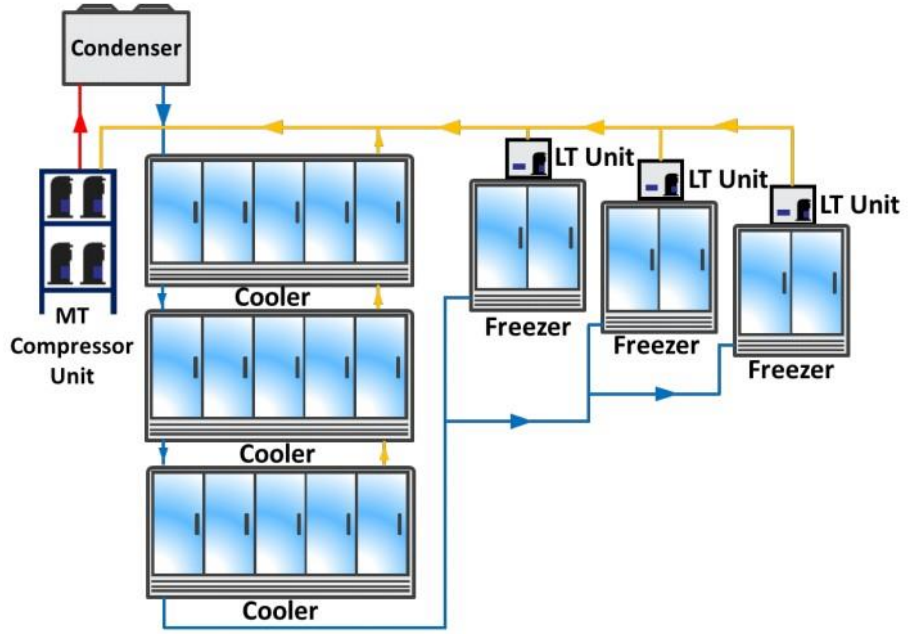
Evaluation of Low Environmental Impact "Distributed Scroll Booster" Technology for Supermarket Refrigeration



Performing Organization(s): ORNL
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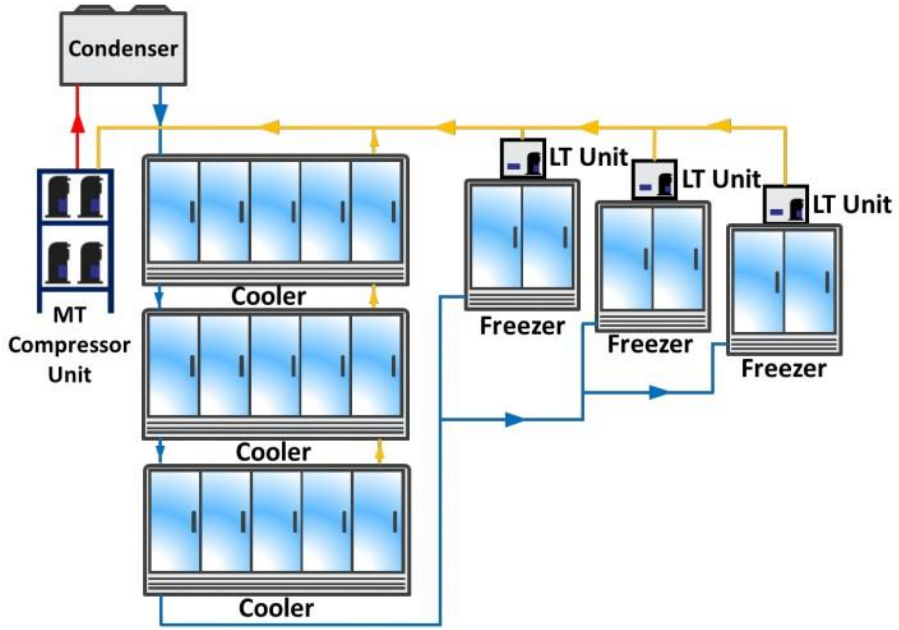
Project Summary

Objective: Enable distributed/Scroll-Booster systems for supermarket refrigeration using ultra low GWP refrigerant R-1234yf (GWP<1).

Outcome: Reduce overall GHG emissions by at least 60% by enabling R-1234yf in supermarket refrigeration applications. Enable the use of 2L refrigerant with no potential for fractionation.



Team and Partners

PI: Samuel F. Yana Motta, ORNL

ORNL Researchers: Vishal, Junjie Luo, Bo Shen

CRADA Partners: Emerson (Mike Saunders, Andre Patenaude)

Collaborators: Hussmann, Chemours

Stats

Performance Period: FY23-FY24

DOE budget: $450k, Cost Share: $450k

Milestone 1: Lab Performance – Q3 FY23

Milestone 2: Detailed LCCP Analysis – Q4 FY23

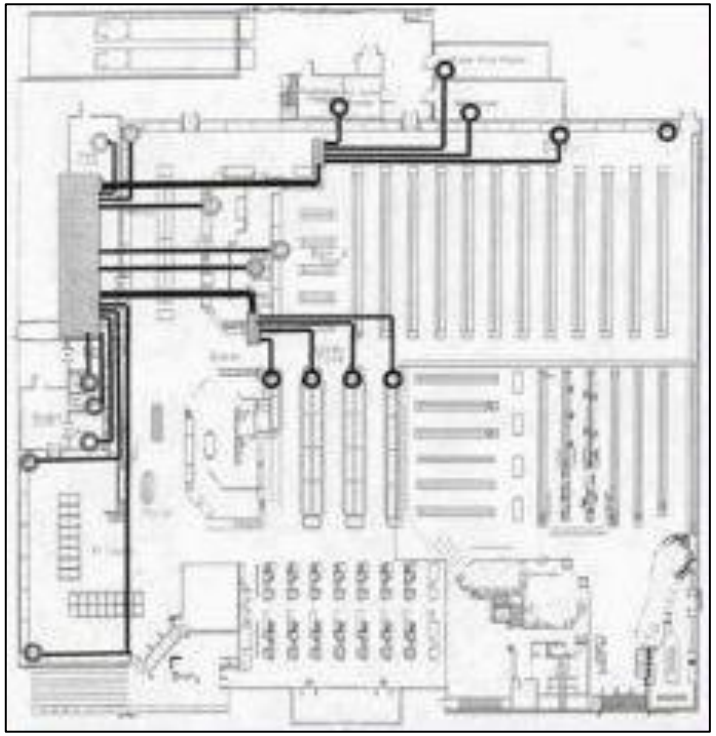
Milestone 3: Field Evaluation – Q4 FY24

Problem: High Environmental Impact of Current Supermarket

The Problem

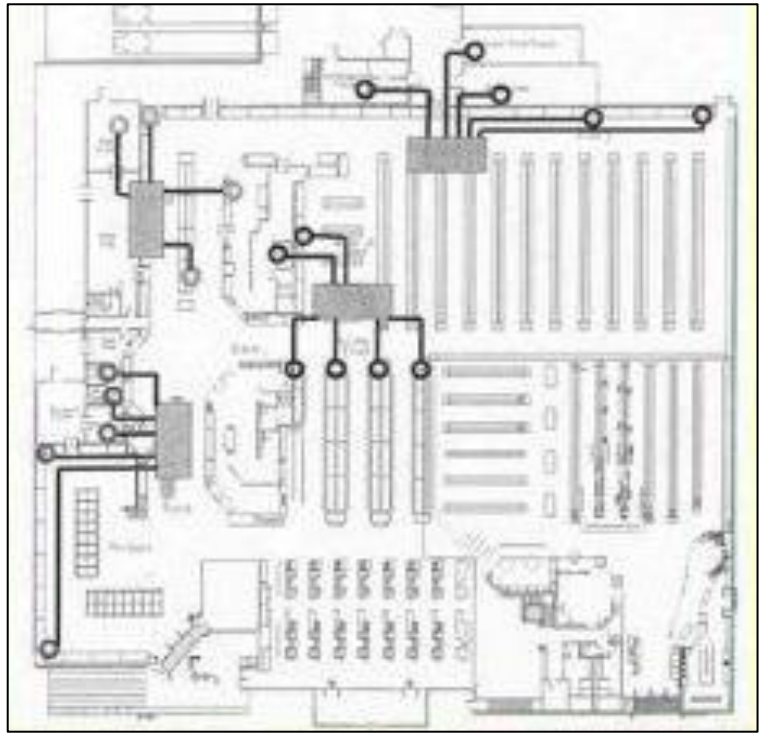
- Current centralized refrigeration system carry ~3500 pounds of high GWP refrigerant R-404A (GWP of 3,922), have a high leakage rate (~25% per year).
- There is a clear need to reduce the environmental impact by using low GWP refrigerants while maintaining or improving energy efficiency
- There are over 38,000 supermarkets, 14,000 grocery stores, 154,000 convenience stores in the US which have a significant level of GHG emissions:
  - 43.8 million Tons $CO_{2\ eq}$ /year (***69.7%***) of direct emissions
  - 19.08 million Tons $CO_{2\ eq}$ /year (***30.3%***) of indirect emissions

Central DX



One central system distributes the refrigerant across the whole store

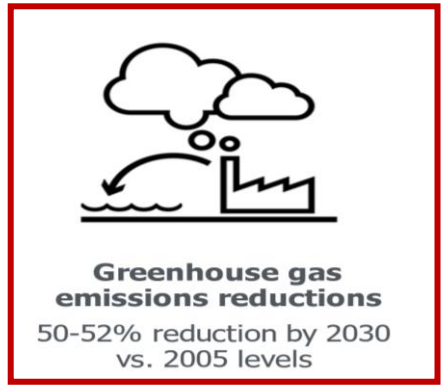
Distributed DX



Several smaller systems reduce the charge (60%) and the leak rates (below 10%).

Alignment and Impact

- **Major Goals:**
  - Reduce supermarkets direct GHG emissions by enabling the use of Ultra-Low GWP refrigerant R-1234yf
    - Distributed/Scroll-Booster systems have ***reduced charge*** and ***low leak rates*** (<5% per year) and uses R-1234yf (GWP<1).
  - Reduce supermarkets energy consumption by up to 5% compared to current systems
    - Use class 2L refrigerant in the whole store according to latest safety standards (UL 60335-2-89).



- **Contribution to EERE goals:**
  - **Reduce GHG emissions** from supermarket segment by ~60%. Higher than EERE's target of 50% to 52% established for 2030.
  - **Energy savings:** up to 5% reduction of energy consumption compared to current central DX R-404A systems. Any energy saving help the decarbonization of the power system
  - The **use of smaller-footprint systems** (distributed) and reduced refrigerant requirement
    - Lower installation and maintenance cost
    - Help faster deployment
    - **Better reach disadvantaged communities**

Approach

- **Modeling**
  - **Modeling of test system to** Verify energy savings of up to 5%
  - **Modeling of a typical store to obtain a life cycle climate analysis.** Verify reduction of overall CO_2 emissions by at least 60%.

Will use a calibrated version of HPDM to simulate current and new configuration of supermarket system.

The LCCP will employ the Bin method to simulate the weather in at least 3 US cities

- **Proof of concept by detailed laboratory testing**
  - **Validate the energy efficiency predictions of the modeling through detailed experimental measurements.** Simulated energy efficiency must match experiments within experimental uncertainty (±3%). Update expected CO_2 emissions reduction.

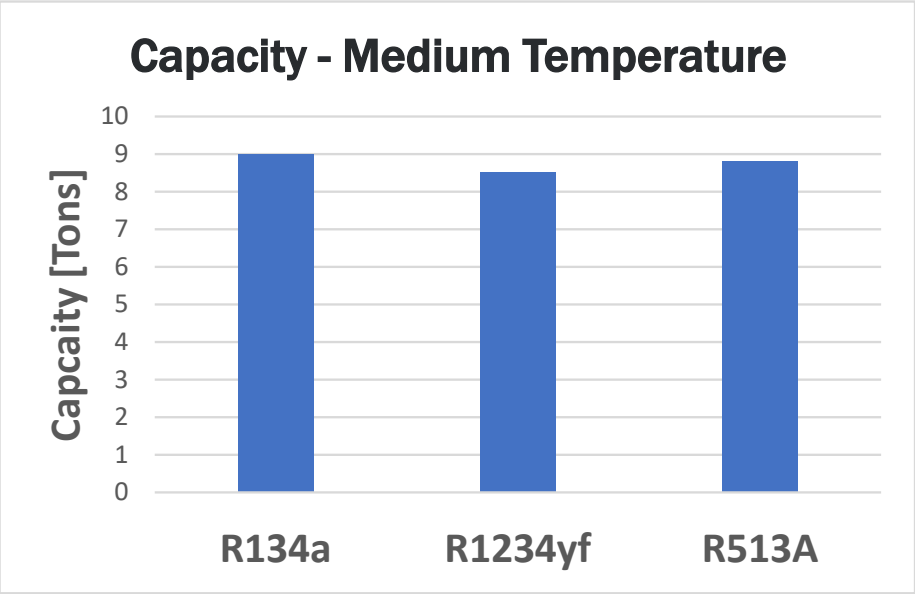
A scale prototype of a supermarket will be designed, constructed and tested at a wide range of ambient temps.

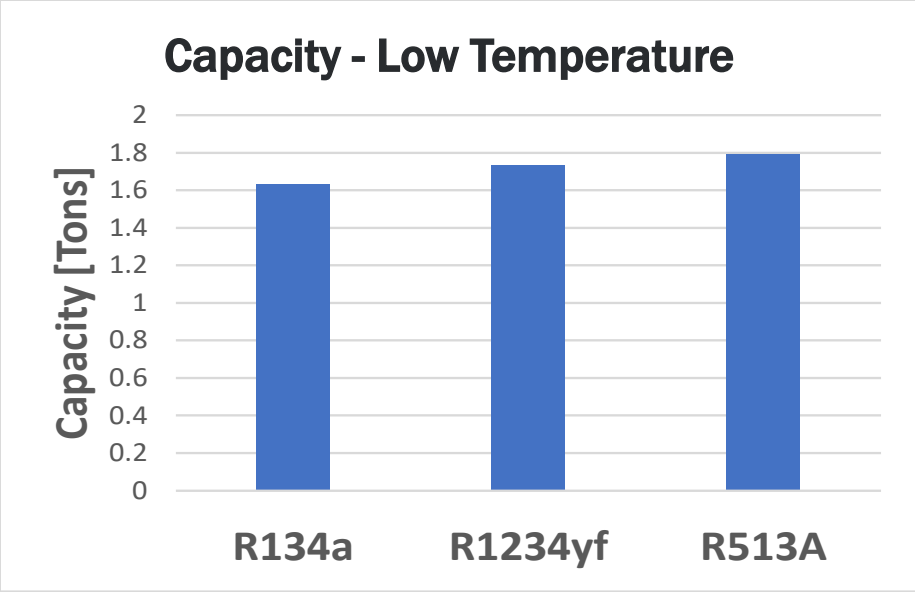
Data will be used to further calibrate HPDM and validate the LCCP (proof of concept)

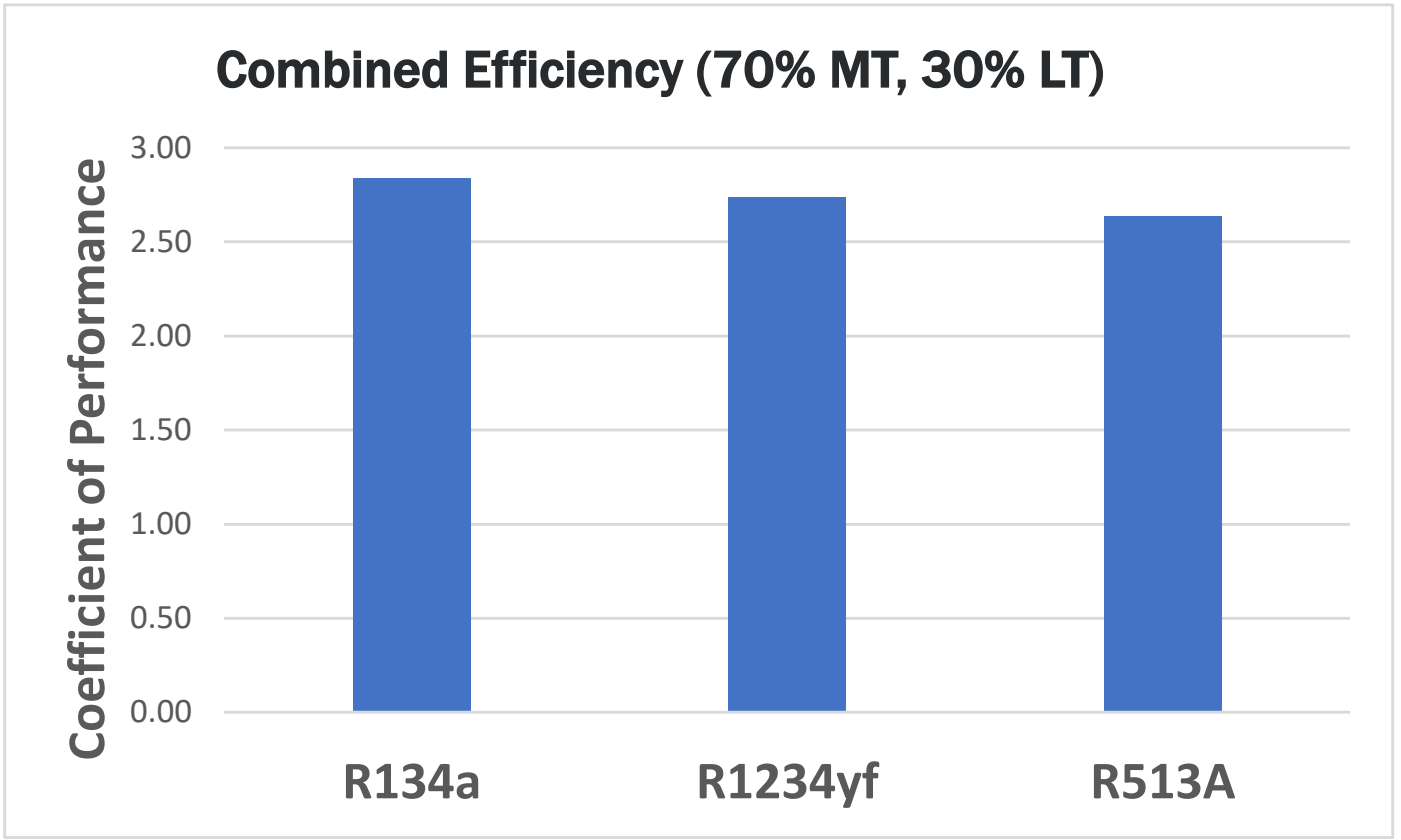
- **Field evaluations in at least two stores.**
  - 1-year data collected to demonstrate at least a 5% energy savings and 60% reduction in overall CO_2 emissions compared the baseline refrigeration system.

One supermarket store will be fully equipped to obtain energy data for a full season (1 year).

Preliminary Modeling of the test system

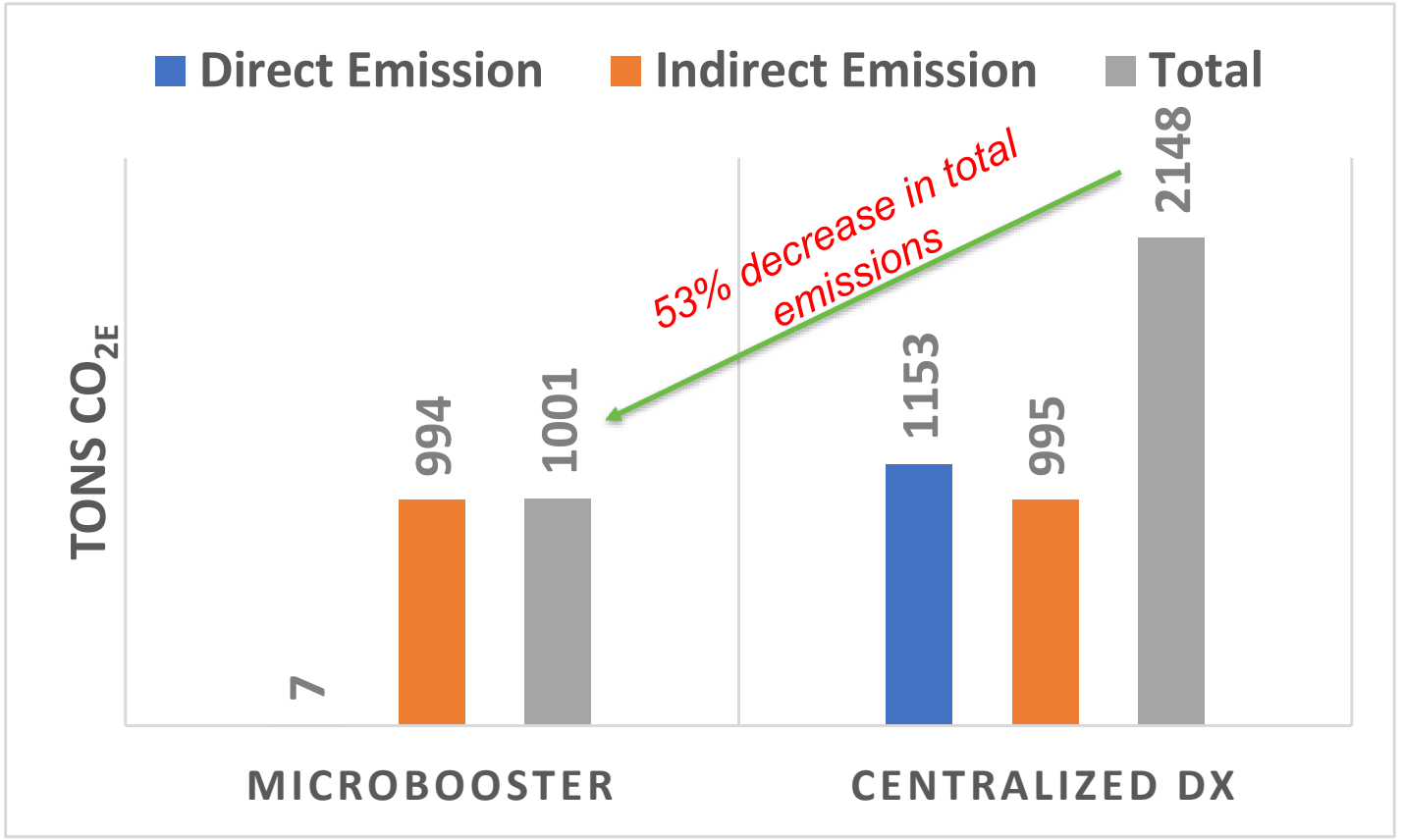






Taking into account that the typical experimental uncertainty is ±5%, R-1234yf Performance is similar to R-134a

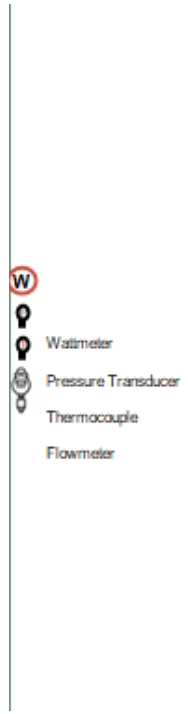
LCCP analysis of an actual store

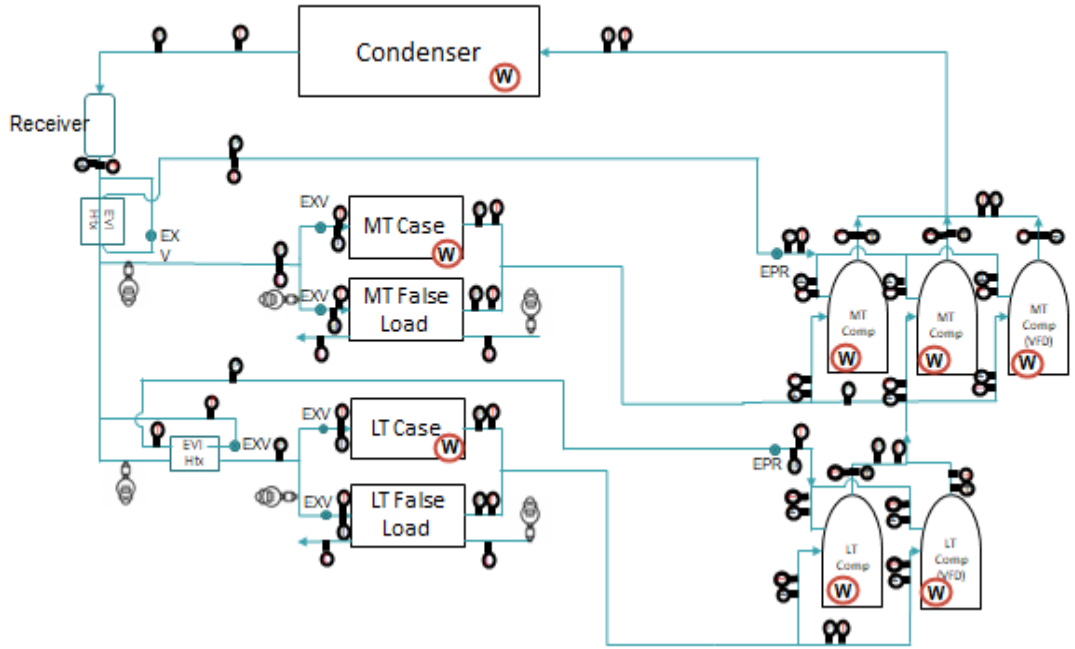


- LCCP analysis performed for a 35000 ft^2 supermarket located in Atlanta GA using bin methodology.
- Assumed 25% leak rates for central DX, and less than 10% for the scroll distributed system.
- Used efficiencies of existent R-134a compressors.
- Overall GHG emissions are reduced by more than 60% compared to the central DX

Laboratory testing: Test setup

- **Refrigerants:** R134a, R1234yf
- **Equipment:**
  - LT Case + False load: 3 tons (28.5%)
  - MT Case + False load: 7.5 tons (71.5%)
  - Rack equipped with Scroll Emerson Copeland compressors.
  - Air-cooled micro-channel condenser
- Instrumentation:
  - Six Coriolis flow meters will be installed in in the refrigerant liquid lines.
  - The flow meters and the corresponding system parameters (pressures, temperatures) will allow to obtain energy balance in all heat exchangers..
  - Power transducers to measure compressors, display cases separately.
- Experimental uncertainty estimated within ±5%

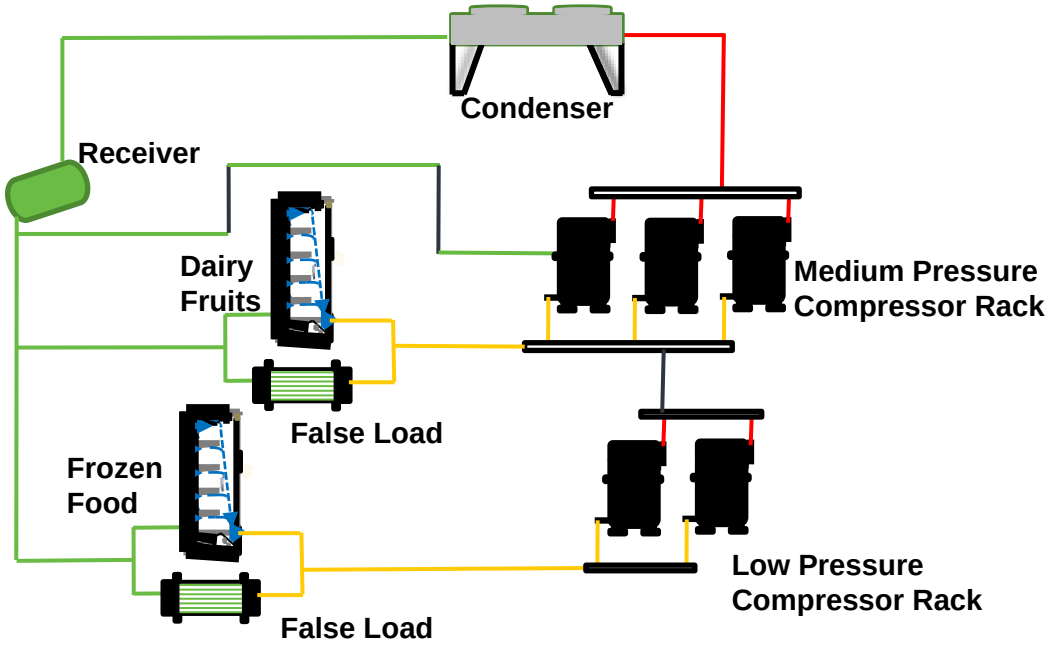




Laboratory Test Plan: Benchmark and New Scroll-Booster system

Benchmark: 12 tons (70% MT, 30% LT)
R-404A system ORNL report 75272 (2017)

Micro-Booster: (71.5% MT, 28.5% LT)
designed for R-1234yf and R-134a



Refrigerants tested: R-404A and R-448A
Capacity: Operating conditions were similar to the plan for the scroll booster

Refrigerants: R134a, R1234yf
Operating conditions: Outdoor (55F, 75F, 95F, 110F), Indoor (70F and 60% RH)

Will use the efficiencies measured for R-404A as a benchmark for comparison with the new Scroll Booster system

Overall Description of the Scroll Booster Equipment

Compressor Rack
(equipped with Scroll compressors)

Fresh Food Display Case
(includes false load)

Air Cooled Condenser
(Equipped with a Micro Channel Heat Exchanger)

Future Work

- **Verification of system performance through experimental testing**
  - Obtain and install system prototypes, Complete by Q2 of FY2023
  - Complete testing of lab prototype, Complete by Q3 2023
  - Update LCCP analysis based on lab data. Complete by Q4 2023
- **Field trials**
  - Start store by Q4 of FY 2023.
  - Complete field trials by Q4 of FY 2024
- **Conclude project with final report by Q4 of FY 2024**
  - Two journal articles (modeling and lab testing), and
  - A magazine publication expected from this project. (field trials – help the commercialization)

CRADA partner is actively searching for a proper site and the availability of equipment.

Thank you

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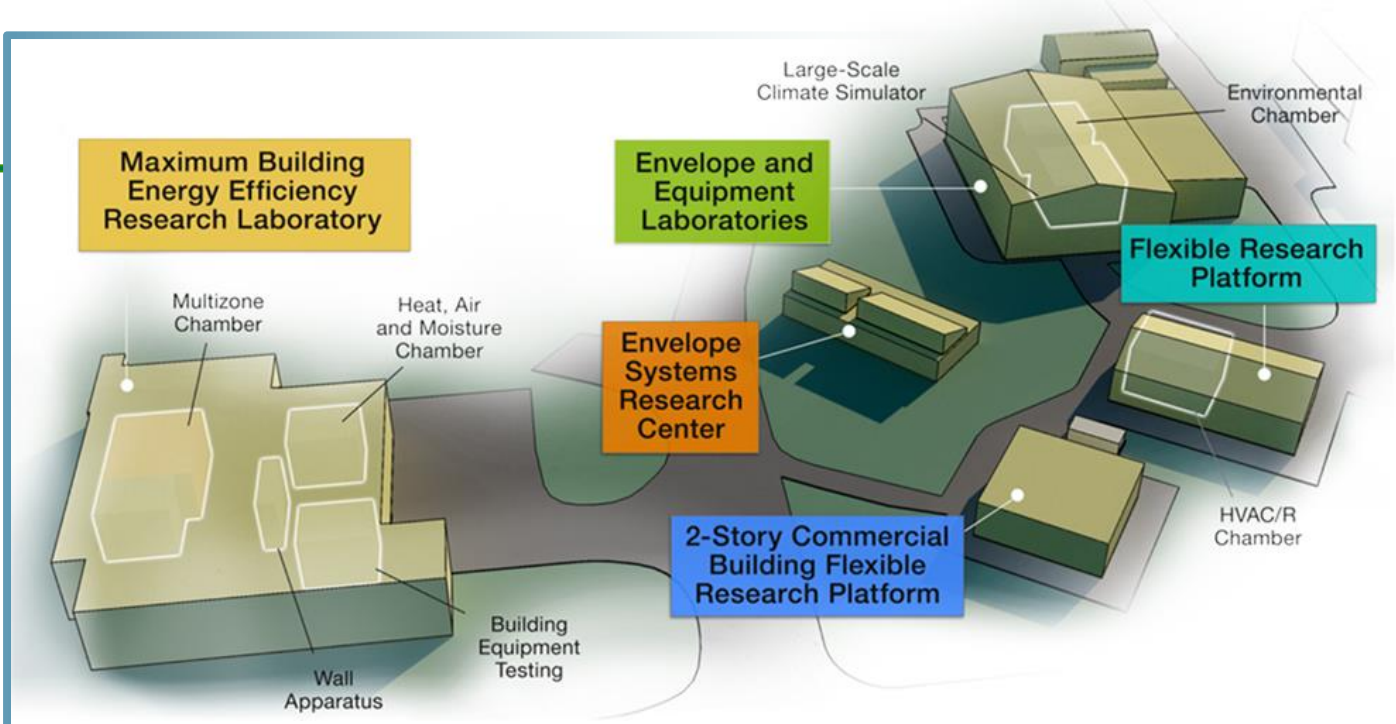

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Scientific and Economic Results

236 publications in FY22
125 industry partners
54 university partners
13 R&D 100 awards
52 active CRADAs

BTRIC is a DOE-Designated National User Facility

REFERENCE SLIDES

Control Plan

	2022				2023			
Tasks Months →	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24
1 - Modeling and simulation of system								
Task 1.1: Identify characteristics of the system								
Task 1.2: Develop a thermodynamic model								
Task 1.3: Simulate system and LCCP								
Task 1.4: Develop optimized system design								
2 - Performance testing at steady state conditions								
Task 2.1: Fabricate laboratory-scale system								
Task 2.2: Develop test plan								
Task 2.3: Evaluate steady-state performance								
3 - Field evaluation to verify performance								
Task 3.1: Identify test site								
Task 3.2: Fabricate and install refrigeration system								
Task 3.3: Evaluate refrigeration system performance								
4 - Publications in scientific journals and magazines								
Task 4.1: Produce publications and final report								
5 - Commercialization								
Task 5.1: Commercialize novel scroll booster system								