Dalrada Commercial CO_2 Heat Pump Validation

Performing Organization(s): ORNL, Dalrada, GSA
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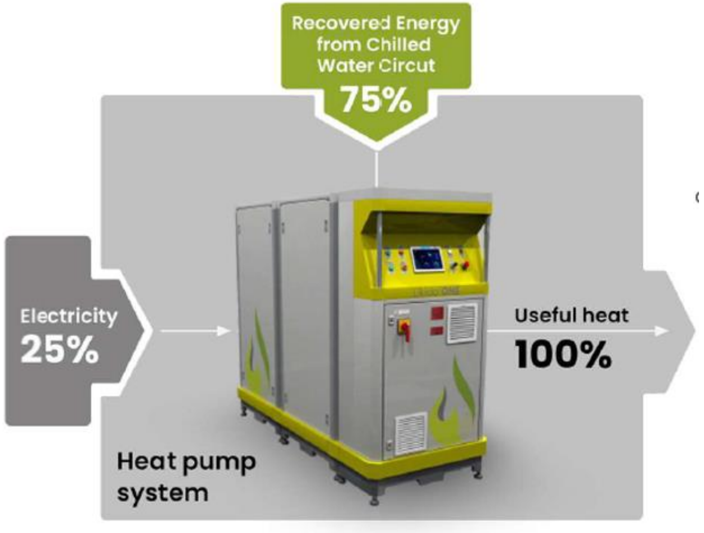
WBS 2.2.2.94

Project Summary

Objective and outcome

Evaluate the net-zero potential of Dalrada CO_2-based heat pump in real-world and laboratory settings, including efficiency, energy saving, return of investment, maintenance



Team and Partners

Lead Organization

ORNL: Jian Sun, Jason DeGraw, Jamie Lian, Kashif Nawaz

Teams

GSA: Joshua Banis, Jessica Higgins

Dalrada: Tony Pagnotti, Jose Arrieta

Stats

Performance Period: 10/2022 – 09/2024

DOE budget: 250 K (CBI) 150 K(ET)

Milestone 1: Select field test sites (completed 01/2023)

Milestone 2: Develop Lab testbed (ongoing 5/2023)

Milestone 3: Complete field and lab tests (not start)

Milestone 4: Report field and lab test results (not start)

Problem Statement

Fifty percent of U.S. heating is supplied by natural gas, which contributes 36% of CO2 emissions. Decarbonizing heating systems is key to achieving net-zero emission economy by 2050. Some challenges are,

- **Cost:** Replacing traditional heating systems with low-carbon alternatives can be expensive.
- **Energy demand:** Decarbonizing heating systems may lead to increased electricity demand.
- **Infrastructure:** Requiring upgrades or new infrastructure investments.
- **Regulatory barriers:** these is a need for supportive policy and regulation to encourage the adoption of low-carbon heating system.

CO2-based Heat Pumps is one of potential solutions to decarbonize heating systems

Problem Statement (cont.)

Dalrada's CO_2 Heat Pump (Likido ONE)

- Environmentally more friendly (GWP = 1, ODP = 0, inflammable, Nontoxic)
- Smaller unit size due to the use of CO_2
- Better heating performance under low ambient temperature conditions
- Higher temperature for heat medium (water)
  - Enable applications for simultaneous heating and cooling (key feature)

Challenges

- System integration difficulty is of important consideration
  - Integration with non-hydronic heating system (e.g. furnace)
  - Remove excessive heating/cooling capacity when insufficient loading
- Maximum performance potential assessment requires selected site to have simultaneous heating and cooling loads in both summer and winter seasons
  - Buildings in hot-humid or mixed-humid regions, OR,
  - Buildings in other regions with certain special features

Alignment and Impact

Impacts

- Saves 60-80% energy compared to conventional heating and cooling systems (i.e., boilers, electric heaters, and chillers)
- Works efficiently in extremely cold weather vs. less efficient conventional heat pumps
- Decarbonizes heat with a combustion-free process and low-GWP refrigerant, reducing emissions and energy use, and allowing highly efficient recovery of waste heat
- Compact and modular design reduces the space required in mechanical rooms and requires minimal maintenance.

How will success be measured

- The test will assess three key manufacturer claims: **60% heating and cooling savings, payback in less than 8 years, and minimal maintenance.**

Approach: Field and Lab validation

Field validation test

- Evaluate net-zero potential in a real-world setting
- Compare the performance against specific case/system
- Difficult to establish a clean baseline to be compared against the controlled case

Laboratory validation test

- Verify technology performance under controlled environment
- Tests can be manageable to cover wide range of test conditions
- Comprehensive performance characteristics under various test conditions to support field test
- Understand how technology performance scales
- <u>Leveraging ORNL's efforts of building laboratory test beds for water source heat pump</u>
    - Testbed 1: Plug-in testing of off-the-shelf whole unit
    - Testbed 2: Modular test system design to enable key component testing and R&D

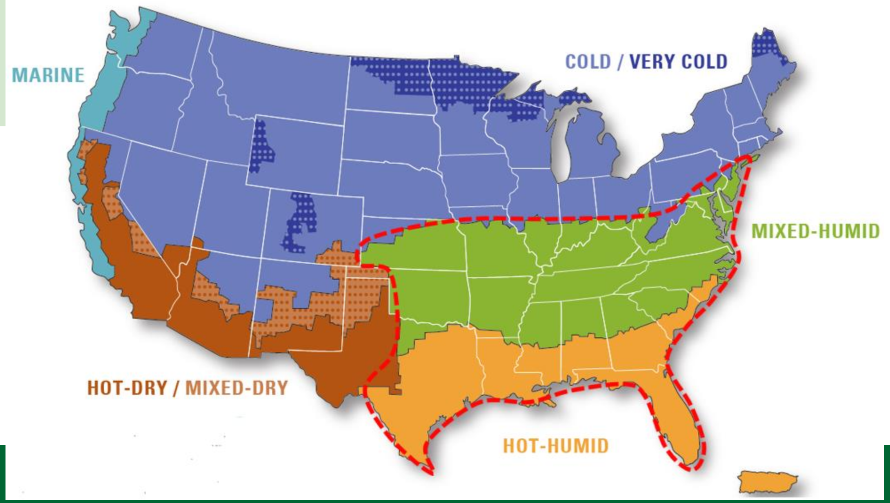
Approach: Field M&V Site Selection Criteria

Key Selection Criteria

	Preferable site characteristics
Load Demand	Simultaneous and continuous cooling and heating load demand in both summer and winter Design cooling load per unit: 34 refrigeration tons Design heating load per unit: 200 kW
Existing Cooling and Heating System	Four-pipe heating/cooling fan coil system Hydronic heating system Dehumidification and Reheat
Historical Electricity Data	Energy consumption data of existing system for cooling and heating equipment/system
Data Acquisition	existing data collection data for building, cooling/heating system, hot water system
Documentation	Architectural drawing and information, e.g., existing cooling & heating system diagram

Preferable Site:

hot-humid or mixed-humid regions



Approach: Field M&V Baseline Construction

Field Baseline of existing heating and cooling system performance:

- The heating and cooling loads experienced by the plant based on outdoor air temperatures and other variables as needed, and
- The existing chillers' efficiencies (i.e., kW/ton),
- key operating conditions of the chiller plant (e.g., condenser water supply temperatures, chilled water supply temperatures, chiller sequencing).

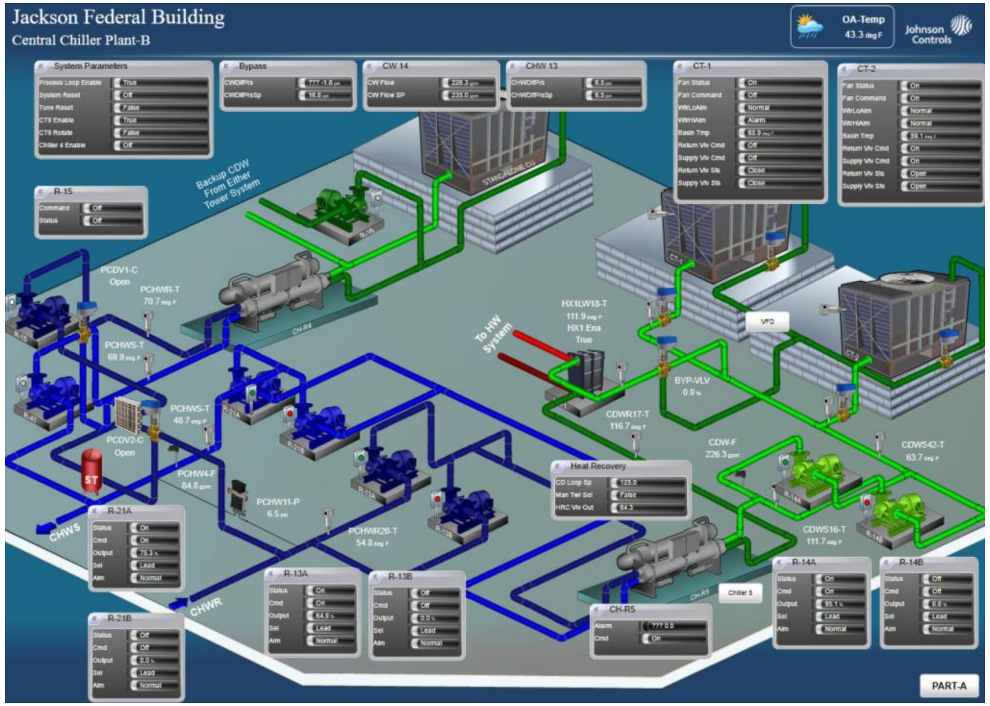
General reference: assuming meet the efficiency requirements for heating and cooling product categories per American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1-2019

Progress - Test Site

Jackson Federal Building at Seattle WA

The building chilled water system consists of three variable flow water cooled chillers, 4 primary pumps with VFDs. There are 3 constant volume single cell cooling towers, and 3 constant volume condenser water pumps

- Plant cooling design load = 1350 tons
- Chiller capacity (tons): 450 per chiller



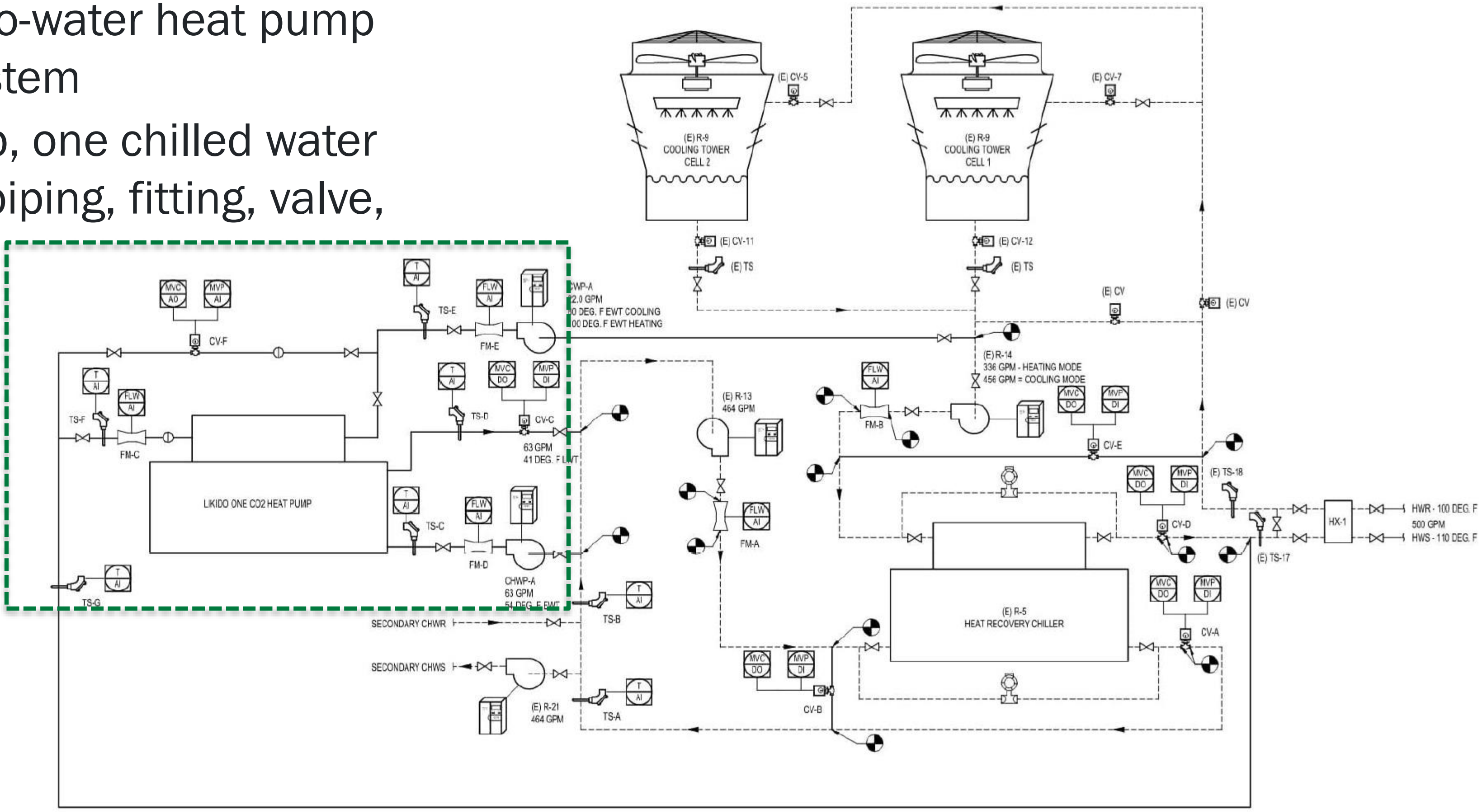
A process loop – chilled water/heat recovery system was designed to include:

- a constant volume heat recovery chiller: 194 tons
- Chilled water pump and condenser water pump.
- Cooling tower with two cells operating in lead-standby configuration

Progress - System Integration Design

System integration design

- Incorporate the Dalrada CO2 water-to-water heat pump into existing heat recovery chiller system
- Main components: a CO2 heat pump, one chilled water pump, one condenser water pump, piping, fitting, valve, sensors, controller.



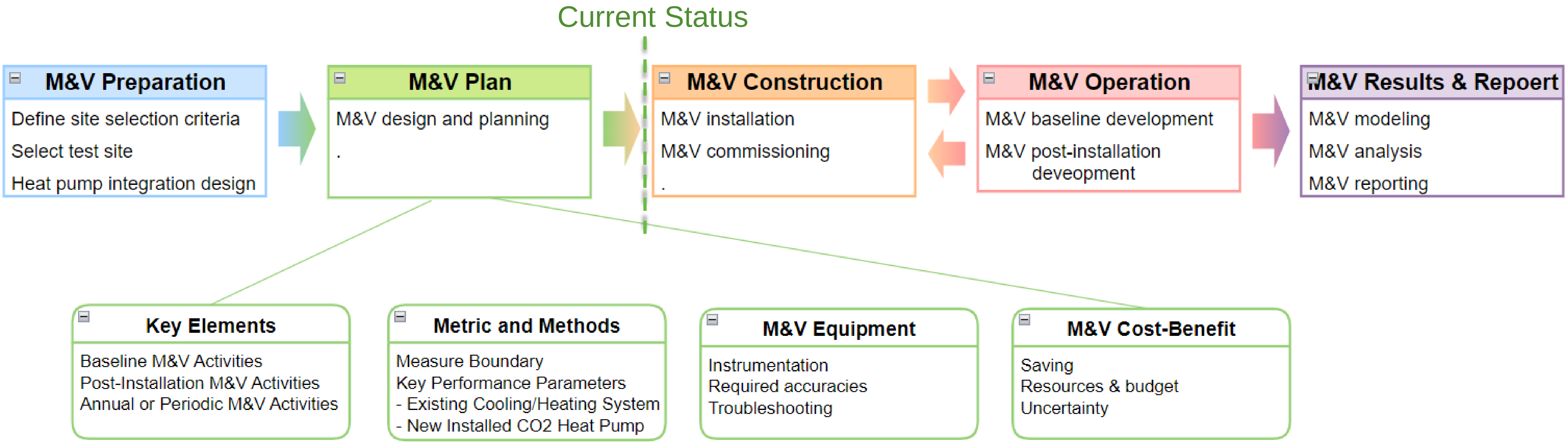
Operating modes

- Heat pump-only operation
- Heat recovery chiller –only operation
- Simultaneous heat pump and chiller operation

Progress - Field M&V

Field M&V

- M&V preparation work has been completed
- M&V plan has been developed



Progress – 2nd Test Site

Jack Brooks Courthouse at Beaumont TX

The building chilled water system consists of two magnetic-bearing chillers with dedicated condenser water and chilled water pumps.

- Chiller capacity (tons): 285 per chiller
- Chilled water pump and condenser water pump.
- Cooling tower with two cells

The building heating system consists of two hot water boilers with hot water distribution pumps and a 3-way mixing valve:

- Boiler capacity (KBTU): 1246 per boiler
- Hot water pump

Simultaneous heating (reheat for dehumidification purpose) and cooling demand in cooling season

Progress - Lab M&V: Test Unit

Lab Test CO_2 heat Pump Unit: Likido loop

Key design parameters

- Heating output: 50 kW
- Hot circuit working range: 15 to 75 degree C
- Cooling output: up to 35 kW
- Chilled water temperature: 6 to 14 degree C
- COP: 5.7

Main Components

- CO_2 semi-hermetic reciprocate compressor
- gas cooler
- Economizer
- Evaporator
- Receiver, filter, valve, pressure relief

Progress – Lab M&V Testbed

Lab testbed development for plug-in whole-unit testing (collaboration with ET program)

Main Components

Water pumps

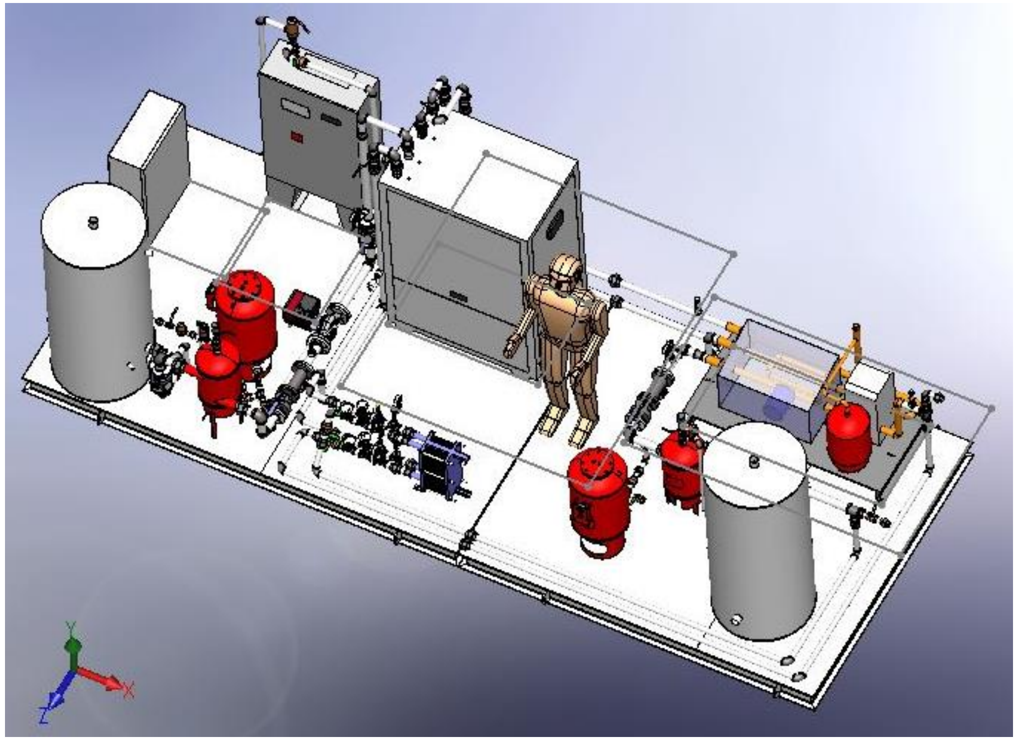
Storage tanks

Plate and Frame Heat exchangers

Electric water heater

Expansion tanks

Air-cooled chiller



Test Capability

Heat capacity : 50 kW

Future Work

Field Test

- Installation of Dalrada CO2 heat pump system
- Installation of M&V instrumentation
- Conduct M&V test
- Analyze test results and prepare the report

Lab Test

- Installation of testbed and data acquisition system
- Commissioning the testbed
- Define the test plan and run the performance test
- Record the test data and
- Analyze test data and report the results

Thank you

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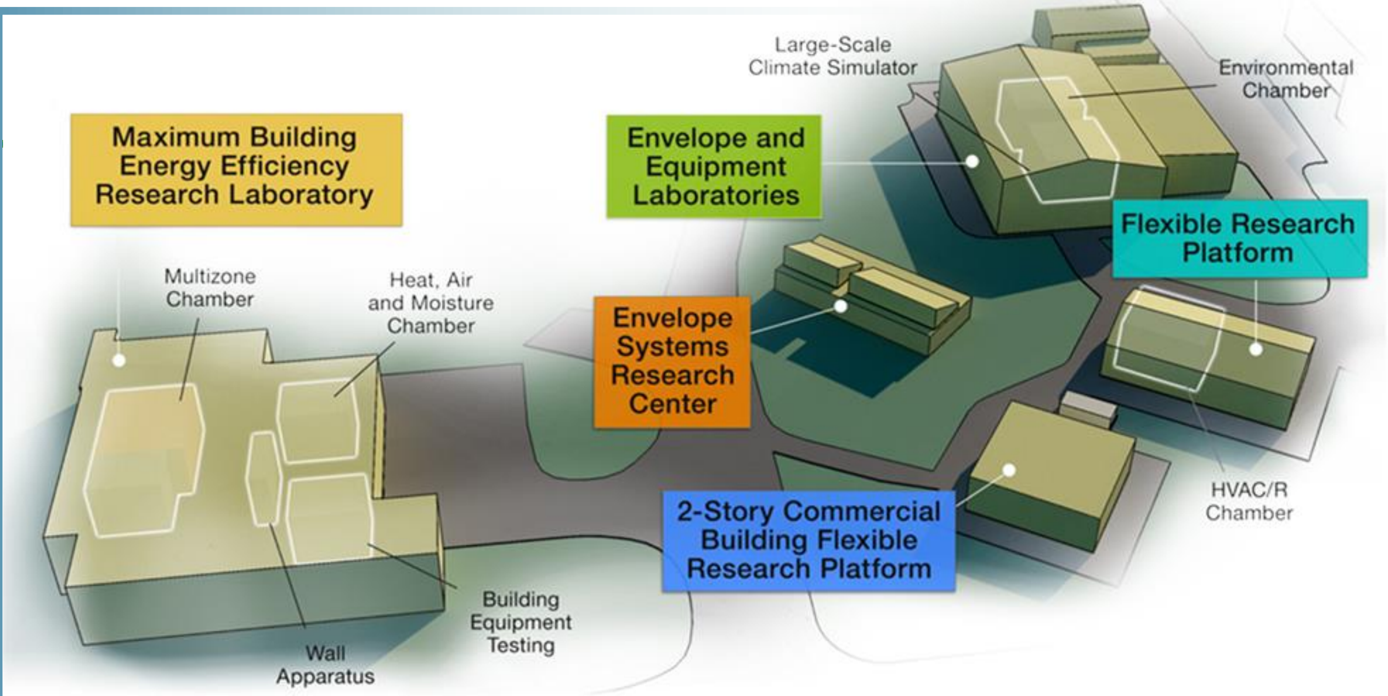

ORNL's Building Technologies Research and Integration Center (BTRIC) has supported DOE BTO since 1993. BTRIC is comprised of 60,000+ ft^2 of lab facilities conducting RD&D to support the DOE mission to equitably transition America to a carbon pollution-free electricity sector by 2035 and carbon free economy by 2050.

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

Project Execution

	FY2023				FY2024				FY2025			
Planned budget	200K				200K							
Spent budget	100K											
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work												
Q1 Milestone: Site Selection	◆											
Q2 Milestone: M&V Plan Development		◆										
Current/Future Work												
Q3 Milestone: Lab Testbed Development			◆									
Q4 Milestone: M&V Installation				◆								
Q1 Milestone: M&V Data Collection					◆							
Q2 Milestone: Lab Testing						◆						
Q3 Milestone: Data Analysis							◆					
Q4 Milestone: Reporting								◆				