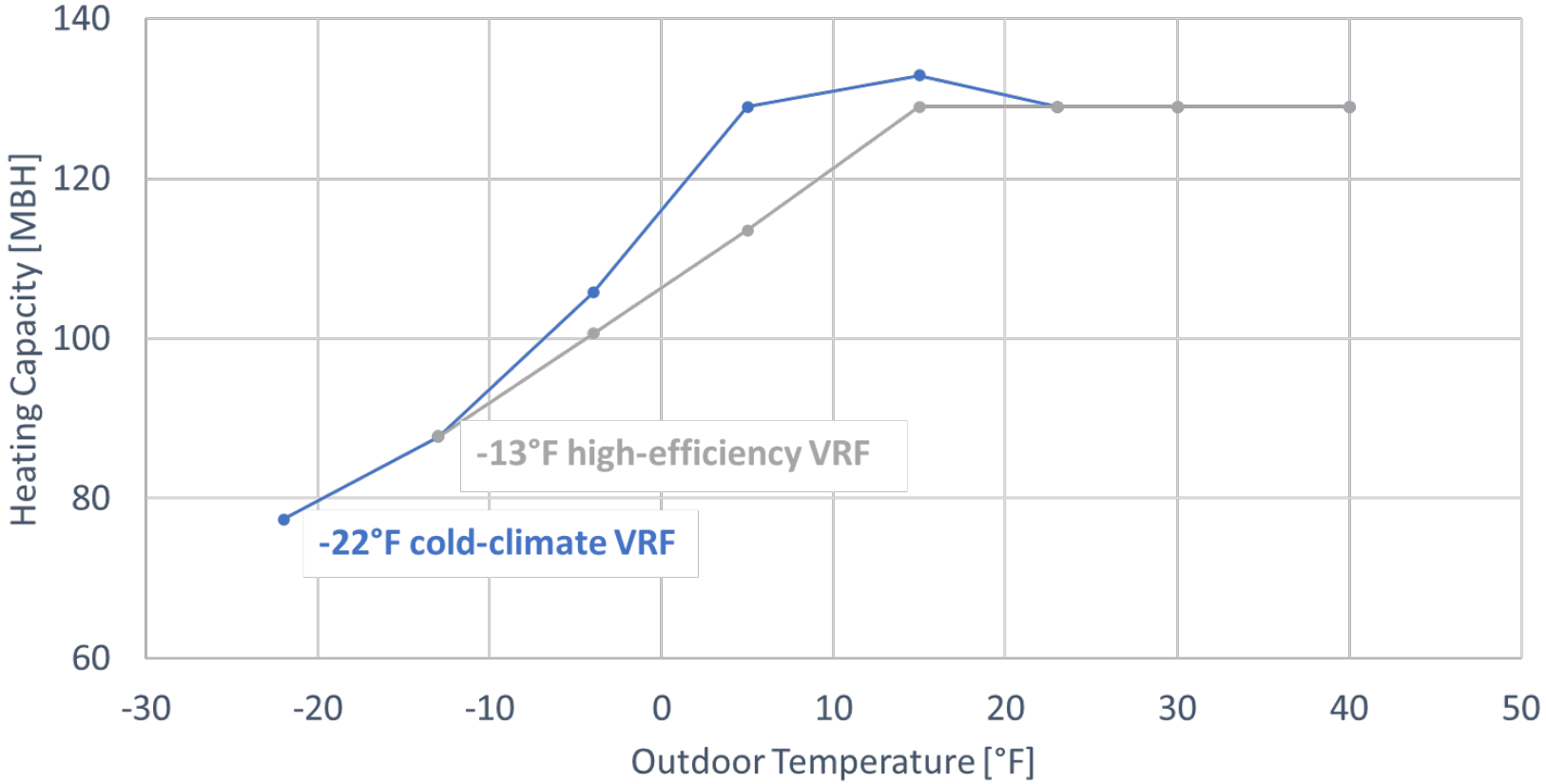


ccVRF

- Air-source VRF was limited to -5°F.
- New technology now allows cold-climate operation rated to -22°F.
- This brings a midsize, all-electric, air-source heat pump solution to cold climates

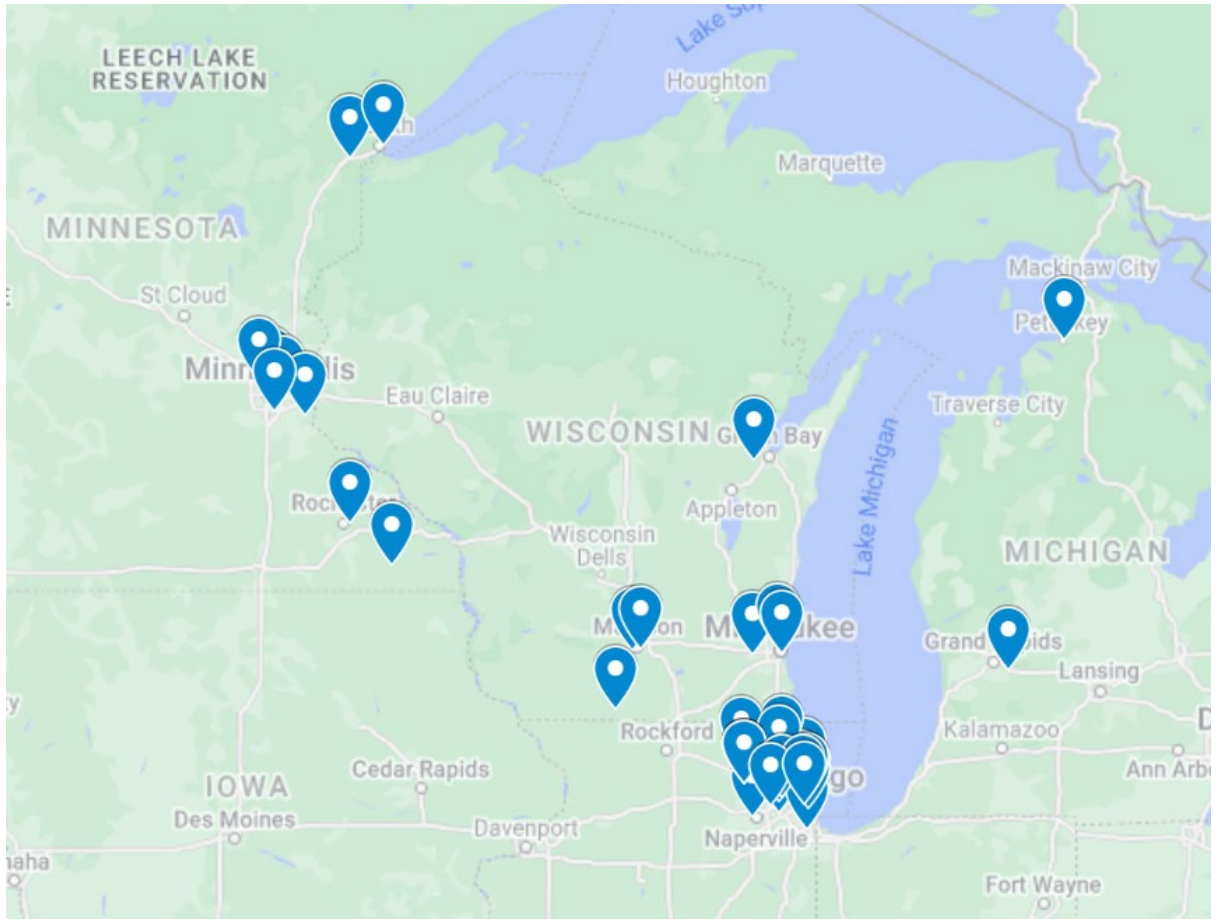


Heating Capacity and Efficiency in the Cold



ccVRF needs to be “oversized” to have capacity in the cold.

Buildings in the upper Midwest with any VRF system



- VRF can be found throughout the Upper Midwest, but…
- VRF is still not a popular option in Minnesota.
- Distrust of VRF heating at all levels of the supply chain.

These are locations of buildings with VRF, including both ccVRF and VRF with supplemental heat



Field Demonstration Methodology

Research Objectives

- **Evaluate the energy savings potential of VRF in Minnesota.**
- **Confirm whether ccVRF systems can meet occupant comfort preferences** in commercial and multifamily buildings in Minnesota.
- **Identify challenges and benefits of ccVRF experienced by operators or occupants.**

Site Summary

General VRF Assessment

	Health clinic	Multi-family B	Multi-family C
City	Rochester	Rochester	Twin Cities suburb
Use Type served by VRF	Outpatient Health Clinic	Market rate Multifamily	Market rate Multifamily
Project Type	New Construction	New Construction	New Construction
Square Footage served by VRF	16,115	594,207	390,546
Supplemental heat	Penthouse Approach	Penthouse Approach	Penthouse Approach

Detailed VRF Monitoring

	Small Office A	Multi-family A	Large Office	Small office B
City	Twin Cities	Twin Cities	Cloquet	Delano
Use Type served by VRF	Office	Low-income Multifamily	Office	Office
Project Type	Retrofit	New Construction	Retrofit	Retrofit
Square Footage served by VRF	2,170	90,300	7,800	1,600
Supplemental heat	Electric Resistance	None	Electric Resistanc e	Industrial Equipment

Field Assessment Approaches

General VRF Assessment

- Facility/Mechanical Review
- Facility Manager/Contractor Interviews
- Utility Bill Analysis
- Comfort Survey

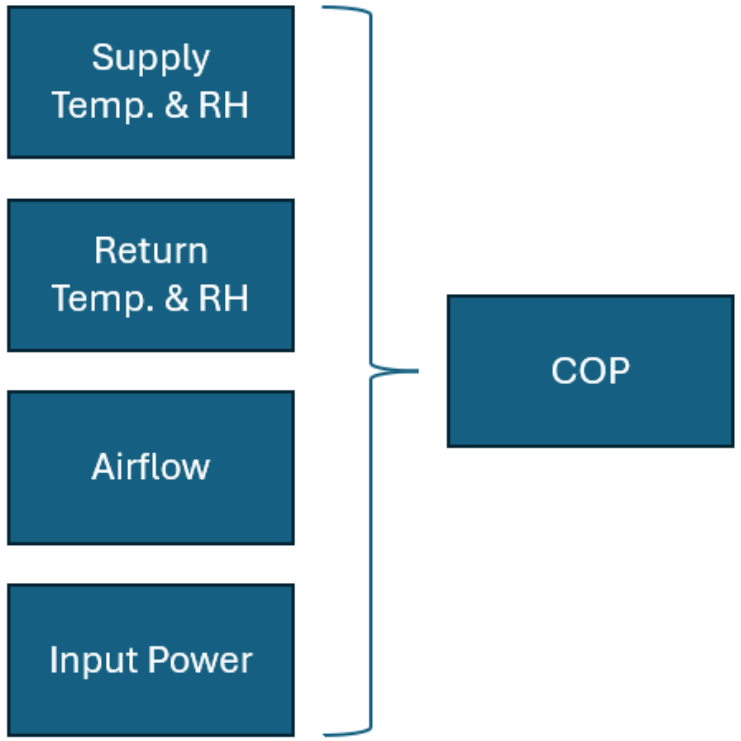
Detailed VRF Monitoring

- All General Assessment steps, PLUS
  - VRF power monitoring
  - Continuous Temp. & RH monitoring
  - Controls assessment
  - Airflow measurement

Detailed Monitoring Performance Metrics

Power and Capacity measurements used to calculate:

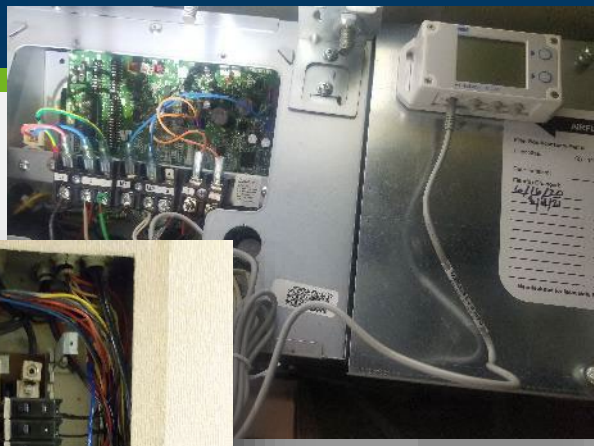
- HVAC Energy by Component
- VRF Daily Electricity vs. Outdoor Temperature
- VRF time at part-load
- COP vs. Outdoor Temperature
  - Relies on accurate measurements from many sources

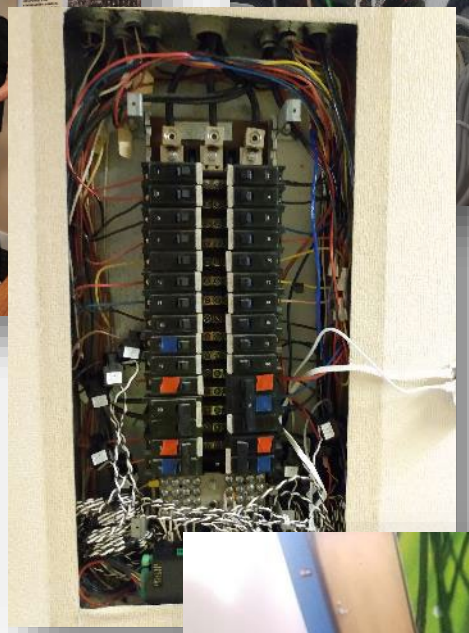


Instrumentation

- Indoor & Outdoor unit power
- Temperature and RH sensors
- CT on indoor unit fan
- One-time airflow measurements + power correlation
- Supplemental heating electric power or gas energy









Interviews

Contractor interviews

- General VRF Experience
- Specific site experience
- Satisfaction/perception

Building owner interviews

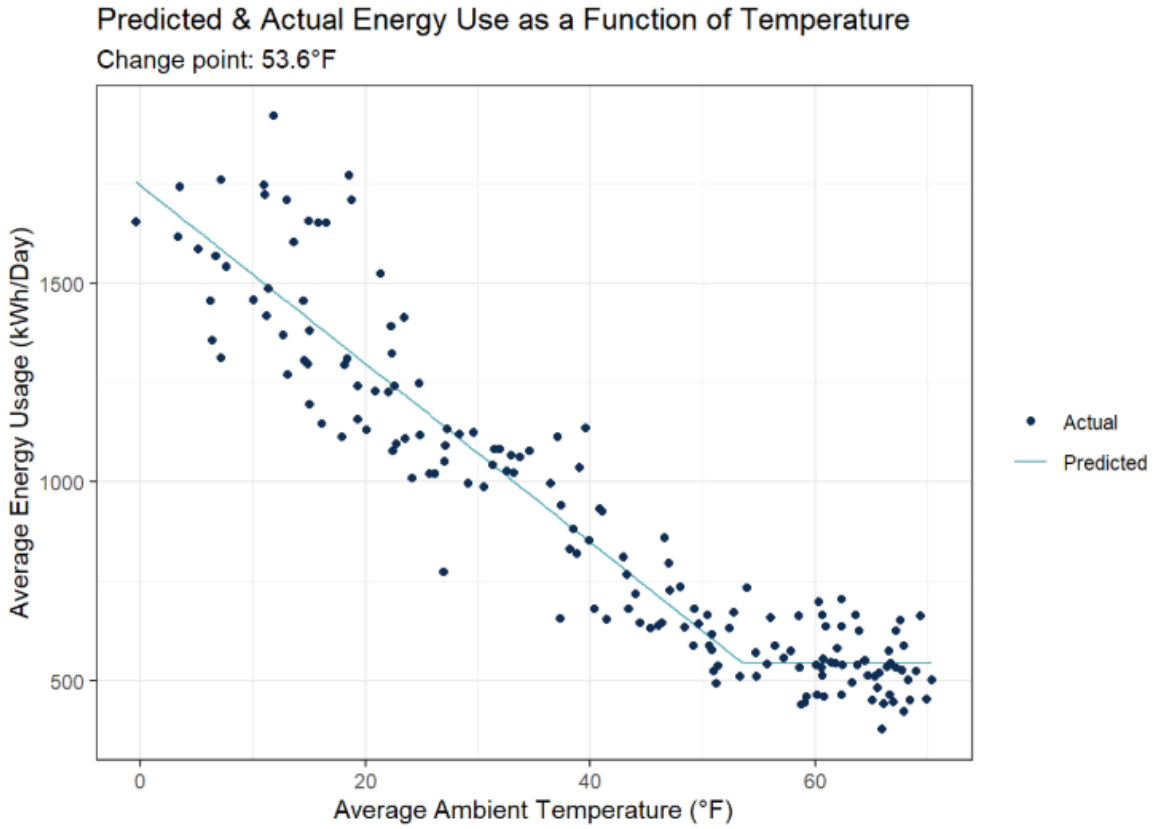
- VRF installation context
- Operating practices
- Satisfaction/perception

Manufacturer Rep. Interviews

- VRF sales in Minnesota
- Most common applications
- Costs

Utility Bill Analysis

- Electricity use vs.
  - Time
  - Ambient Temperature
- Estimated weather dependency
- Estimated EUI
- Calibrated Energy Models



Energy Modeled Savings

Site Name	Small Office A	Large Office	Multifamily A	Health Clinic	Multifamily B
Calibrated Energy Model of VRF system	ccVRF	ccVRF	ccVRF	VRF Penthouse	VRF Penthouse
Energy Modeled Baseline System	Furnace A/C	Furnace A/C	Furnace A/C	Furnace A/C	Furnace A/C
	ASHP + Elec. Heat	ASHP + Elec. Heat	WSHP	ASHP + Elec. Heat	WSHP
		Single Zone DX RTU	PTAC	VAV RTU	PTAC
				ccVRF	ccVRF



Results

Study Findings

The good

- Energy Savings
- Emissions Savings
- Cold-climate performance

The not as good

- Cold-climate performance?
- High first cost and limited payback
- Installation issues
- EPA refrigerant phasedown

Should we design, install, and incentivize VRF in Minnesota?

Energy Savings

26%

Site Energy (EUI) Savings

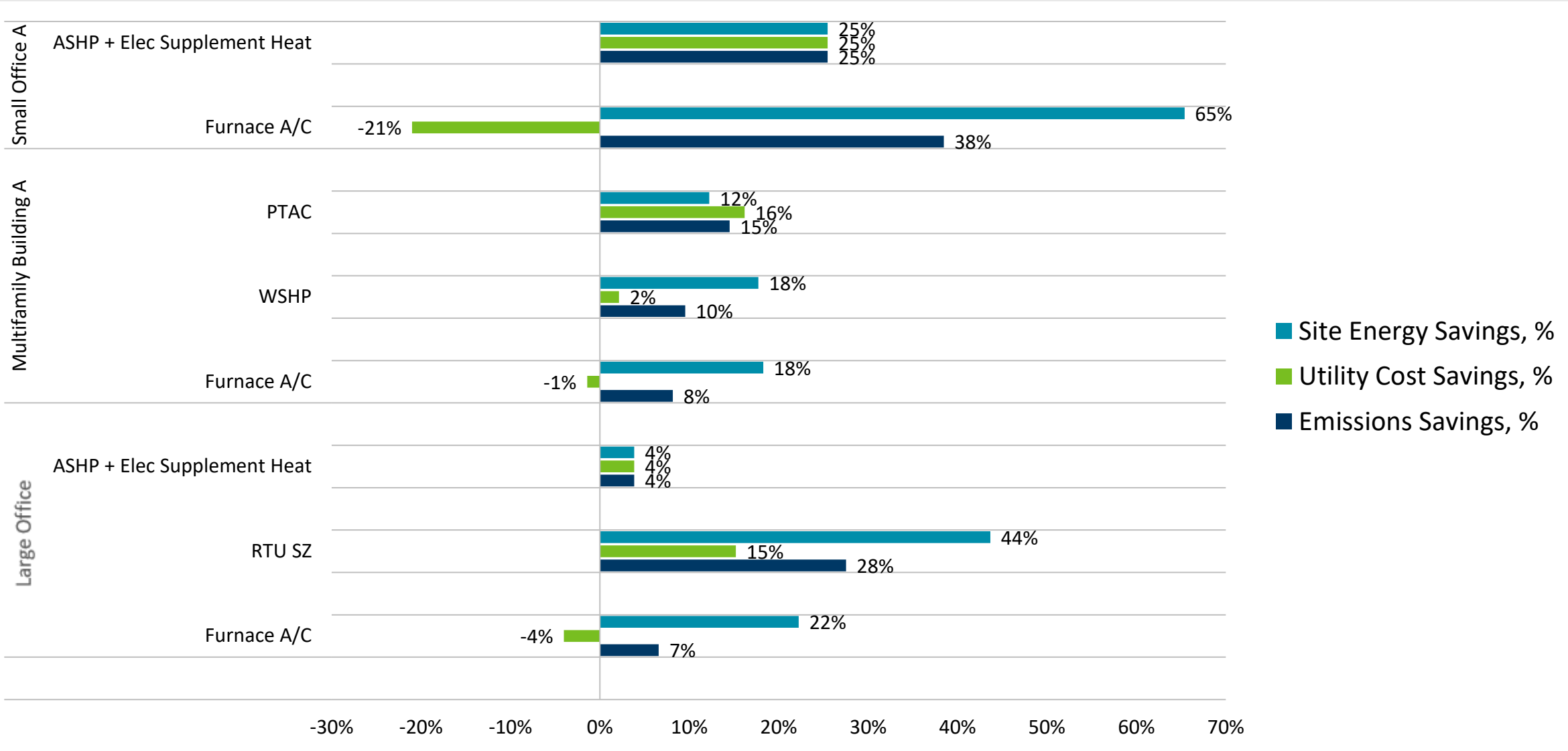
18%

Average HVAC Annual Emissions Savings

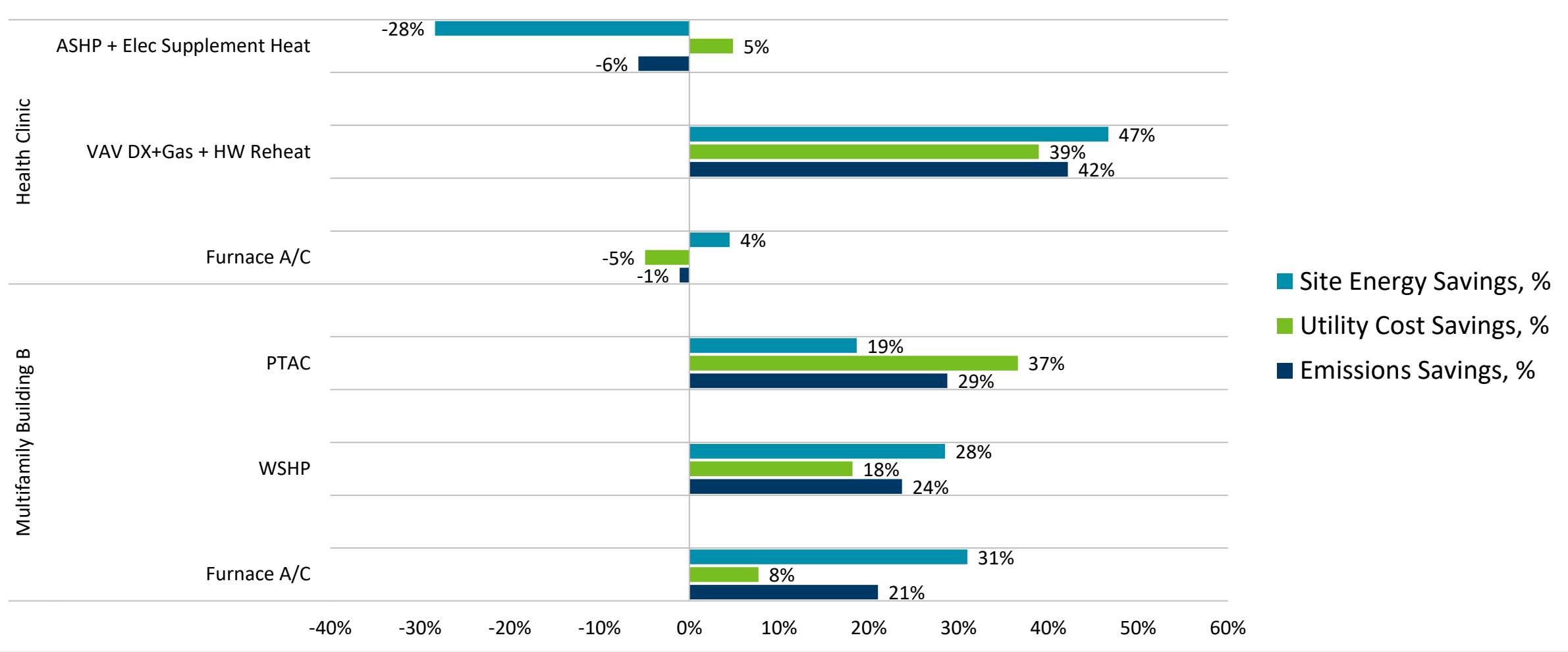
6%

HVAC energy cost reduction*

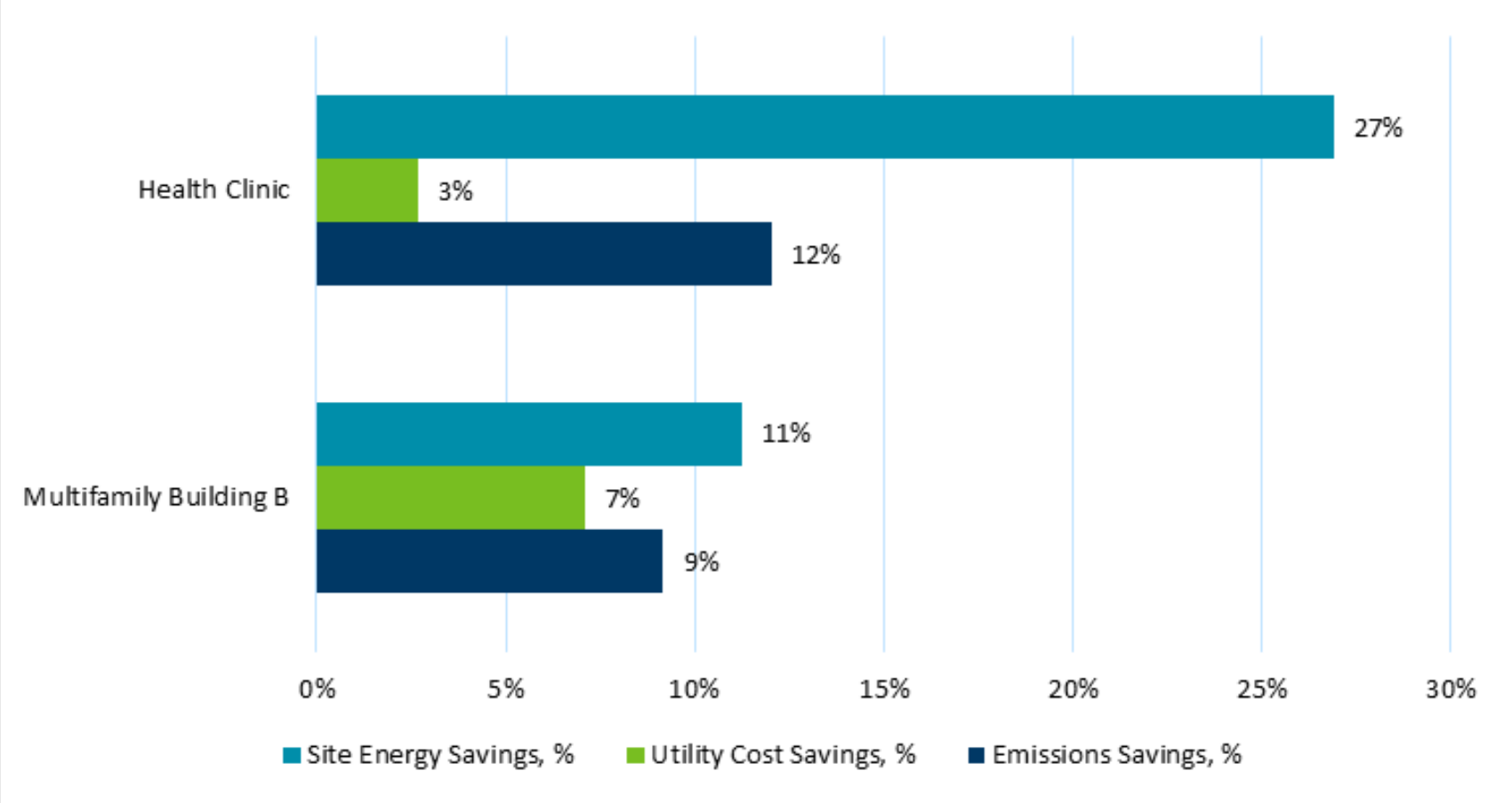
ccVRF Savings



VRF Penthouse Approach Savings

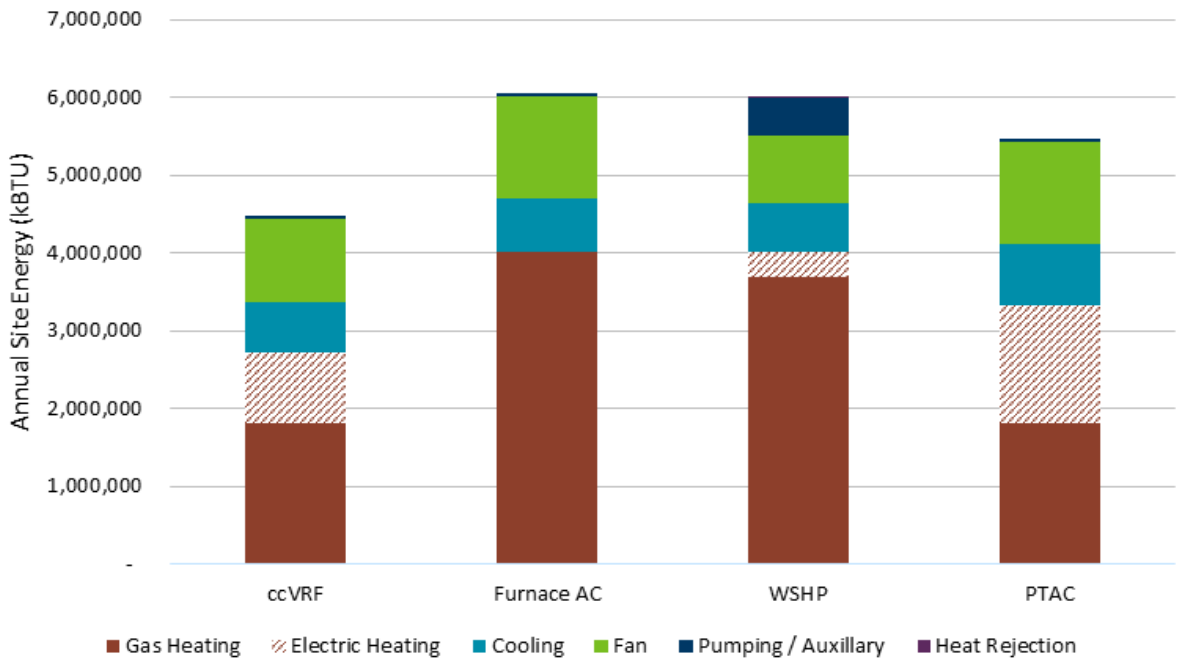


VRF Penthouse Approach vs. ccVRF Savings

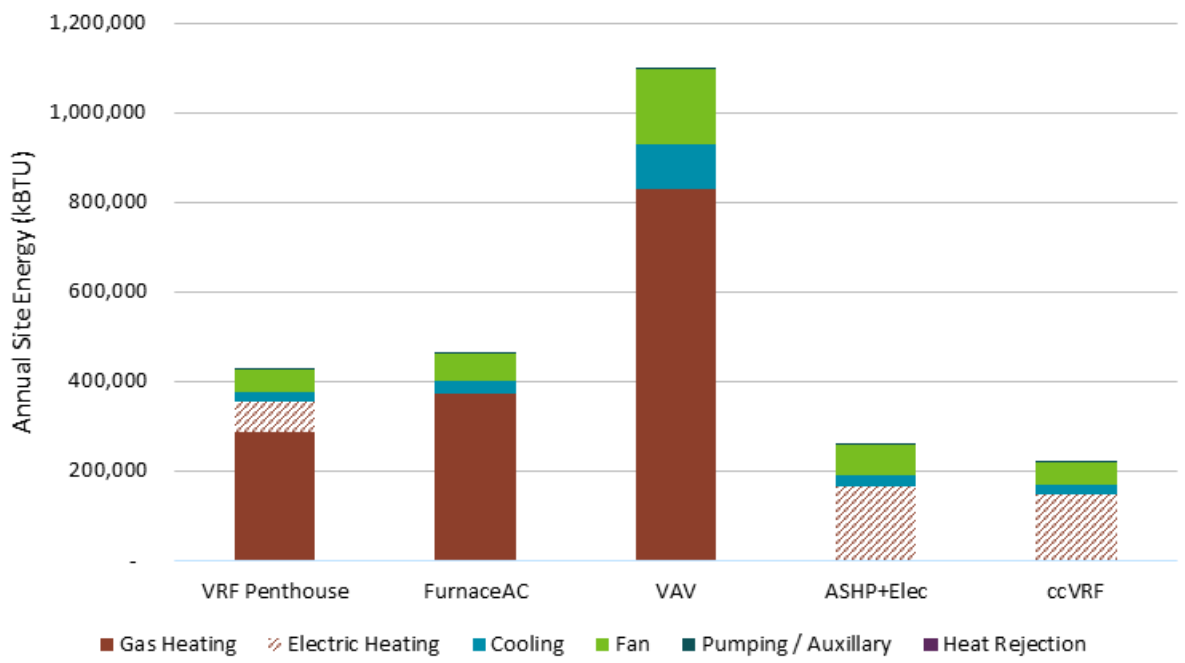


Energy by End Use

Multifamily Building A - Energy by end use

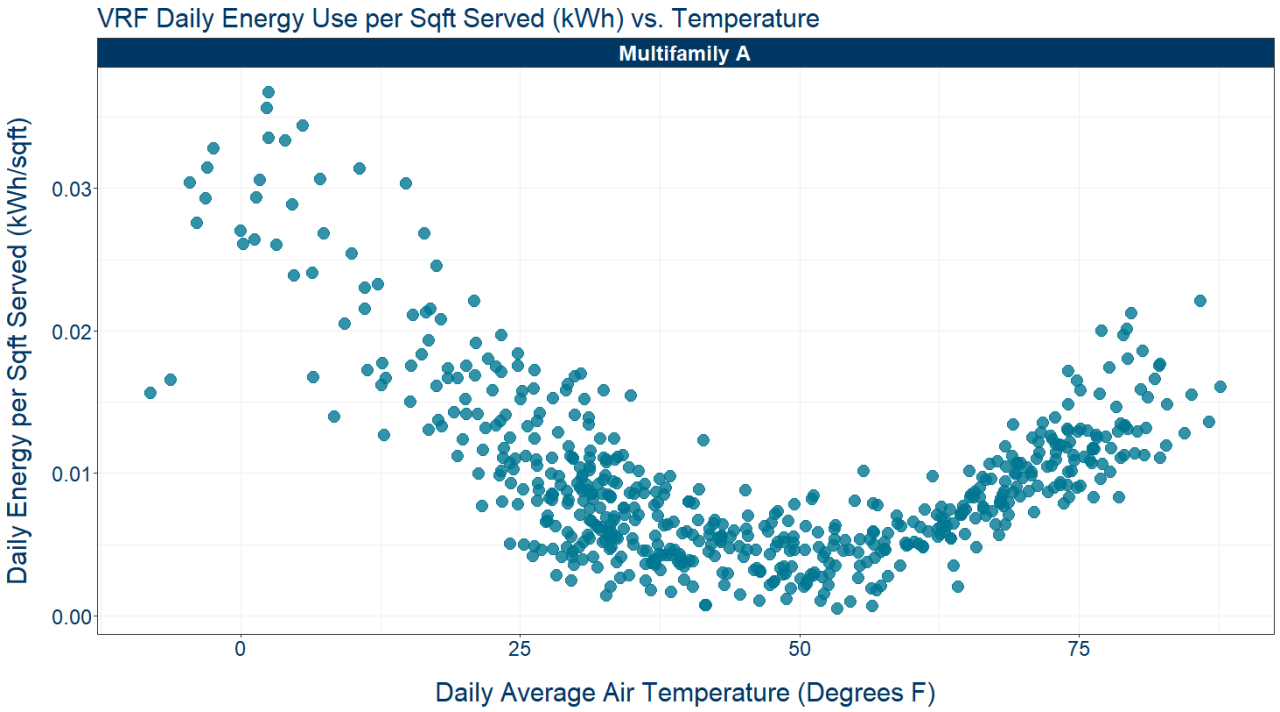


Health Clinic – Energy by end use

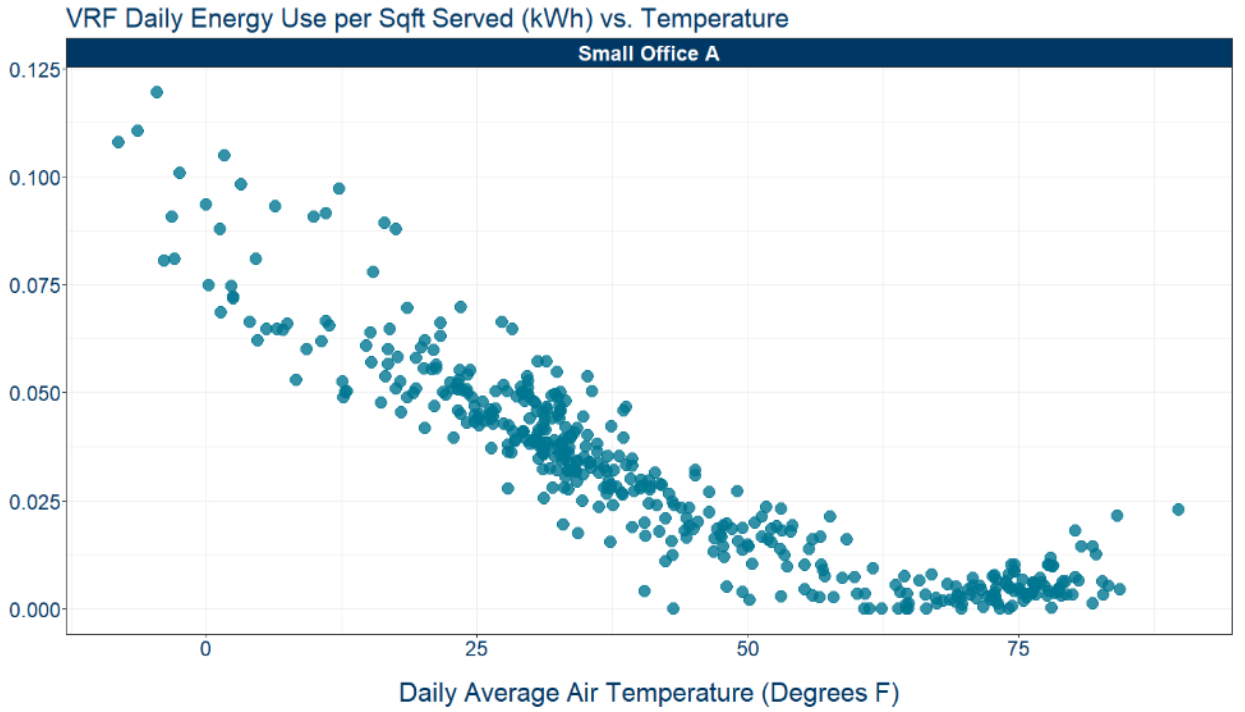


ccVRF Outdoor unit daily electricity vs. daily temperature

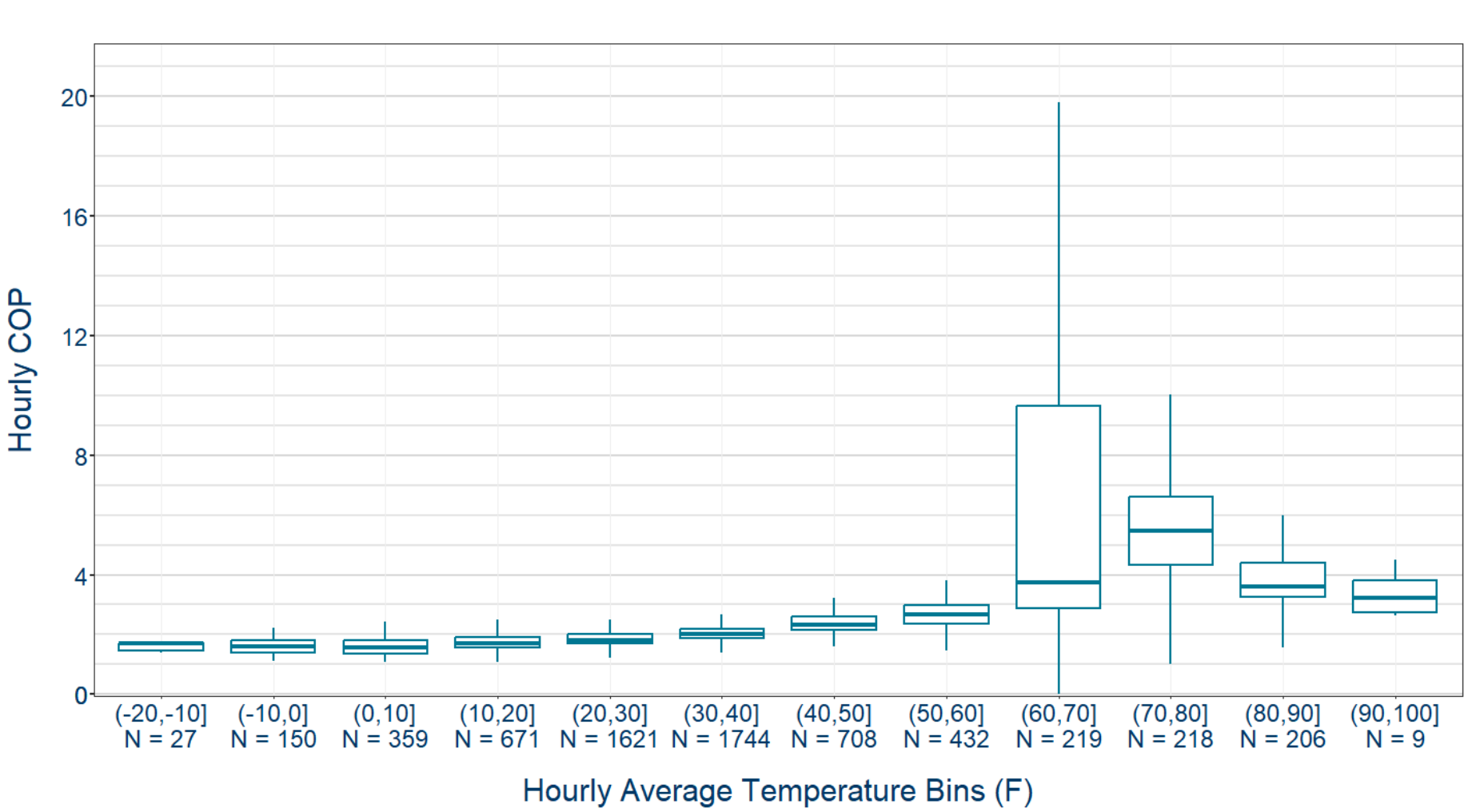
Multifamily Building A



Small Office A



Small Office A: VRF 1 COP

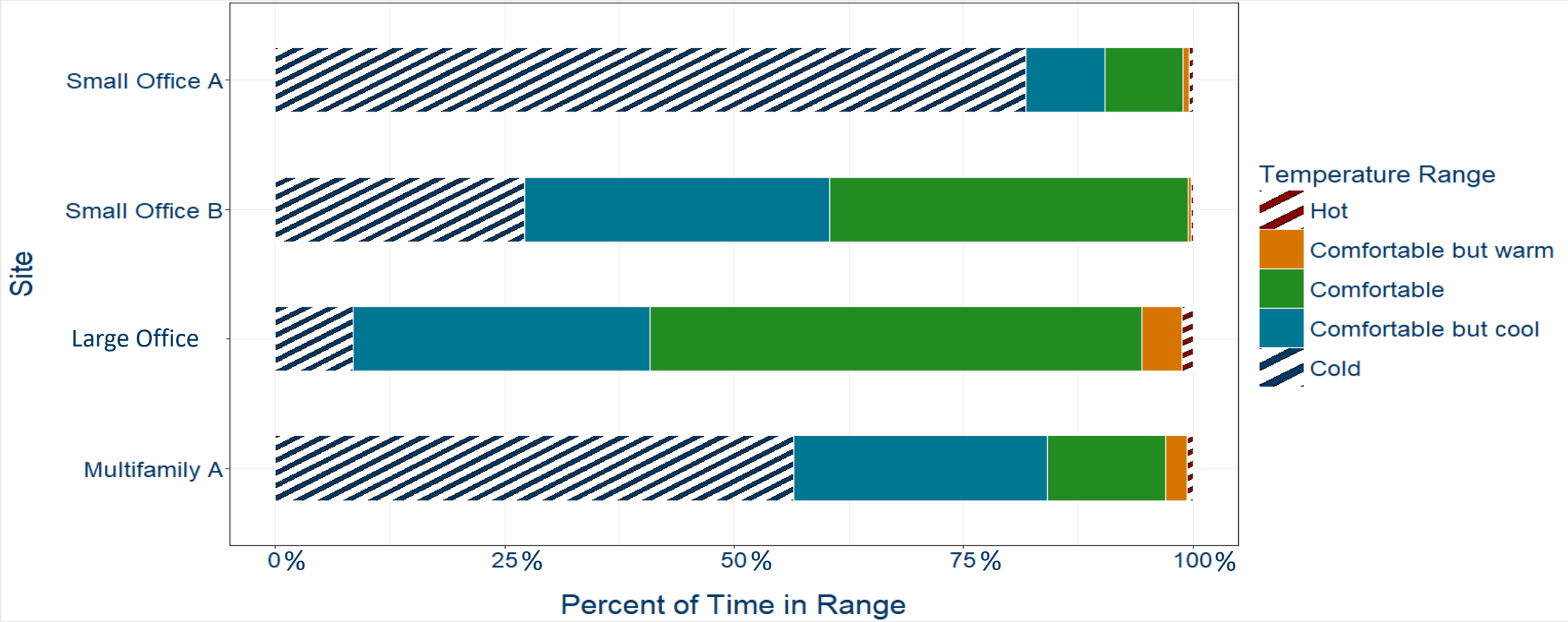


	VRF 1	
Mode (Outdoor Temp.)	Calculated COP	Uncertainty Range
Heating (<56°F)	1.9	1.5 – 1.9
Cooling (>78°F)	3.9	2.9 – 4.3
Mixed (56 -78°F)	4.2	2.9 – 5.1
Overall	2.0	1.6 – 2.0

A lot of valid data points in the winter

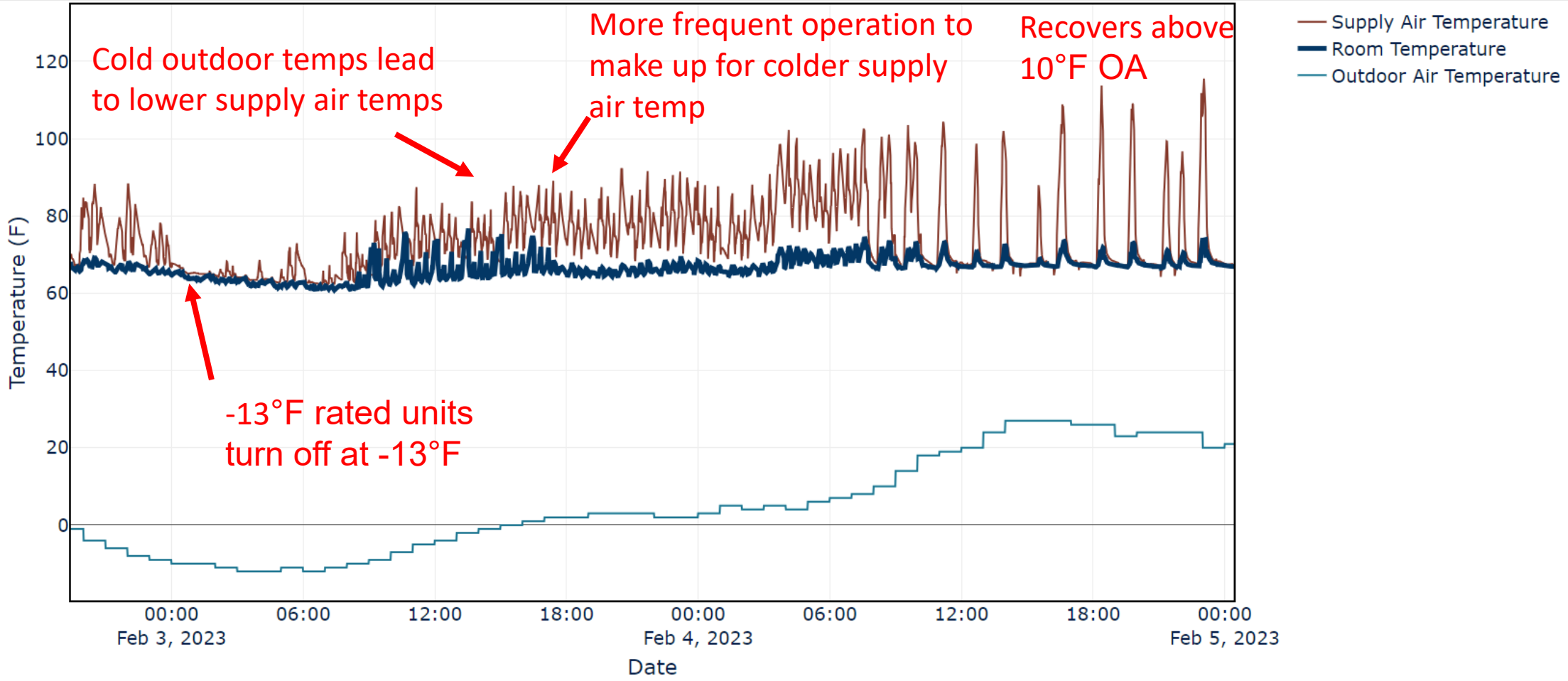
Few valid data points in the summer

ccVRF - Thermal Comfort in Winter



Building Type	Outer Range Low Temperature	Inner Range Low Temperature	Inner Range High Temperature	Outer Range High Temperature
Offices and Large Office	69.3	71.8	76.7	78.5
Multifamily	71.2	74.7	77.9	80.3

Multifamily Building A – Cold Weather Operation



Simple Payback

	Primary Heating Fuel	Small Office A	Multifamily Building A	Large Office	Health Clinic	Multifamily Building B
Baseline HVAC System	-	ccVRF	ccVRF	ccVRF	VRF Penthouse	VRF Penthouse
Furnace A/C	Gas	**Never pays back**	**Never pays back**	**Never pays back**	**Never pays back**	**More than 50 years**
RTU SZ	Gas	-	-	21 years	-	-
VAV DX+Gas + HW Reheat	Gas	-	-	-	16 years	-
WSHP	Electric and Gas	-	**Immediate**	-	-	**8 years**
PTAC	Electric	-	**More than 50 years**	-	-	**More than 50 years**
ASHP + Elec Supplement Heat	Electric	**12 years**	-	**More than 50 years**	**More than 50 years**	-

VRF Operator Interviews

VRF was often selected for energy efficiency potential.

VRF is easy to maintain, quiet and efficient.

“Black box” controls and difficult thermostat can be frustrating.

- “Skit” for new residents on how to use the thermostat.
- Supplemental heat controls may use more energy.

Need a service contractor to perform repairs.

Equipment Failures

- Concerning number of VRF equipment failures within 2 years of installation.
- This is not just in Minnesota.
- Happened with multiple building types and variety of VRF manufacturers.
- Multifamily can be the most burdensome.
- It is almost always related to installation, sometimes electric power quality.



VRF Installation

Attention to detail for refrigerant piping is key

- No traps
- Exact fittings
- No deviation from plans
- Excellent braze joints: cleaned and purged with inert gas prior to brazing
- Proper pipe insulation to prevent unintended phase change

Consequences of failing to comply with these rules are severe

- Improper refrigerant charge or quality = insufficient cooling or heating
- Insufficient lubrication, or debris in piping = compressor damage

VRF Learning Curve

"We had some issues with the systems in the first building, but in the next two buildings **we haven't had those issues**"

"**We're happy with the system.**"

"Sections of the building have **no consistent heat**."



VRF Learning Curve

VRF Refrigerant Transition

EPA AIM ACT

- Phasing out Hydrofluorocarbons (HFCs) which have Global Warming Potential (GWP) more than 700.
- New VRF can no longer use R410 starting January 1, 2026.
- Replacements will be R32 and R454B. You cannot change refrigerant system type in an existing system
- R32 and R454B are low flammability (A2L)

VRF systems will need to meet new ASHRAE 15 requirements because of flammable refrigerants:

- Refrigerant Leak Detection
- additional isolation valves
- chase and plenum restrictions, etc.



Key Outcomes

Study Findings Cont.

The good

- Energy Savings
- Emissions Savings
- Cold-climate performance

The not as good

- Cold-climate performance?
- High first cost and limited payback
- Installation issues
- EPA refrigerant phasedown

Should we design, install, and incentivize VRF in Minnesota?

Yes, if VRF is applied correctly



Minnesota Utility Program Interventions

Recommended Interventions

To grow VRF adoption and accelerate the learning curve for commercial VRF system, Minnesota and its Utility partners should take the following steps:

1. Only incentivize VRF systems after January 1, 2026, or only incentivize systems with refrigerants that comply with the EPA AIM Act (GWP less than 700).
2. Provide training for designing systems with new A2L refrigerants.
3. Require or pay for installer training with any VRF systems.
4. Raise awareness that VRF systems are a viable solution when care is taken to design and install them properly.
5. Offer prescriptive incentives to reduce first cost. Mass Saves offer $3,500/ton.

Questions?

Cold Climate Variable Refrigerant Flow (ccVRF) System Demonstration and Market Research



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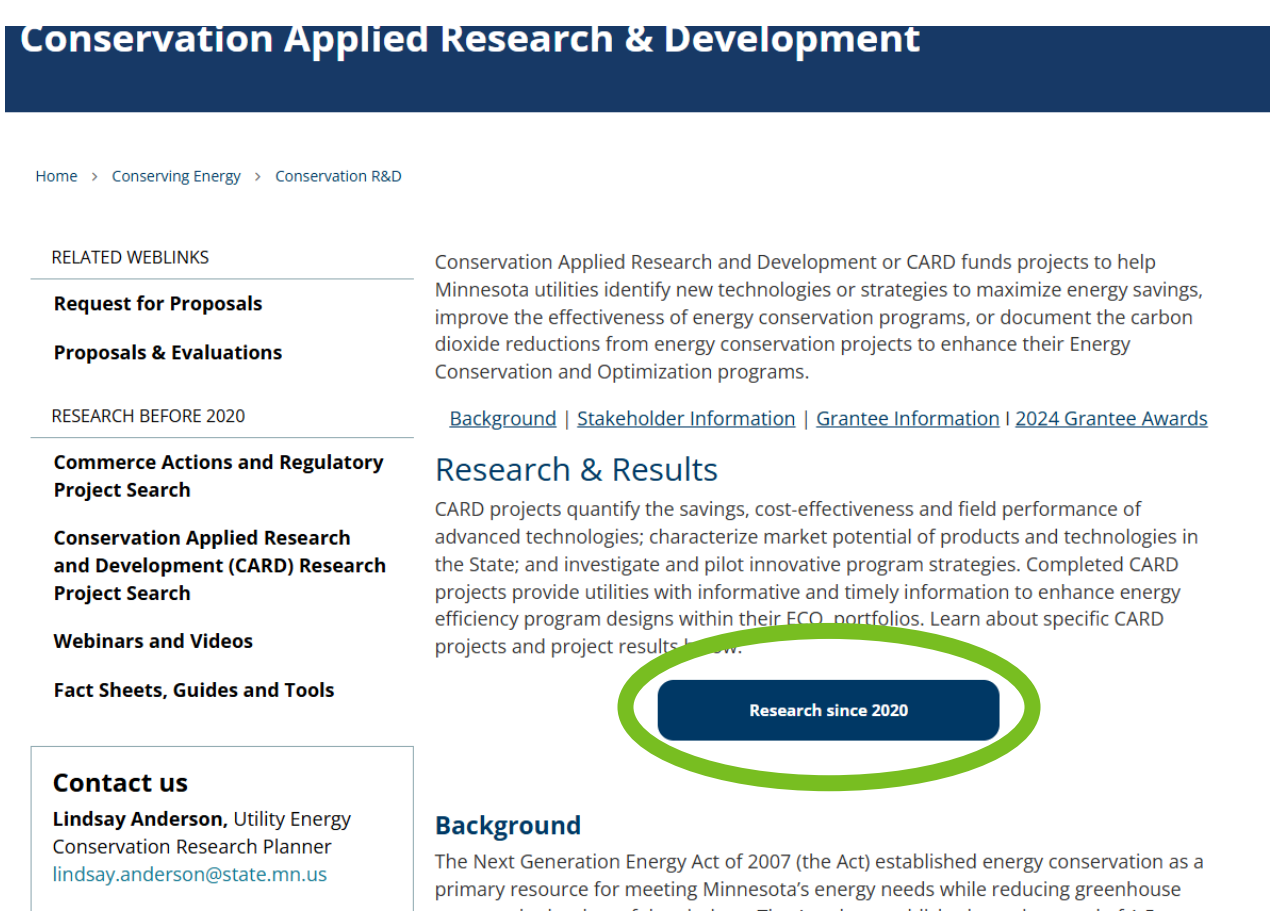
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Access CARD Research Online

- Final reports, webinars, fact sheets, & other resources available on the Conservation R&D webpage mn.gov/commerce/energy/conserving-energy/applied-research-development/
- CARD final report archives can also be accessed through the following link, in "Energy Data and Reports", Topics: "Conservation Improvement Program"

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