Cold Climate Variable Refrigerant Flow Program Study

06/30/21

slipstream

Research Questions

- What is the path for VRF systems to become a Focus On Energy program offering? What is the market potential in Wisconsin for this technology?
- Is the supply chain in Wisconsin capable of supporting a program offering?
- What are the system baselines for calculating energy savings for a VRF system?
- Are VRF systems cost-effective?
- Do VRF systems have any substantial advantages over traditional HVAC systems for both a comfort and performance standpoint?
- Is VRF more applicable to existing building retrofits or new construction?

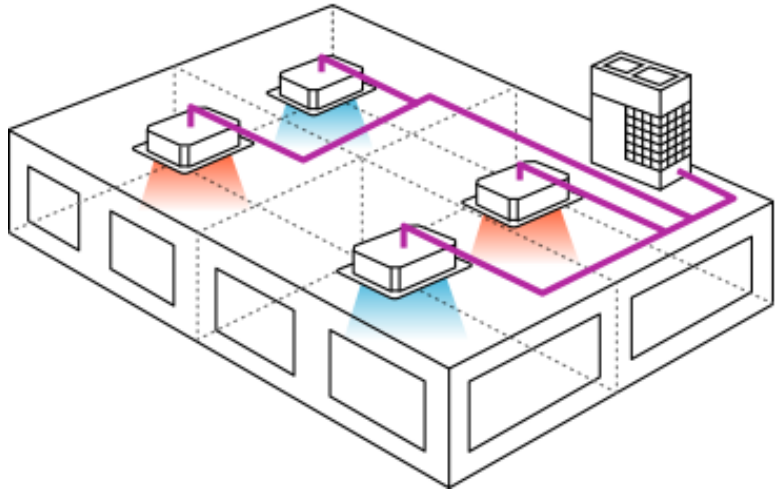
Research Tasks

1. Product, Supply Chain and Trade Ally Network Review
2. Program Baseline, Energy Savings and Economics
3. Market Assessment
4. Site Assessment
5. Program Framework

Product, Supply Chain and Trade Ally Network

Summary

- VRF systems offer a solution to electric heating and cooling
- Highly efficient – variable speed equipment, refrigerant is energy dense, heat recovery potential, typically paired with DOAS



- Great for buildings with many zones, simultaneous heating and cooling, or duct space limitations

Product, Supply Chain and Trade Ally Network

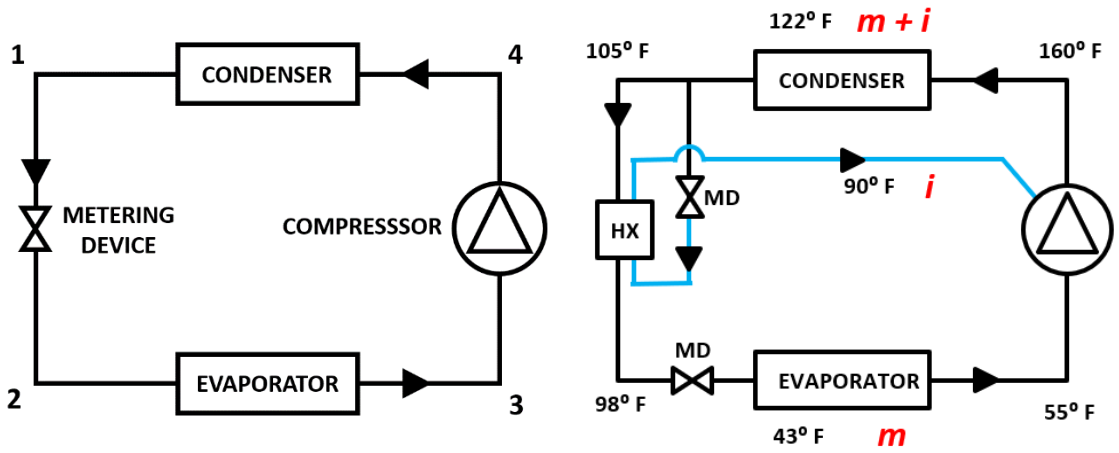
Challenge

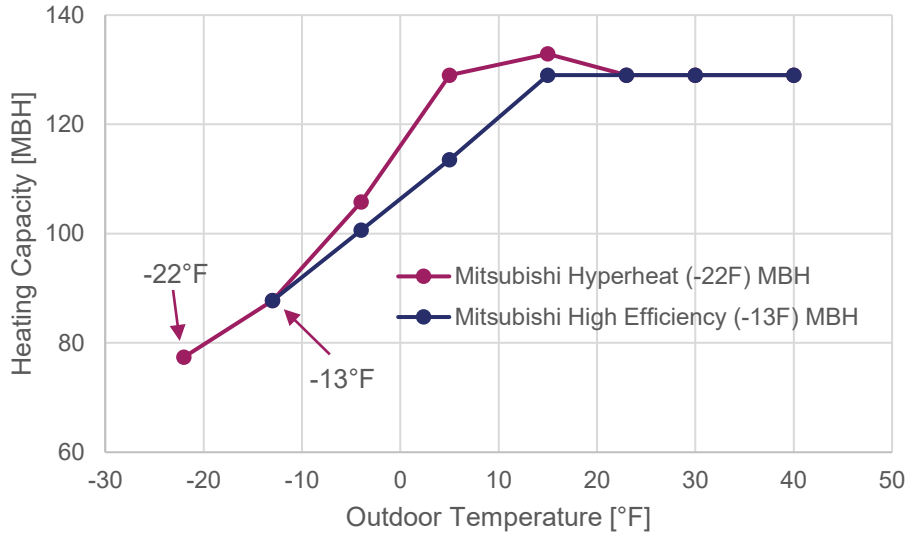
- Cold weather performance - below 5°F heating capacity decreases. Older systems were unable to operate (at all) in cold conditions.
- Required supplemental or secondary heating systems.
- Complexity

Product, Supply Chain and Trade Ally Network

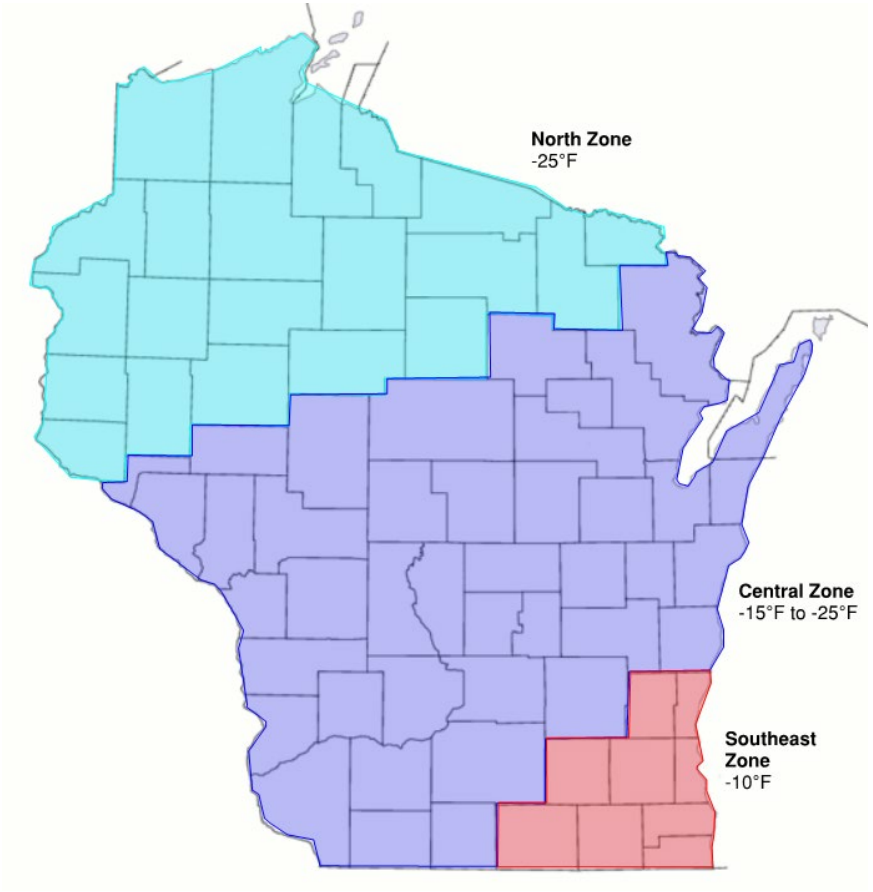
Solutions

- Design strategies
  - Oversizing
  - Penthouse approach
  - Supplemental heating system
  - Oversizing outdoor air system (DOAS)
- Cold Climate VRF





Product, Supply Chain and Trade Ally Network



North Zone

- Water-source VRF systems
- Air-source VRF systems with penthouse or other auxiliary heating source

Central Zone

- Air-source ccVRF systems
- Air-source VRF systems with penthouse or other auxiliary heating source

Southeast Zone

- Air-source VRF systems

Product, Supply Chain and Trade Ally Network

Interviews

Product and Building Types

- Nursing Homes, multifamily, offices, K-12, retail, hotels
- Two cold climate installations
- Penthouse approach popular

Installation and Maintenance

- Building load calculations are important when sizing
- Design and installation protocols differ between manufacturers
- New system to market – engineers, prospective owners, installers are less familiar

Barriers, Challenges, Solutions

- Upfront costs still higher
- Lack of experience with newest generation of systems
- Lack of program support

Product, Supply Chain and Trade Ally Network

Refrigerants

Increased use of harmful refrigerants

- Systems currently use R-410A (GWP 2,090 / ODP 0)
- Systems are complex and feature significant amount of piping connections and potential leak points
- Manufacturers recommend leak testing systems
- New refrigerants (R-32) substantially reduce GWP

Program Baseline, Energy Savings and Economics

Program Baselines

- Electric baseline (heat pump or resistance heat)
- Fossil fuel baseline (gas fired systems – RTUs, PVAV, etc)

Program Baseline, Energy Savings and Economics

Energy Model

- ASHRAE 90.1-2004 compliance
- Baseline HVAC systems comply with current code
- VRF system was modeled after LG system – high efficiency

Building Type	Baseline system (Gas-Fired Equipment)	Baseline system (Electric Heating)	Alternate System
Multifamily	Split System AC w/ gas furnace	Packaged terminal heat pump	N/A
Education	PVAV, Gas heated coil in air handler, gas boiler HW reheat.	PVAV, Heat pump air handler, electric reheat.	PVAV, gas heated coil in air handler, electric reheat
Hotel	N/A	Packaged terminal AC with electric resistance heat	N/A
Office	PVAV, Gas heated coil in air handler, electric reheat.	PVAV, Heat pump air handler, electric reheat.	PVAV, gas heated coil in air handler, electric reheat

Program Baseline, Energy Savings and Economics

Savings Results

		VRF Savings over baseline system			
Building Type	Baseline System	kWh/ft^2	therm/ft^2	% kWh	% therms
Education	PVAV HW	0.41	0.20	5%	53%
	PVAV Elec	3.00	0.02	27%	9%
	PVAV HW w/ Def	1.44	0.27	15%	61%
	PVAV HP w/ Elec RH	4.57	-0.06	37%	-47%
Hotel	PTAC	2.51	0.00	23%	0%
	PTAC w/ Elec DOAS	3.69	-0.08	31%	-111%
Multifamily	Furnace/DX	2.29	0.16	19%	37%
	WSHP	1.45	0.06	13%	17%
	PTHP	1.81	0.01	15%	2%
Office	PVAV HW	0.49	0.18	5%	74%
	PVAV Elec	4.01	-0.02	32%	-33%
	PVAV HW w/ Def	1.10	0.26	11%	80%
	PVAV HP w/ Elec RH	4.64	-0.05	35%	-228%

Program Baseline, Energy Savings and Economics

Economics

- Cost data gathered from contractors and sales representatives
- Energy cost data from EIA
- Energy savings data from energy models

Building Type	Baseline System	First Cost Increase $/ft2	Annual Energy Cost Savings $/ft2	Simple Payback years
Education	PVAV HW	2.50	0.16	15
	PVAV Elec	6.00	0.33	18
	PVAV HW w/ Def	2.50	0.31	8
Hotel	PTAC	13.50	0.27	50
Multifamily	Furnace/DX	3.70	0.34	11
Office	PVAV HW	2.50	0.16	15
	PVAV Elec	6.00	0.47	13
	PVAV HW w/ Def	2.50	0.27	9

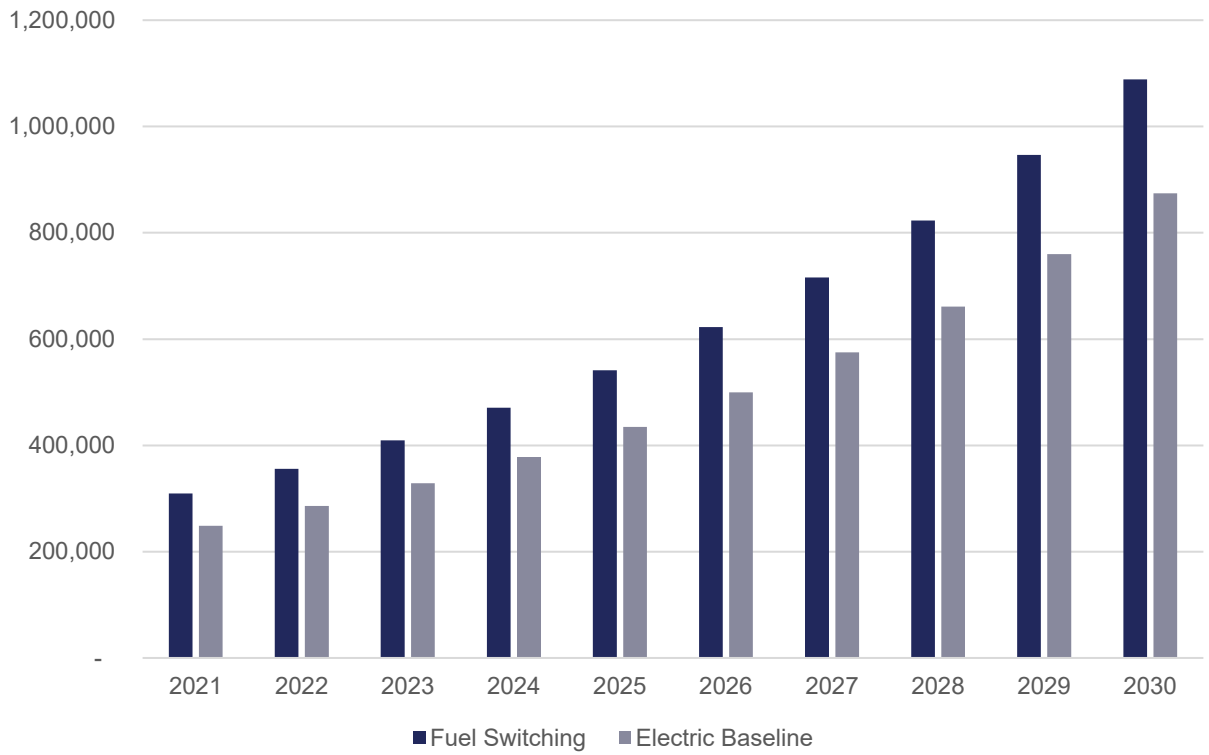
Market Assessment

Method

- Used CBECS, RECS and the US Census to estimate building population in Wisconsin
- Used information on growth rate and annual projects (from contractors and manufacturers) to estimate existing impact
- Used energy models to estimate energy savings

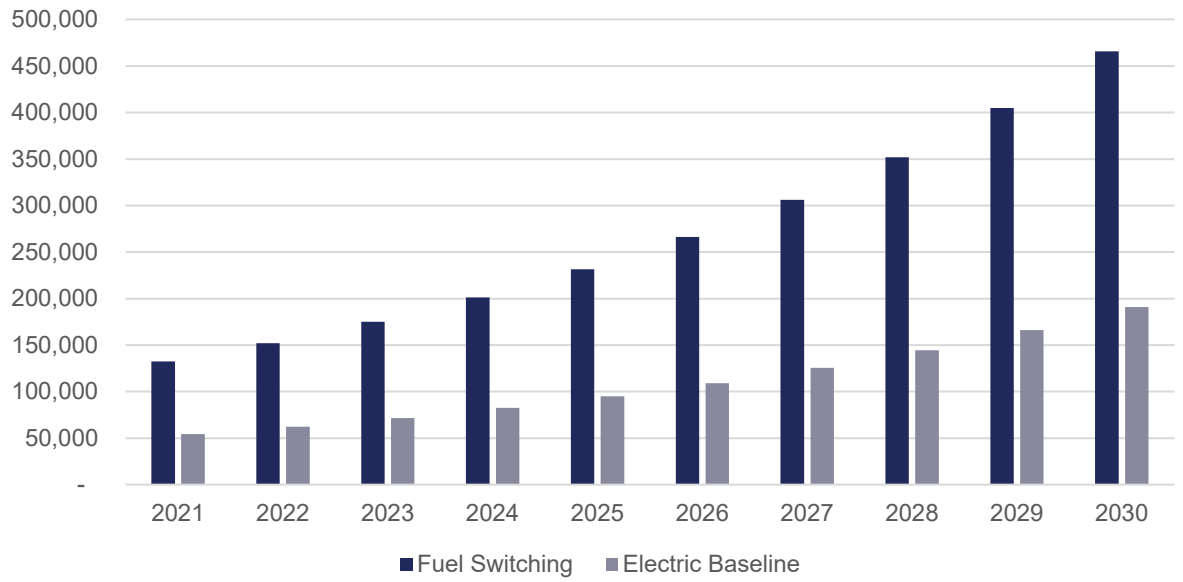
Market Assessment

Commercial Impact



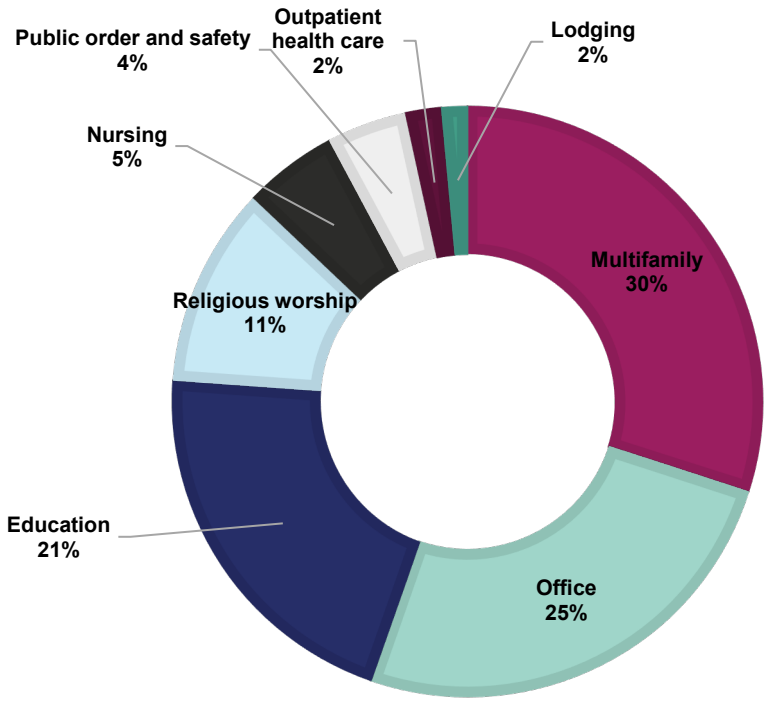
Market Assessment

Residential Impact



Market Assessment

Impact by Building Type



Site Assessment

Method

- Located 5 sites to assess energy and comfort performance
- Interviewed sites, gathered system and operational details
- Requested utility bills
- Conducted comfort interview with building operator
- Challenge: Buildings not regularly occupied (or at all) from March 2020 to Spring 2021.

Site Assessment

Key takeaways

- Only 1 site had no supplemental or secondary heat.
- All sites were in general satisfied with the performance of the system from both a comfort and energy perspective.
- All sites would consider VRF again.
- Most sites displayed some learning curve with operating the system:
  - Hotel – comfort issues with corner rooms, occupants not realizing system was operating
  - Office – control problems with meeting setpoints, morning warmup/nighttime setback issues

Program Framework

Background

- Complete nationwide program review
- Interview relevant programs for additional detail
  - Oklahoma
  - New York
- Review lessons learned
- Review Focus on Energy portfolio

Program Framework

Path to a VRF Offering

- Leverage *Business Offering – HVAC Catalog*
- Easy path to implementation
- Customers are familiar with this offering already
- Customer friendly – incentives are known upfront

Program Framework

Path to a VRF Offering

- Formalize Baseline
  - Electric or Gas
  - Stakeholder buy-in on baseline
- Develop Savings Calculation
  - Prescriptive measure
  - Next step – workpaper to be used as basis for TRM measure
- Offer Incentives
  - Recommended to utilize customer friendly $/ton metric
- Create Criteria
  - Ensure project success and maximize energy savings by developing criteria
    - Qualified contractor list
    - Adhering to VRF manufacturer design, installation, and start up procedures
- Increase Market Awareness
  - Program staff should be able to highlight benefits (energy and non-energy) of VRF systems to ideal projects
  - Create materials that can be used by program staff
  - Develop connections with manufacturers and sales representatives to provide to potential customers.