Regional Emerging Technology Advisory Committee (RETAC)

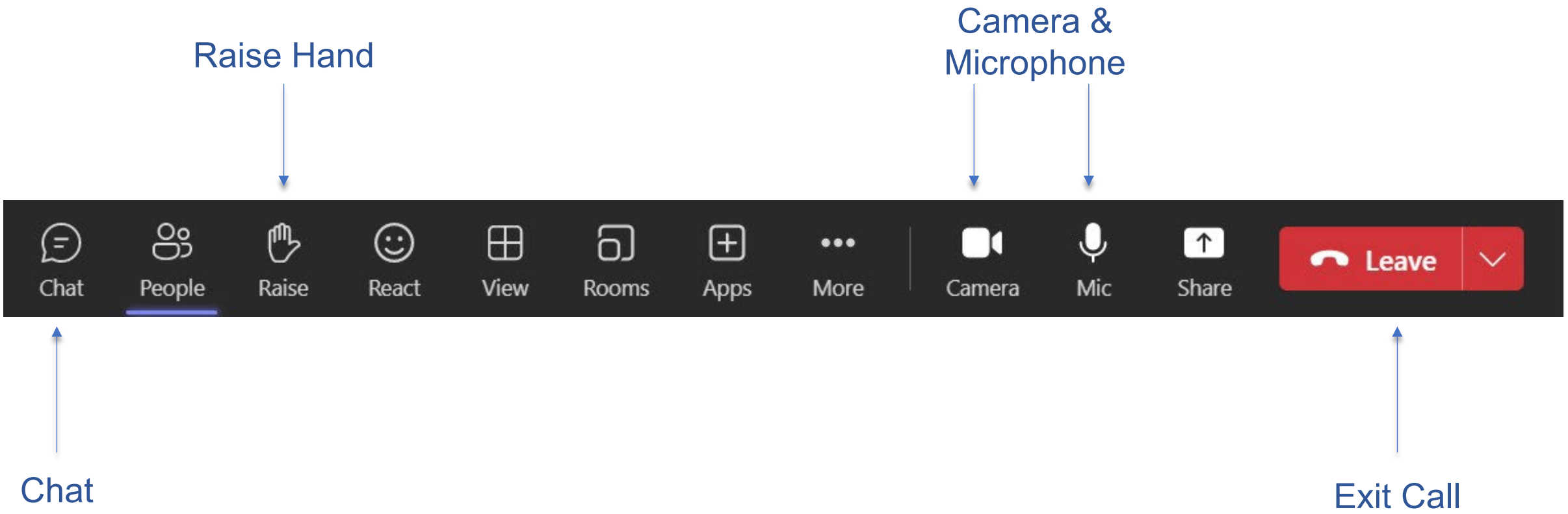
Northwest Energy Efficiency Alliance

Q4 2025 Meeting

December 4, 2025

8:30 a.m. – 12:00 p.m.

Navigating MS Teams Layout



Note: These options may vary, depending on which version you're using.

Name, Title, Organization and…

Share one technology you or your company have been working on this last quarter, or a technology that you're excited about.

Agenda

8:30 am	Welcome and Announcements
8:45 am	Central Commercial Heat Pump Water Heaters
9:30 am	Emerging Technology Update – Energy Trust
10:30 am	*Break*
10:45 am	National Renewable Energy Laboratory (NREL)
12:00 pm	Wrap-Up

Central Commercial Heat Pump Water Heaters

NEEA's Cycle 7 Central HPWH

"Earlier stage opportunities – those in **Concept** or Program Development – will be considered for the portfolio if a viable Market Transformation opportunity is determined and in consultation with the region through NEEA's stakeholder advisory process."

	Initiative Lifecycle Phase			
Product Group	**Concept Development**	**Program Development**	**Market Development**	**Long-term Monitoring & Tracking**
Building Envelope		• High-Performance Windows (dual fuel)		
Consumer Products			• Retail Products Portfolio	
HVAC	• Next Generation Residential Heat Pumps • Rooftop Units with Heat Pumps		• High-Performance HVAC • Advanced Heat Pumps	• Ductless Heat Pumps • Manufactured Homes
Lighting			• Luminaire Level Lighting Controls	
Motor-Driven Systems	• Expansion to New Pump and Fan Applications • Efficient Motor-Drive Systems	• Efficient Fans	• Extended Motor Products (pumps)	
Water Heating	• Commercial/ Multifamily Central Heat Pump Water Heater • Residential Heat Pump Water Heaters for All Applications		• Heat Pump Water Heaters	

[NEEA-2025-2029-Strategic-and-Business-Plans.pdf]

Types of Electric Heat Pump Water Heaters

“Consumer” Water Heaters

Consumer Unitary

Consumer Split

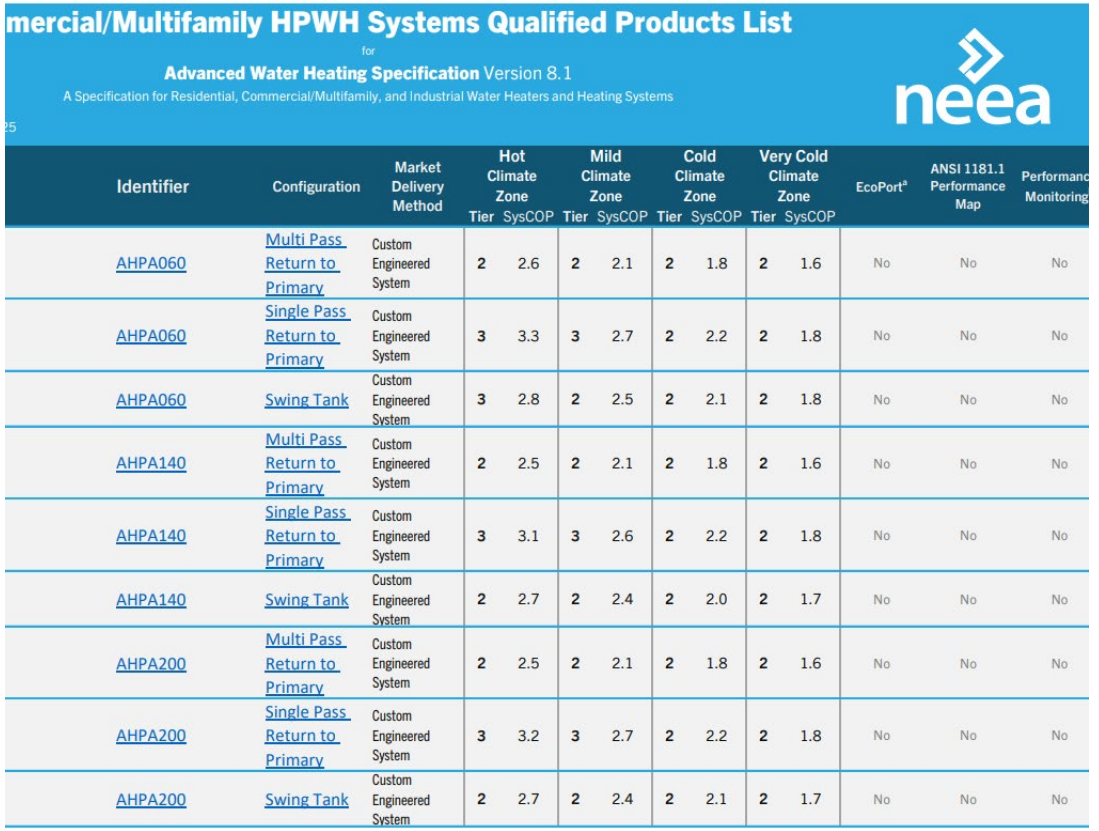
“Commercial” Water Heaters

Commercial Unitary or Packaged

Central Commercial

Central CHPWH Resources

- Advanced Water Heating Specification (AWHS)
- Qualified Products List (QPL)
  - Detailed P&IDs, sequence of operation, and load shift
- Building momentum for alignment between CEE, AHRI, ENERGY STAR…



mercial/Multifamily HPWH Systems Qualified Products List

for

Advanced Water Heating Specification Version 8.1

A Specification for Residential, Commercial/Multifamily, and Industrial Water Heaters and Heating Systems

neea

Identifier	Configuration	Market Delivery Method	Hot Climate Zone		Mild Climate Zone		Cold Climate Zone		Very Cold Climate Zone		EcoPort[a]	ANSI 1181.1 Performance Map	Performanc Monitoring
			Tier	SysCOP	Tier	SysCOP	Tier	SysCOP	Tier	SysCOP			
AHPA060	Multi Pass Return to Primary	Custom Engineered System	2	2.6	2	2.1	2	1.8	2	1.6	No	No	No
AHPA060	Single Pass Return to Primary	Custom Engineered System	3	3.3	3	2.7	2	2.2	2	1.8	No	No	No
AHPA060	Swing Tank	Custom Engineered System	3	2.8	2	2.5	2	2.1	2	1.8	No	No	No
AHPA140	Multi Pass Return to Primary	Custom Engineered System	2	2.5	2	2.1	2	1.8	2	1.6	No	No	No
AHPA140	Single Pass Return to Primary	Custom Engineered System	3	3.1	3	2.6	2	2.2	2	1.8	No	No	No
AHPA140	Swing Tank	Custom Engineered System	2	2.7	2	2.4	2	2.0	2	1.7	No	No	No
AHPA200	Multi Pass Return to Primary	Custom Engineered System	2	2.5	2	2.1	2	1.8	2	1.6	No	No	No
AHPA200	Single Pass Return to Primary	Custom Engineered System	3	3.2	3	2.7	2	2.2	2	1.8	No	No	No
AHPA200	Swing Tank	Custom Engineered System	2	2.7	2	2.4	2	2.1	2	1.7	No	No	No

Questions for RETAC Orgs

1. What is your organization currently doing to encourage efficient electric commercial water heating?

2. What is your organization planning (or would like) to do to support efficient electric commercial water heating?

3. What is stopping your organization from involvement in efficient electric commercial water heating?

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New and Interesting at Energy Trust of Oregon

RETAC, December 4, 2025

Energy Trust of Oregon

Agenda

- Who we are
- What is changing
- Evaluations
- Program expansion and exploration

About us

Independent nonprofit

Serving 2.4 million customers of Portland General Electric, Pacific Power, NW Natural, Cascade Natural Gas and Avista

Providing access to affordable energy

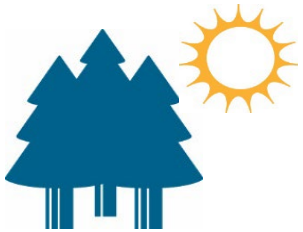
Generating homegrown, renewable power

Building a stronger Oregon and SW Washington

Clean and affordable energy since 2002

From Energy Trust's investment of $3.1 billion in utility customer funds:

842,000 sites transformed into energy efficient, healthy, comfortable and productive homes and businesses



34,000 clean energy systems generating renewable power from the sun, wind, water, geothermal heat and biopower

$15.8 billion in savings over time on participant utility bills from their energy-efficiency and solar investments

46.1 million metric tons of carbon dioxide equivalent emissions kept out of our air, equal to removing 12.5 million cars from our road for a year

Our values, vision and purpose

WE CARE ABOUT PEOPLE

We deliver results because it makes a difference to those we serve. As teammates, we support each other's success and well-being as we work together toward common goals.

WE LEARN AND CHANGE

We continuously learn from listening, experimentation and evaluation. We recognize that emerging needs and complex challenges often require adaptation and new solutions.

WE ARE TRANSPARENT

We work with integrity. We share our work, are honest about what we have done and will do and we hold ourselves and each other accountable.

WE VALUE DIVERSITY, EQUITY, INCLUSION AND BELONGING

We acknowledge the deep importance of DEIB in our work. Everyone brings value; we seek different perspectives because we know our solutions are stronger when we collaborate with each other.

Our vision:
Clean, affordable energy for everyone

Our purpose:

Working together with customers, communities and utilities, we save energy and maximize adoption of clean energy solutions, reducing costs and accelerating community-centered benefits.

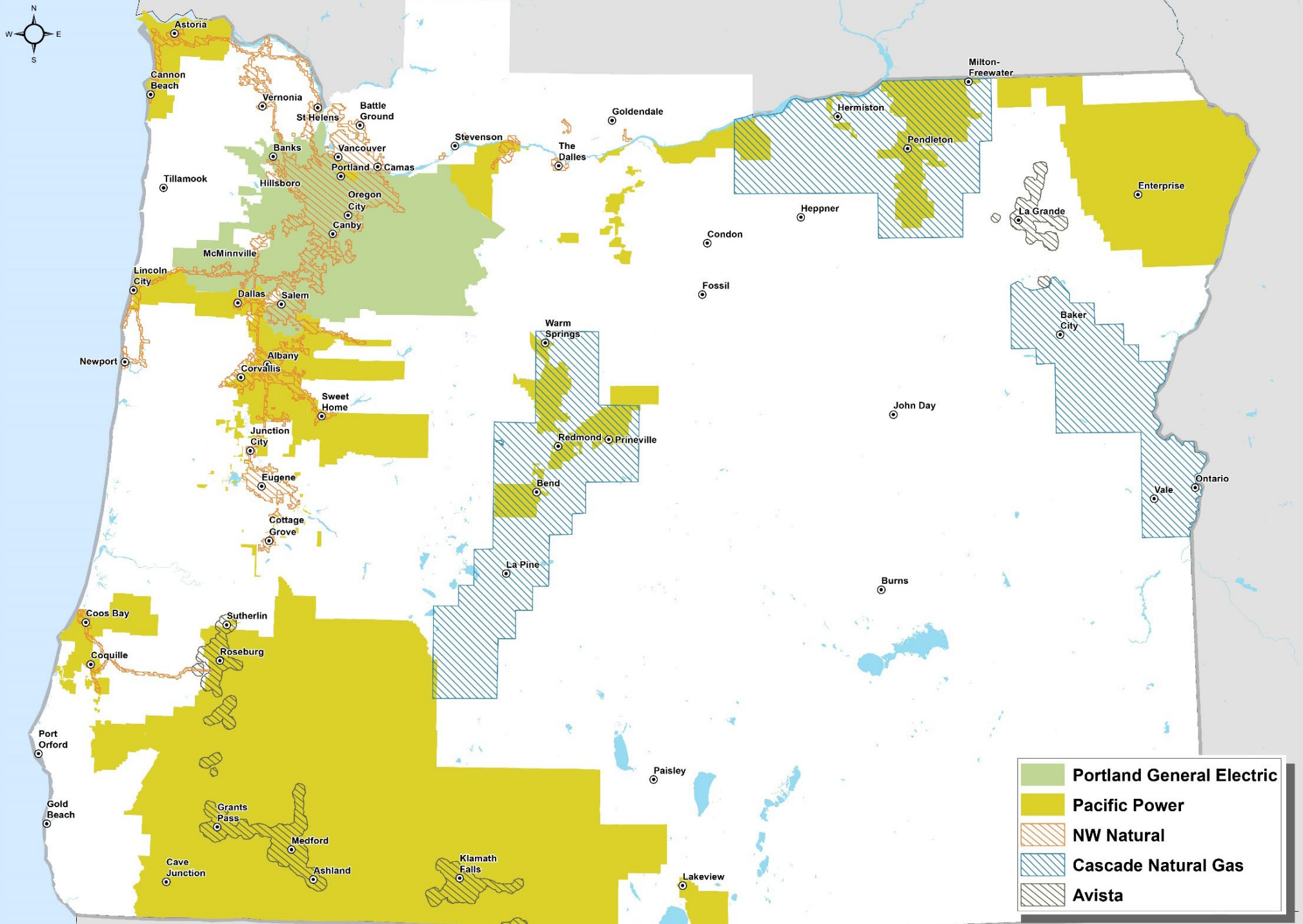
Energy Trust Role

MAXIMIZING CLEAN, AFFORDABLE ENERGY ACQUISITION

Supporting customers and communities to reduce energy costs and realize additional benefits

2025-2030 Areas of Focus

- Reducing the cost of decarbonization
- Creating greater impact for priority customers
- Motivating the next level of customer participation
- Supporting community resilience
- Empowering customers to navigate more choices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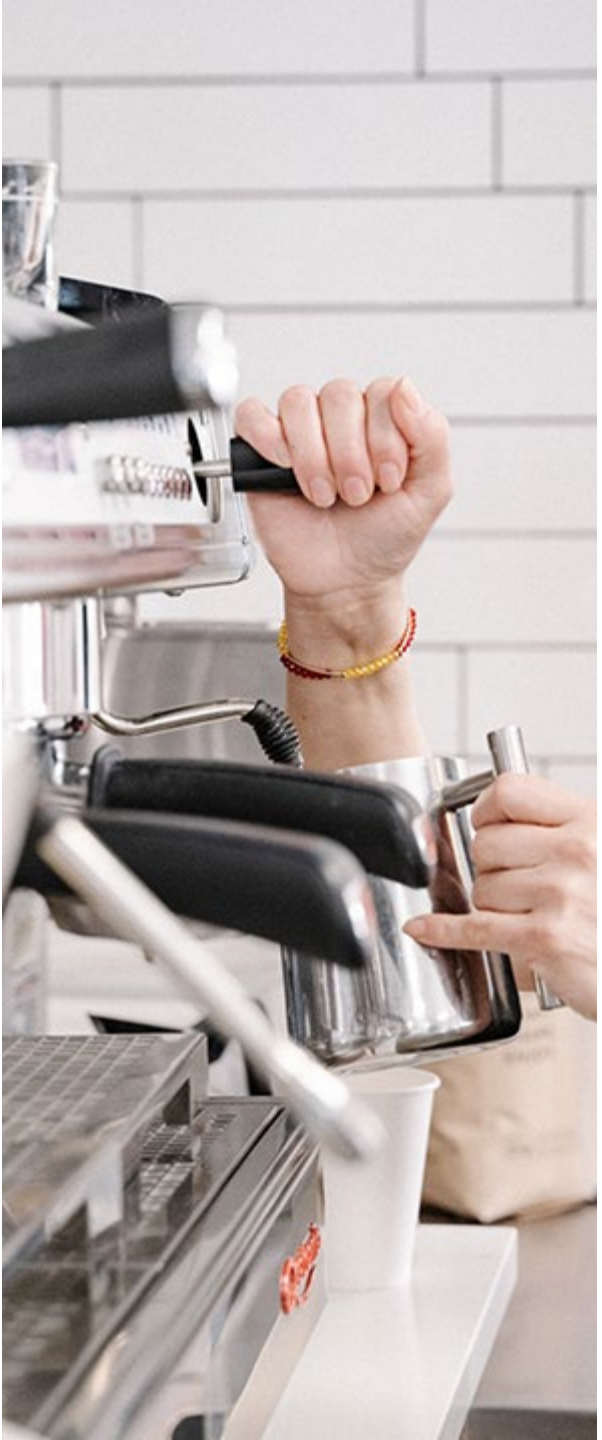
Astoria
Cannon Beach
Vernonia
St Helens
Battle Ground
Banks
Vancouver
Portland
Camas
Hillsboro
Tillamook
Oregon City
Canby
McMinnville
Lincoln City
Dallas
Salem
Newport
Albany
Corvallis
Sweet Home
Junction City
Eugene
Cottage Grove
Coos Bay
Sutherlin
Roseburg
Coquille
Port Orford
Gold Beach
Grants Pass
Medford
Ashland
Cave Junction
Klamath Falls
Lakeview
Paisley
Burns
La Pine
Bend
Redmond
Prineville
Warm Springs
Goldendale
Stevenson
The Dalles
Fossil
Condon
Heppner
Hermiston
Pendleton
Milton-Freewater
Enterprise
La Grande
Baker City
John Day
Ontario
Vale
Portland General Electric
Pacific Power
NW Natural
Cascade Natural Gas
Avista



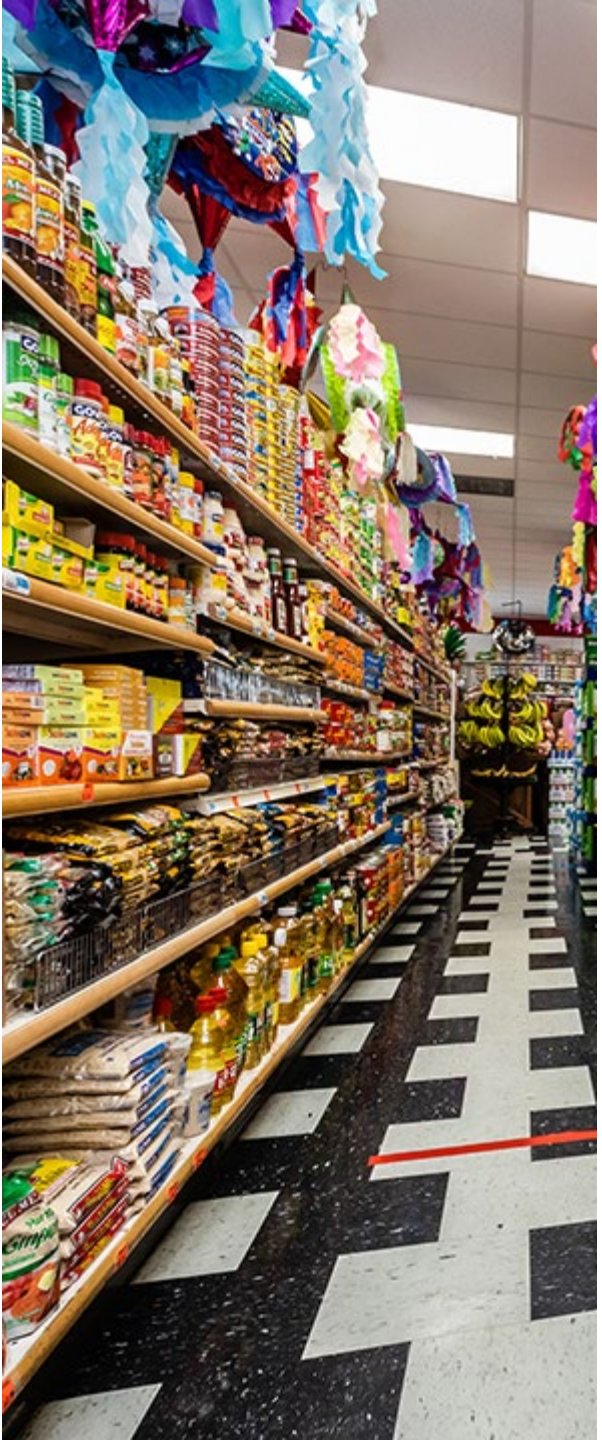
2024 Budget and results

Financial highlights

- ✓ Revenues totaled **$241 million** for the year
- ✓ Expenditures totaled **$283 million** for the year
- ✓ Incentives delivered totaled **$160 million** for the year, 57% of expenditures

Energy results

- ✓ Saved **59.6** average megawatts
- ✓ Saved **6.95 million** annual therms
- ✓ Generated **5.45** average megawatts
- ✓ Avoided **267,000** metric tons of carbon dioxide



Multi-year strategic planning

- More ambitious goals
- Increased programmatic flexibility
- Support for equity and priority customers

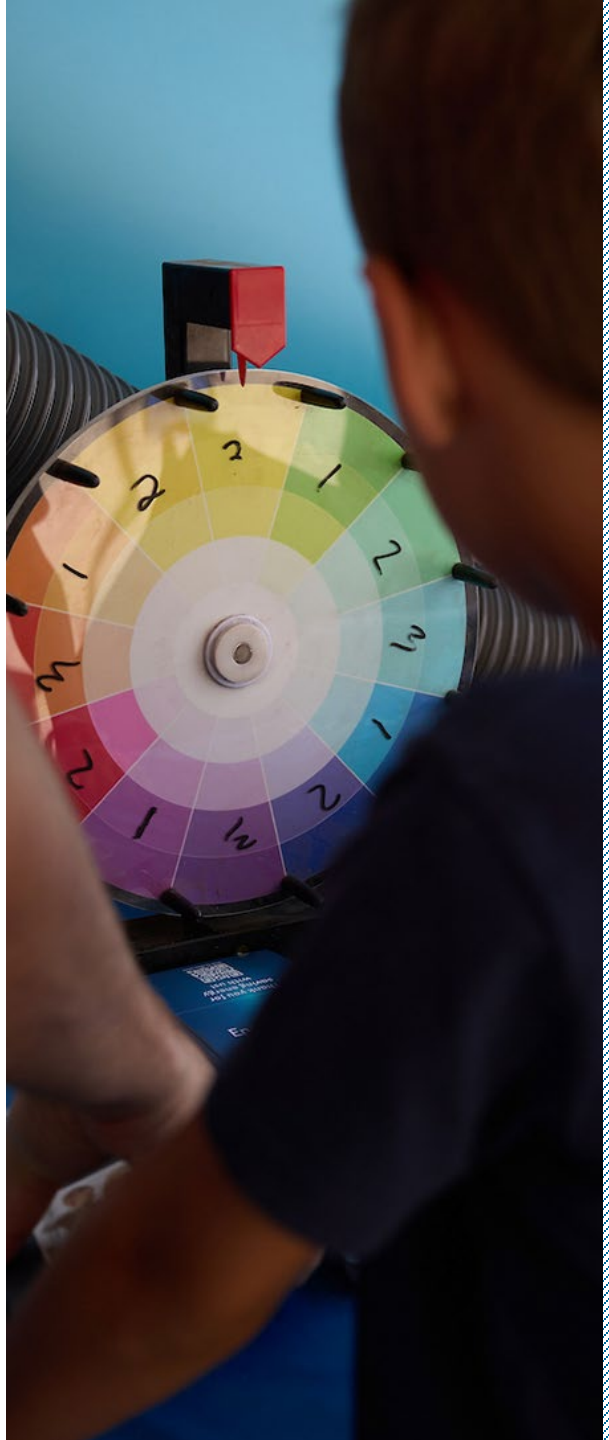
Increased focus on equity

Who have we historically excluded?
Where are we on the adoption curve?

Recently published evaluations

On our website:

- Adjustable Wattage Fixtures
- Residential Thermostats
- Greenhouse Measures Market Research
- Independent Restaurant Study
- Cannabis Dehumidifiers



Upcoming research

HB 2531

- Ban on linear fluorescent distribution in Oregon
- Impact on customers TBD

Indoor Agriculture Lighting

Programmatic expansion and exploration

- Supporting Oregon's Building Performance Standards
- Residential HP work
- Residential prescriptive duct sealing
- Working with community partners
- Expanding our commercial midstream offering and consolidating program delivery

Questions?

Kenji Spielman, Engineer – Planning and Evaluation
kenji.spielman@energytrust.org
+1 503-445-2947

Energy Trust of Oregon

BREAK

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Overview of NREL and Key Highlights from Ongoing IDSM Projects

Ramin Faramarzi, P.E.
Jason Woods, PhD

NEEA ET Advisory Committee Meeting

Dec. 4, 2025

Photo by Joshua Bauer, NREL 61725

Coast to Coast

The **17** national laboratories have served as the leading institutions for scientific innovation in the United States for more than 90 years.

NREL Campuses

South Table Mountain Campus

Flatirons Campus

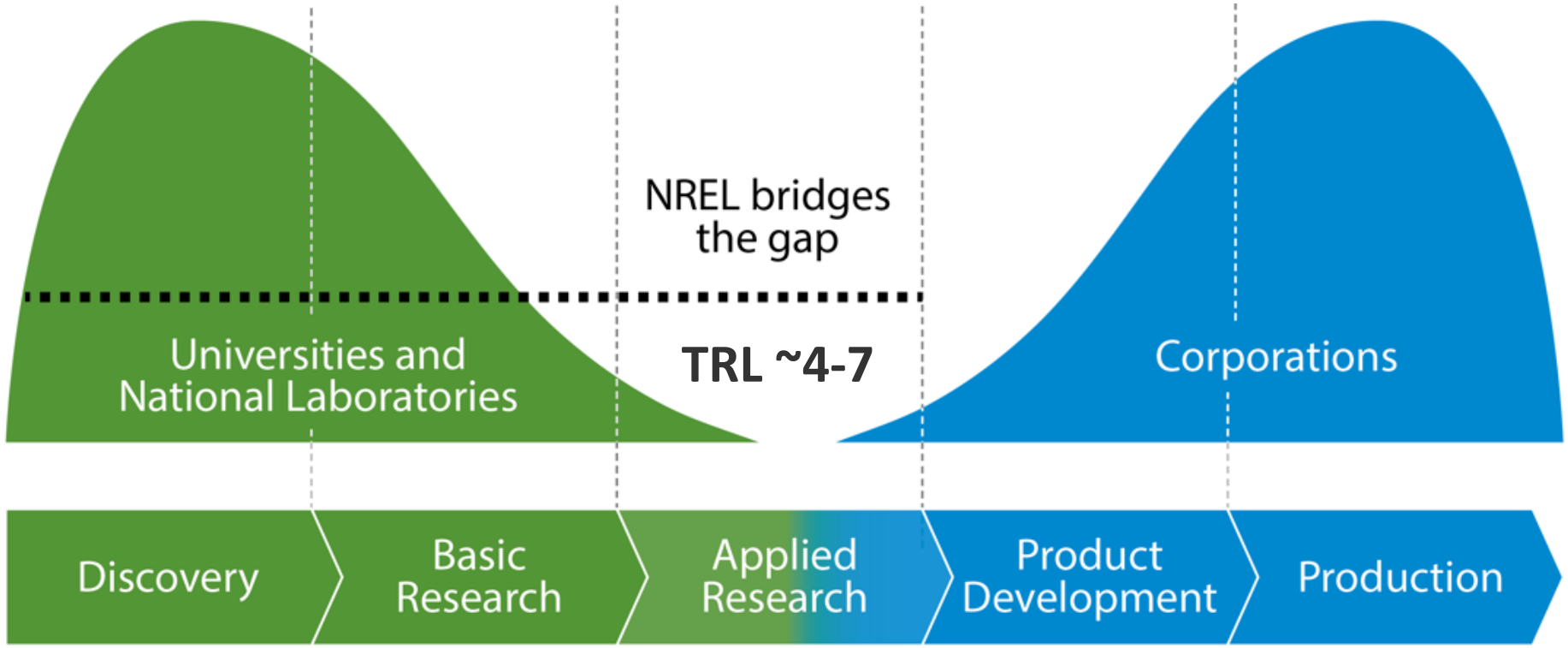
Alaska Campus in Fairbanks

Washington, D.C., Office

About the Laboratory's Capabilities

Photo by Joshua Bauer and Bryan Bechtold, NREL 80544

We Reduce Risk in Bringing Innovations to Market



NREL helps bridge the gap from basic science to commercial application

Forward-thinking innovation yields disruptive and impactful results to benefit the entire U.S. economy

Accelerated time to market delivers advantages to American businesses and consumers

NREL Science Drives Innovation

Energy Systems Integration

- Energy Security and Resilience
- Grid Modernization
- Cyber Security
- Integrated Energy Solutions

Transportation and Fuels

- Bioenergy
- Hydrogen and Fuel Cells
- Transportation and Mobility

Buildings and Industry

- Buildings
- Advanced Materials and Manufacturing
- Industrial Energy
- State, Local, and Tribal Governments

Energy Sources

- Geothermal
- Water
- Solar
- Wind

Photo by Werner Slocum, NREL 66364

Partnering with Business for Competitive Advantage

In **2024**, NREL had:

more than **1,100** active partnerships with **utilities, industry, academia, and government**

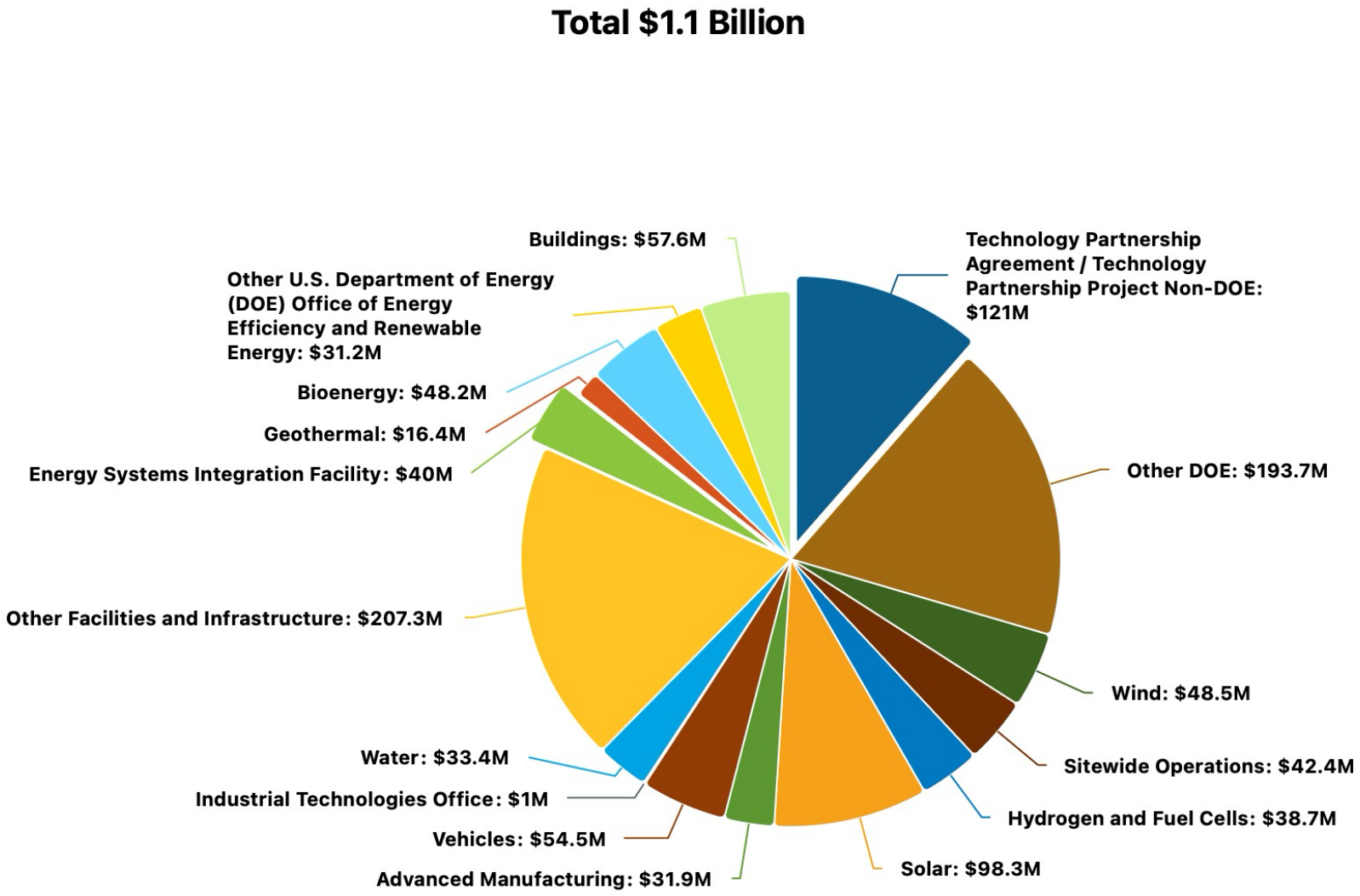
365
new partnership agreements

$170M
value of new partnership agreements

301
unique new partners

812
unique active partners

NREL Funding Portfolio - FY25



Key Capabilities for Utility Solutions

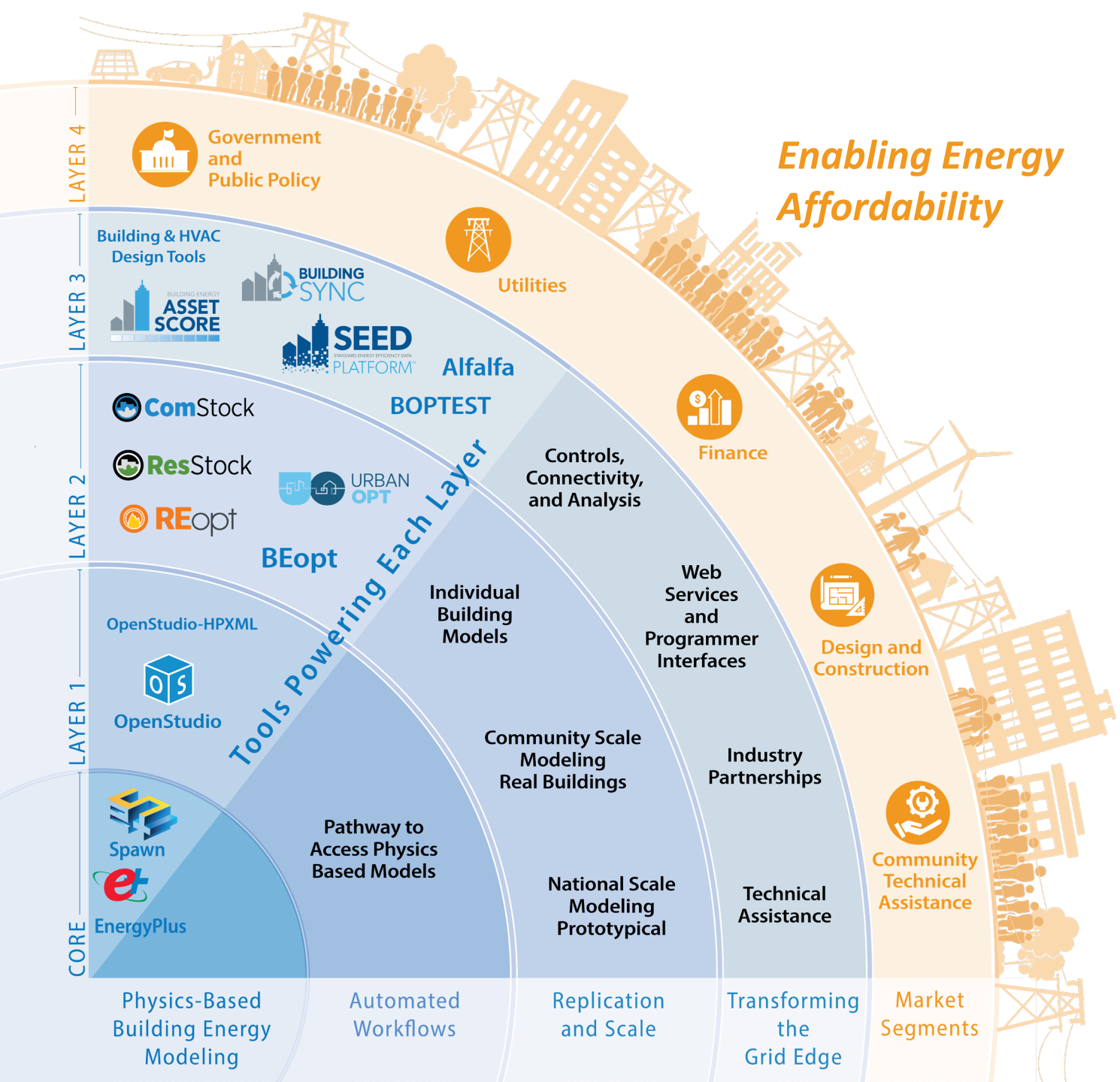
Topic Area	Partners
DER planning, integration, and management	Utilities
Load forecasting and performance for EE/DR and electrification; Buildings	Utilities, Energy Agencies
Data centers planning and integration	Utilities, Data Centers
Electric vehicles and planning	Utilities, Cities and Local Jurisdictions

Topic Area	Partners
Grid modernization	Utilities
Wildfires and resilience mapping/planning	Utilities, Cities, State Government
Cyber and AI	Utilities

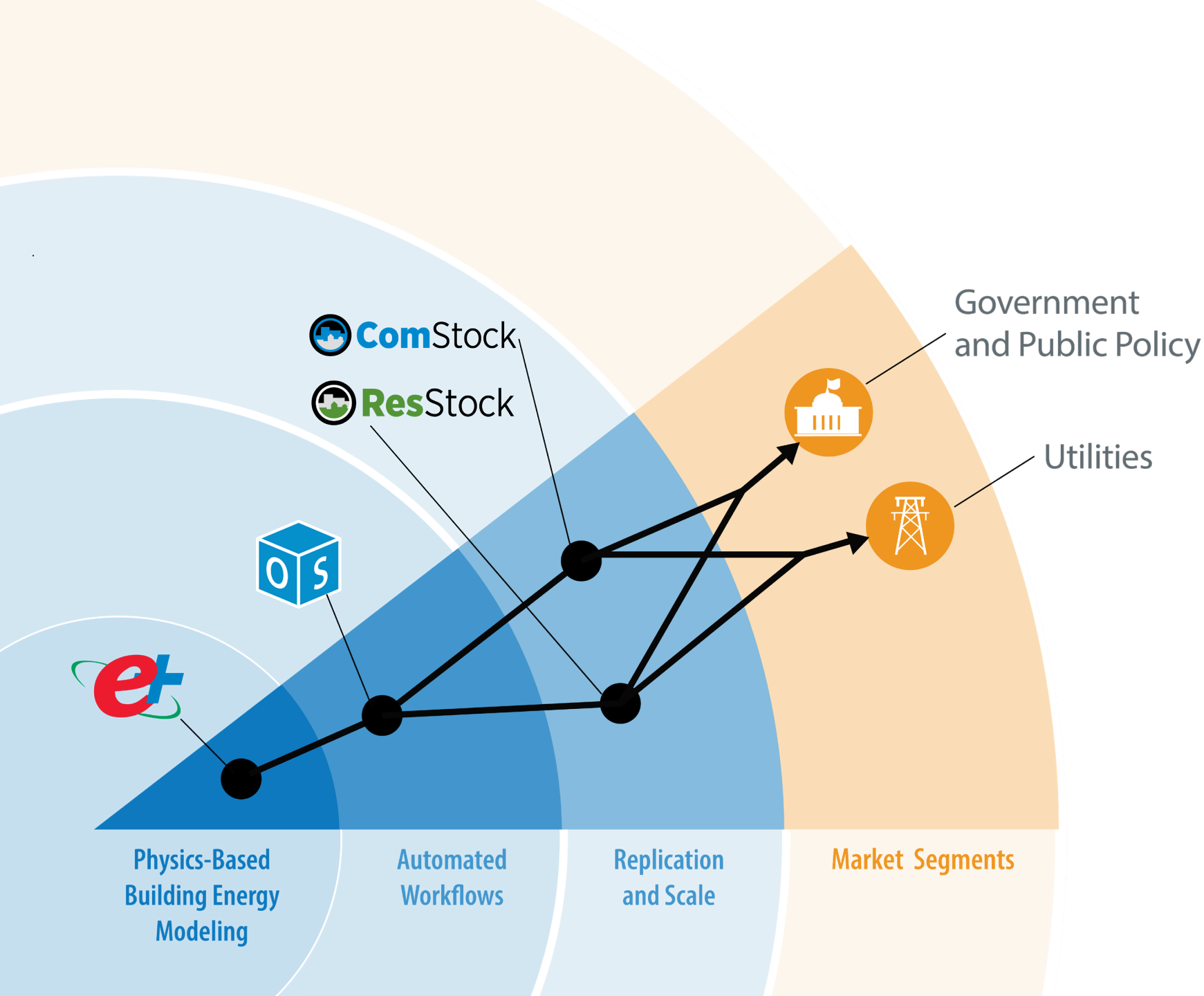
NREL HVAC&R Systems Research Capabilities

- Modeling and analysis
- Laboratory performance experimentation
- Field evaluation
- Hardware-in-the-Loop & Digital-Twin
- Novel technology development
- Multi-scale integration: connecting components to systems to buildings through interconnected modeling and experiments

NREL's Advanced Modeling Platforms: ***Empowering Utility Programs***



NREL and DOE's suite of building energy analysis tools enable utility-scale modeling efforts in multiple market segments.



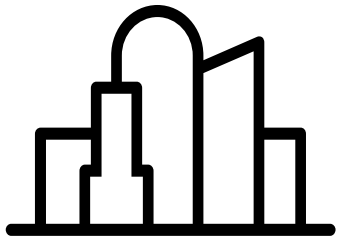
IMPACT

Utilities, including the Los Angeles Department of Water and Power, Southern California Edison, and Southern Cal Gas Co., utilize **stock modeling outcomes for comprehensive service territory-wide impact analysis:**

- **Measure development (IDSM/DR/DER)**
- **Load profiles and forecasting**
- **Economic Factors**

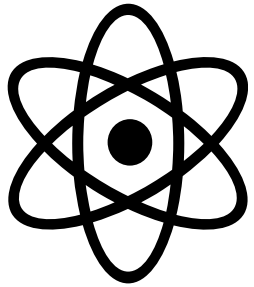
Building Stock Modeling - Technical Approach

ComStock ResStock



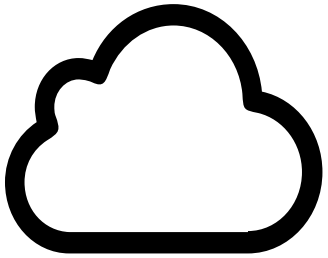
Building stock characteristics database

- Variation in building type; size; location; vintage; HVAC system, etc.
- **Over 100** probability distributions of various attributes



Physics-based computer modeling

- Representative set of **900,000+ OpenStudio energy models**

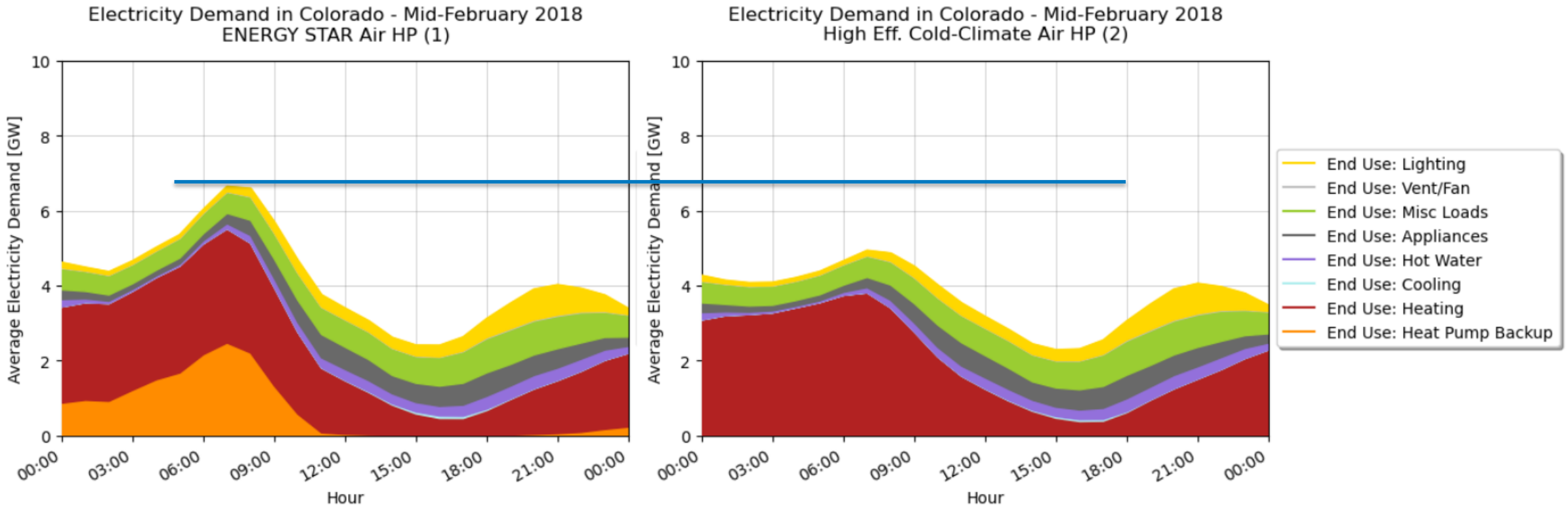


High-performance computing

- Simulate models
- Process raw data
- Apply scaling factors
- Publish data

Harnessing Service Territory Wide End-Use Data for Smarter Utility Program Design

Available Data to evaluate design consideration such as:
Seasonal impacts from varying technologies and performance levels (SEER 13 vs 21)



From ResStock Dataset 2024.2 release webinar slides:
https://www.nrel.gov/docs/fy24osti/89600.pdf

NREL Building Technologies Research Facilities

World-Class Facilities

- **Thermal Testing Facility**
- **Energy Systems Integration Facility**
- Industrialized Construction

Grid Edge Integration

- ARIES
- Hardware-in-the-Loop
- Modeling and Analysis

Unique Partnerships

- Technology Development
- Market Transformation
- Community Engagement

Industry-Leading Expertise

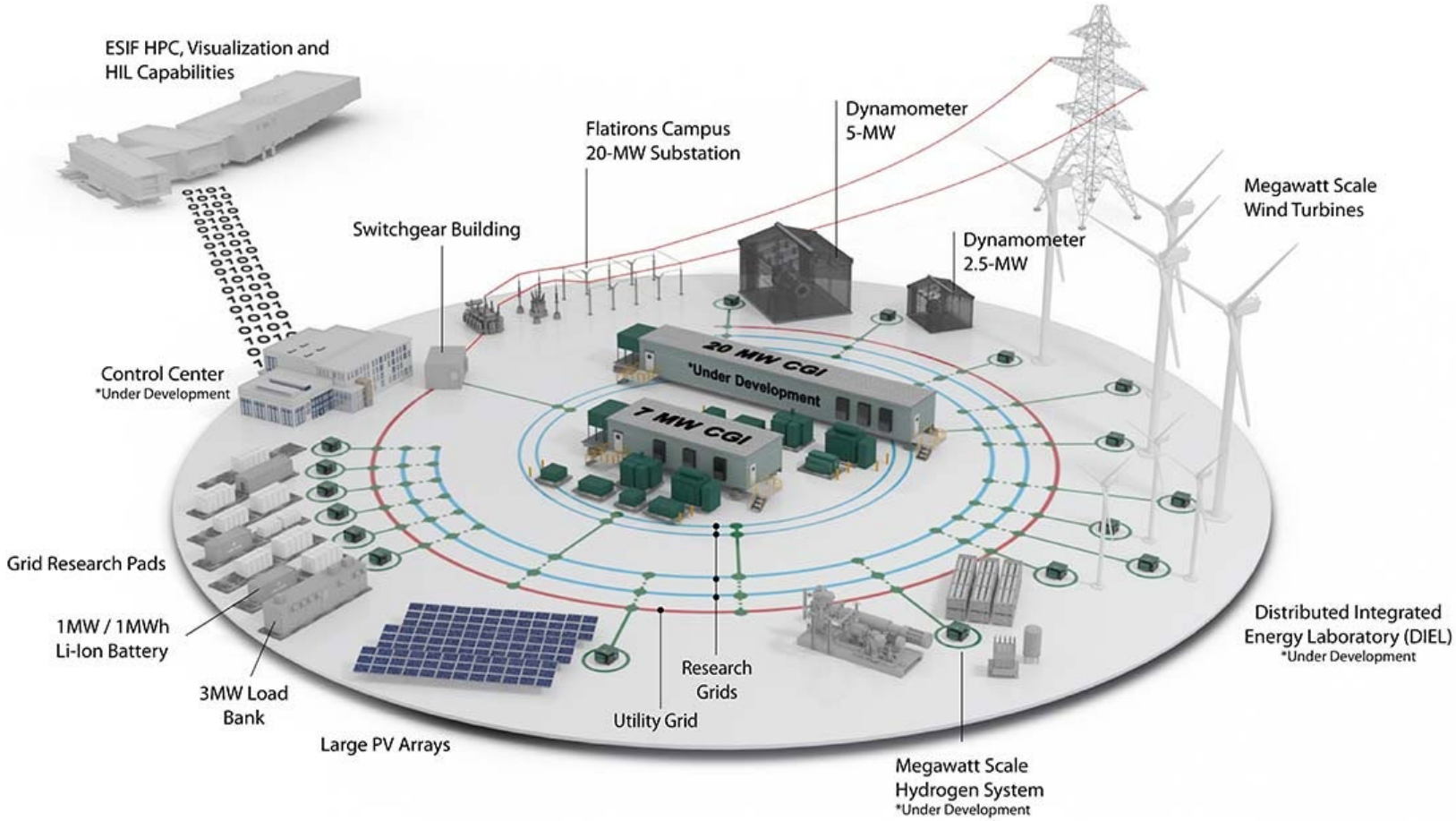
- 100+ Dedicated Researchers
- 11 Patents Issued in FY23
- $630M+ in follow-on funding for start-up partners

Photo by Werner Slocum, NREL 80060

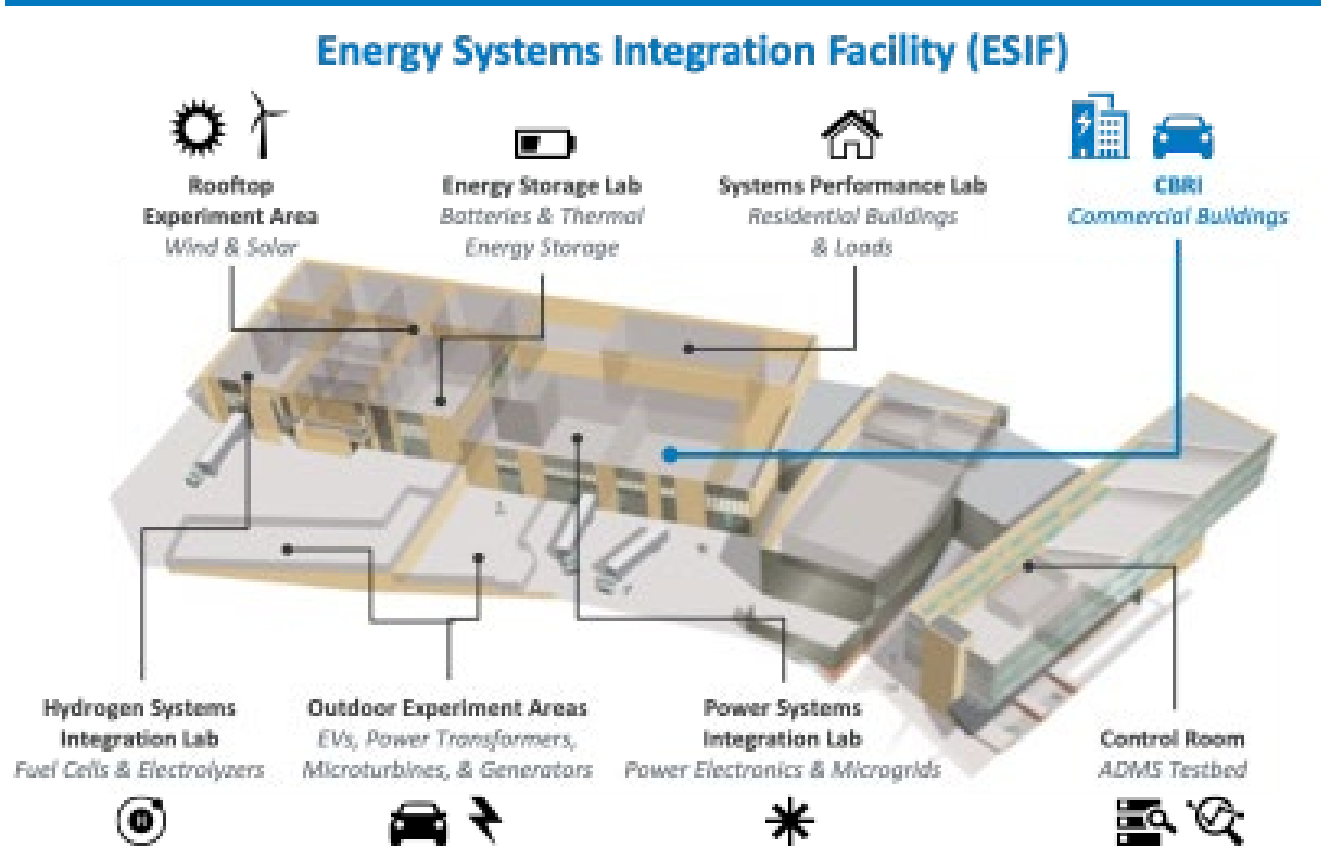
Unique Laboratory Facilities (partial list)

Advanced Research on Integrated Energy Systems -ARIES

ARIES platform is designed to derisk, optimize, and secure current energy systems and provide insight into future energy systems



Unique Laboratory Facilities (partial list)



Grid-Interactive Buildings Lab

HVAC Systems Lab

Advanced Mobility Lab

Residential Research Infrastructure Lab

HVAC/R Research Projects

Energy Efficiency and Load Flexibility

Photo by Werner Slocum, NREL 74630

NREL HVAC&R Systems Research

NREL's HVAC&R research objectives:

1. Assess Performance Uncertainty and De-Risking of Emerging Technologies:
    - *Energy Efficiency and Demand Reduction*
    - *Load Flexibility*
    - *Affordability*
    - *Environmental Impacts*
    - *Human Comfort*
    - *Resilience*
2. Program Support:
    - Connect R&D and innovation with electric and gas utilities' measure pipelines
    - Inform program design and development
    - Load Forecasting
    - Regulatory Compliance Challenges (workpapers critical constituents, Realization rates)

Overview of NREL's HVAC/R Projects

HVAC/R: Selected Research Projects

Refrigeration:

1. Supermarket thermal networks coupling refrigeration and space conditioning loads using natural refrigerants, thermal energy storage (TES) and heat recovery
2. ***Next Gen Refrigerated Display Case (EE + load flexibility)***
3. Design and techno-economic analysis of adding cold TES to refrigeration systems in a specific supermarket
4. Low-cost TES for load shifting and resiliency for supermarket refrigerated display cases

Bold *projects will be highlighted later in the presentation*

HVAC/R: Selected Research Projects

Residential space heating and cooling with thermal storage:

1. ***Modular multifunctional residential R290 heat pumps***
2. Stash Energy's residential split systems with embedded (2+-hour) TES

Commercial space heating and thermal storage:

1. Mitigating peak power from heat pump defrosting
2. ***HVAC Technology Challenge – efficient heating in cold climates***
3. ***Cascade air to water HP for 160-180 F hydronic heating***
4. ***DC nano HP rooftop unit (RTU), a novel DC HVAC nanogrid HP rated up to 12.5 tons with a DC backbone, an on-site photovoltaics and TES***
5. ***NREL's HP DOAS that provides a new approach to first-stage heating that can cut heating energy use by 50% with embedded (3- to 5-hour) TES.***
6. Scale-up of thermochemical energy storage for space heating

HVAC/R: Selected Research Projects (Cont'd)

Dehumidification:

1. Blue Frontier's efficient-humidity and sensible-control single-storage system providing 6-12 hours of energy storage in summer and 3-6 hours of thermal heating storage in winter
2. Mojave's efficient humidity control and HP
3. Copeland's efficient humidity control using liquid desiccant and membrane technology that protects from air streams
4. Transeara's new metal-organic-framework technology that improves the dehumidification cycle of solid desiccant systems

Other Advanced Technology Research Projects (HVAC/R Relevant)

Other advanced technologies:

- High-efficiency HP clothes dryer.
- Modular construction
- Plug-and-play retrofittable economizer thermal switches with thermal storage to reduce HVAC energy and enhance occupant comfort.
- Development of the open-source TES Sizing, Benefits and Decision Tool (TESSBeD) to address key market barriers to TES adoption

1. **Next Gen Refrigerated Display Case (TRL ~ 5)**

PI: Ramin Faramarzi

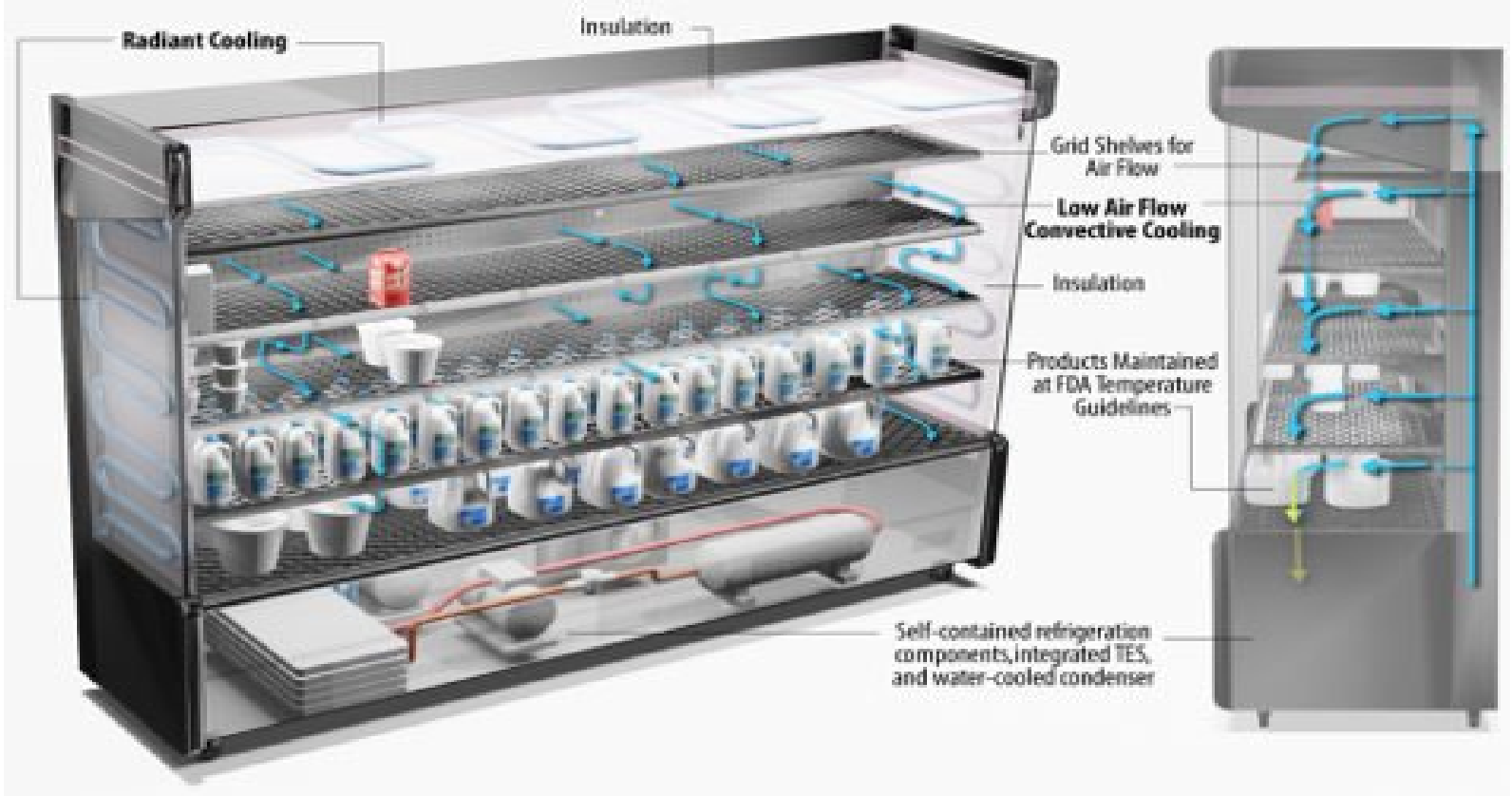
High Efficiency and Load Flexibility in Refrigerated Display Case

For the objective, outcome, and impact, the team aims to develop a next-generation self-contained, refrigerated open vertical display case (OVDC) that leverages radiation and TES to:

- Improve **energy efficiency**
- Provide **demand flexibility**
- Improve **human comfort**
- Reduce **impacts of refrigeration**.

The team includes members from:
- NREL
- Copeland Corporation
- NetEnergy.

Deployment and commercialization partners include:
- Arneg USA
- Albertsons
- Commonwealth Edison Co.

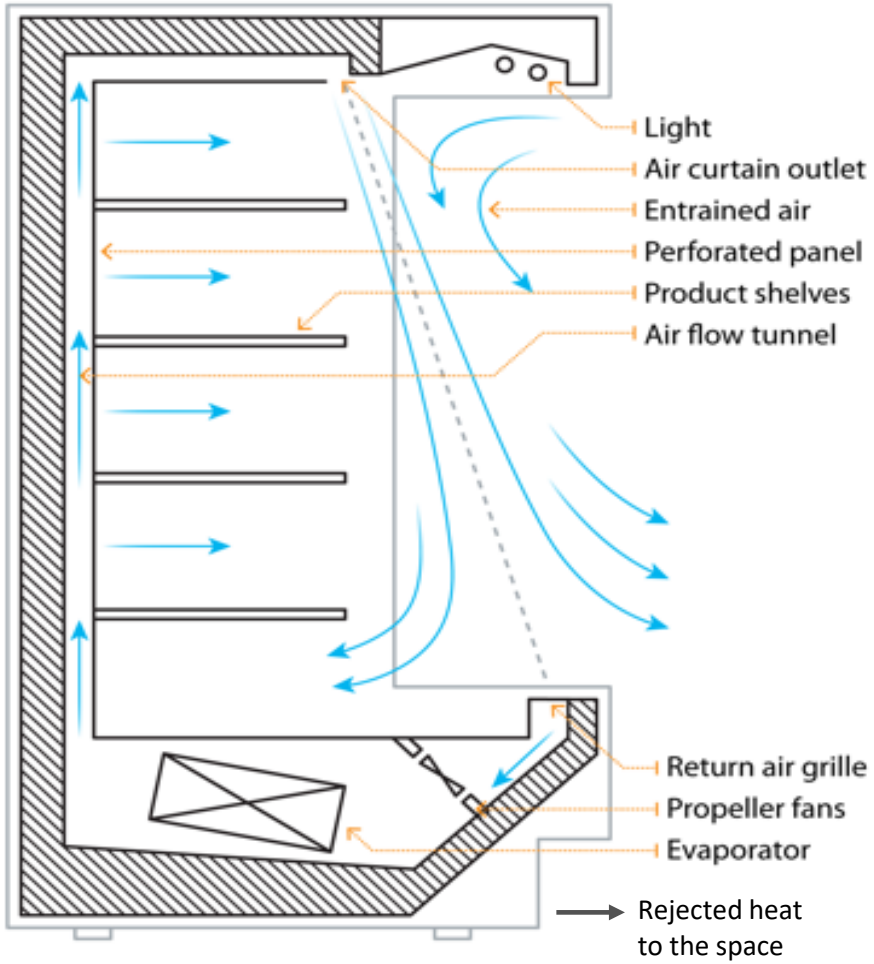


Graphics by MS, NREL

Problem Statement

The problem addresses that:

- **Forced convection** used to cool refrigerated products results in large mass exchange with the surrounded space, where:
  - Air infiltration accounts for **80% of the cooling load**
  - The **spilled cold air** adversely **impacts human comfort**
  - **Frost formation** on the evaporator restricts air flow and **hampers heat transfer,** which degrades energy efficiency
  - Highly variable and **nonuniform product temperature** occurs between shelves (up to 10 °F)
- **Refrigeration heat** rejected into the sales floor **cannot be reclaimed** by heating systems
- Existing designs **cannot reliably participate in demand response** events and load shaving/shifting strategies.

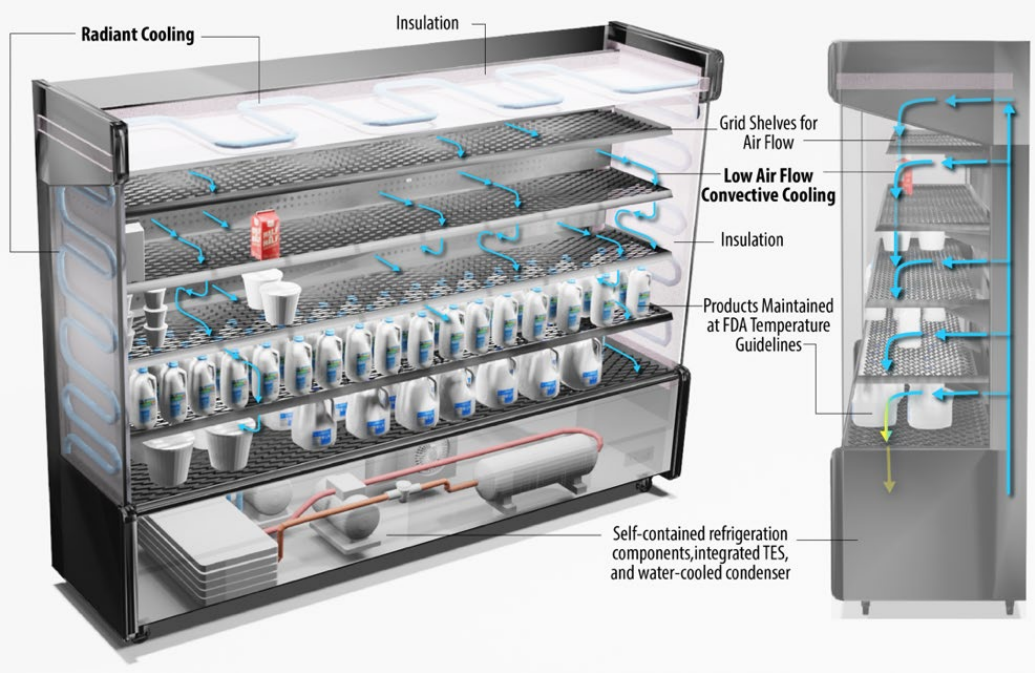


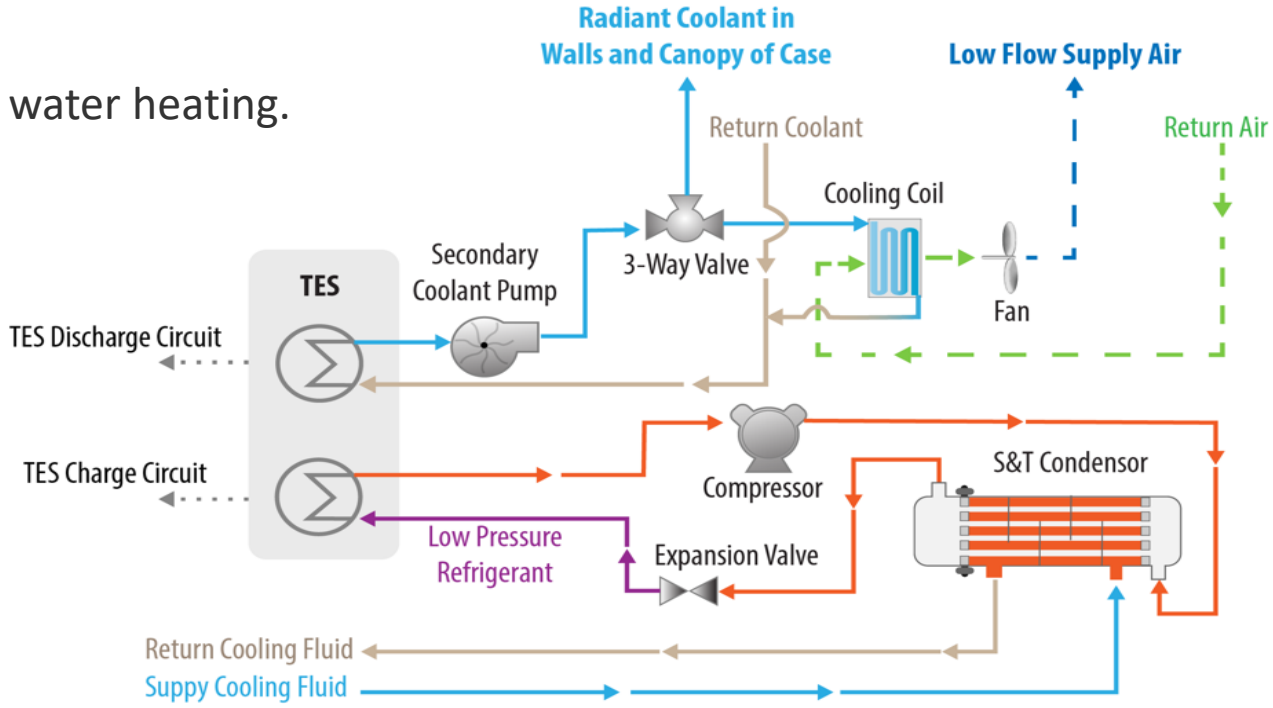
Current State of Technology

Proposed Innovation

The novel solution features:

- Complete removal of air curtain system replaced with hybrid radiant and convective cooling using R290
- TES
- Water cooling integrated with building space and water heating.





- Hybrid cooled OVDC with an Integrated TES (left) involves several processes (below). Graphics by NREL

Project Next Steps

- 2026: Complete performance evaluation of hybrid cooling mechanism with partner Arneg (funded)

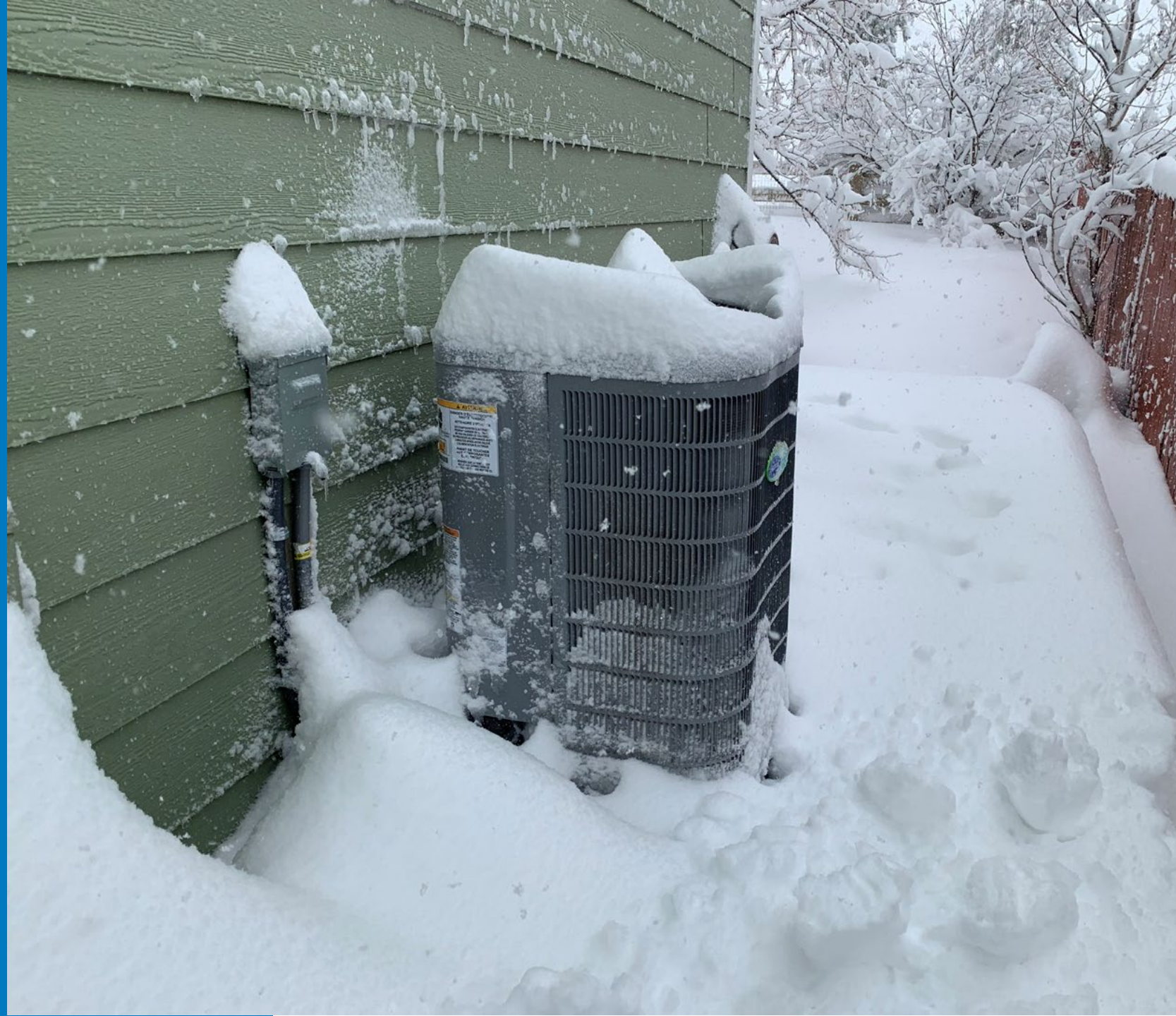
- 2026-2027: Testing load flexibility of next gen display case with integrated thermal energy storage (not yet funded; looking for partners)

2. **Modular residential cold climate heat pump (TRL ~ 3)**

PI: Juan Catano

What are the biggest challenges facing HP today?

- High installation cost
- Perception of low comfort
- High peak power consumption

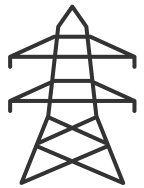


What are we doing to address these challenges?

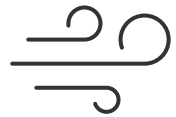
Develop a modular CCHP for space conditioning and water heating that compared to a typical residential heat pump:

- Reduces **installation cost by 40%** (50% lower install time)

- Reduces **4-hour peak-load by 50%** in summer and by **40%** in winter

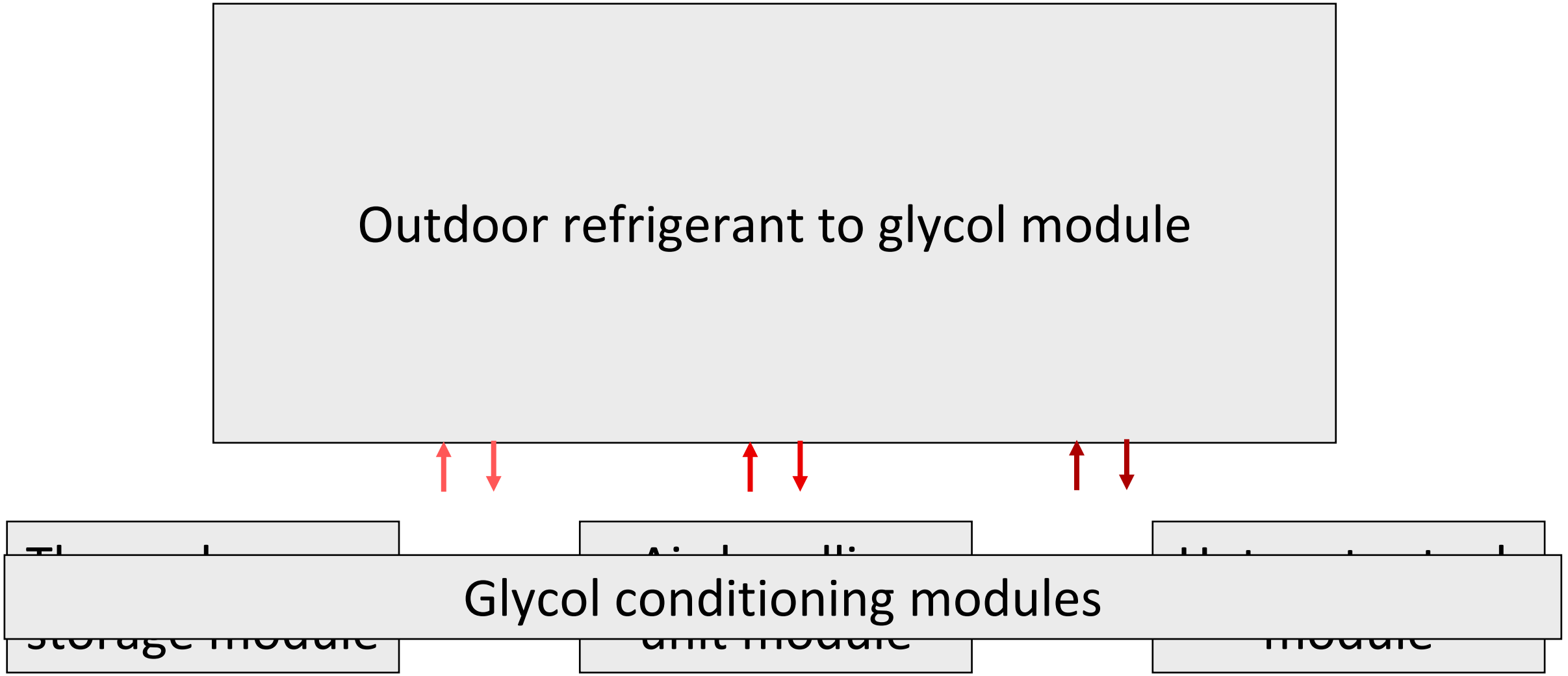


- Can provide **space heating during** a **defrost** cycle



Payback period: 2-3 years with TOU pricing (TES module < $40/kWh$_{th}$)

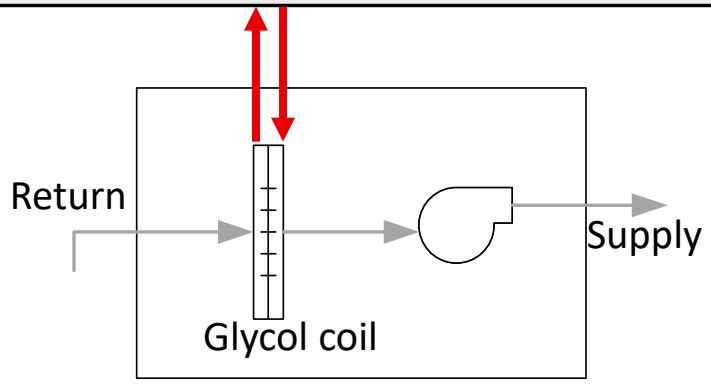
Modular CCHP for Space Conditioning and Water Heating



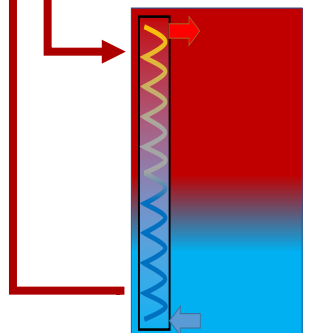
Conditioning Modules

Outdoor refrigerant/glycol module
(factory charged)

Thermal energy storage module

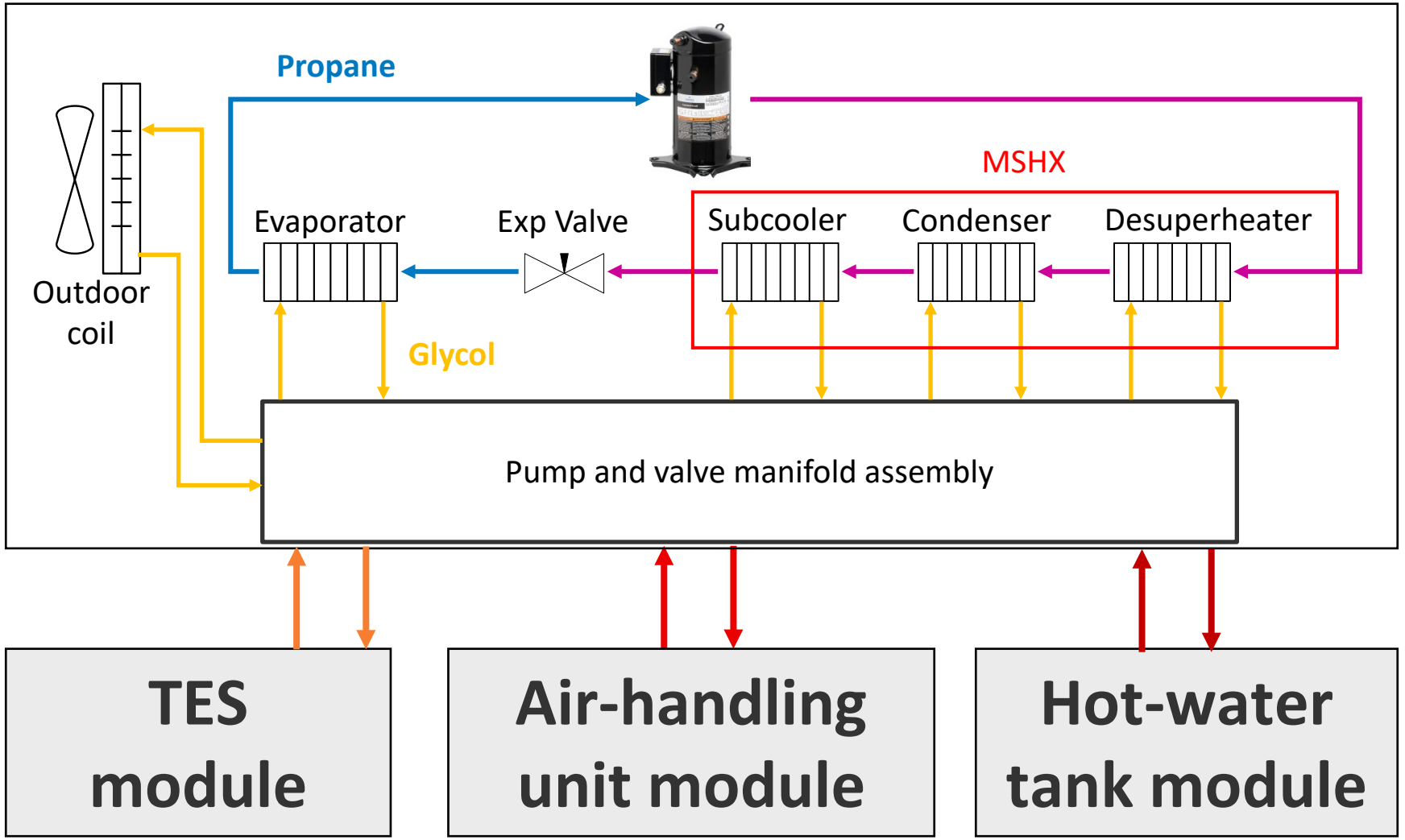


Air-handling unit module



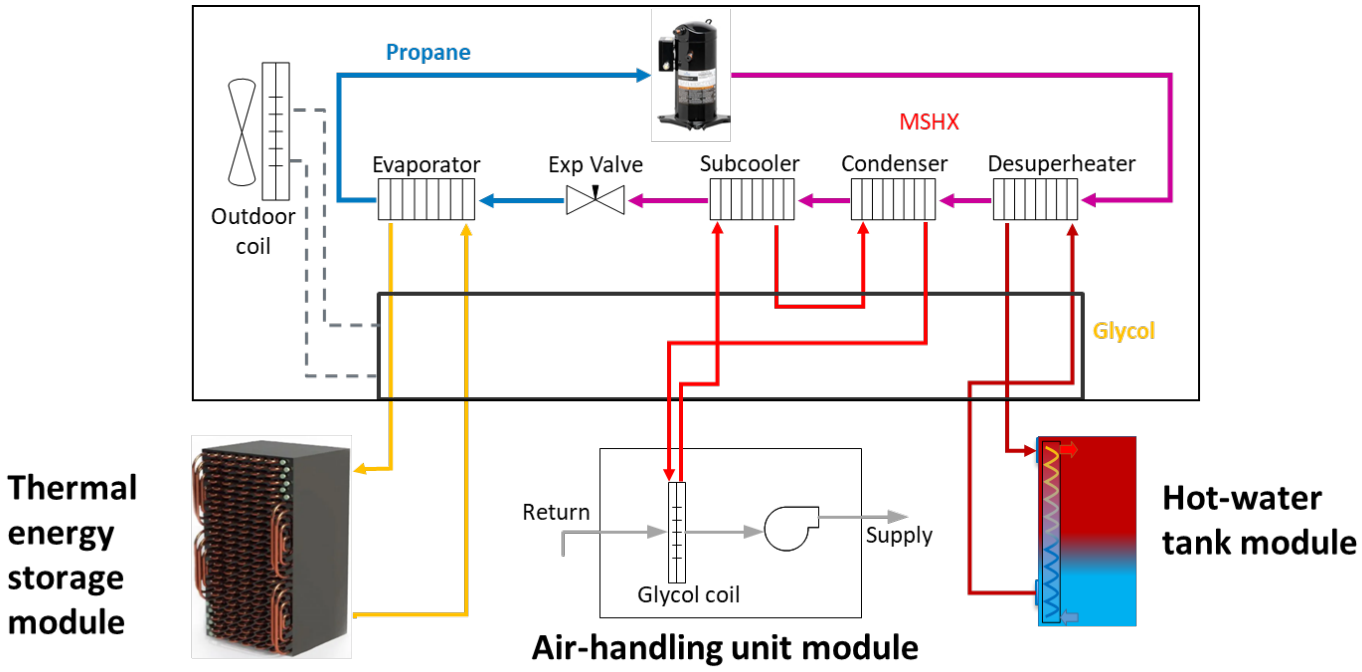
Hot-water tank module

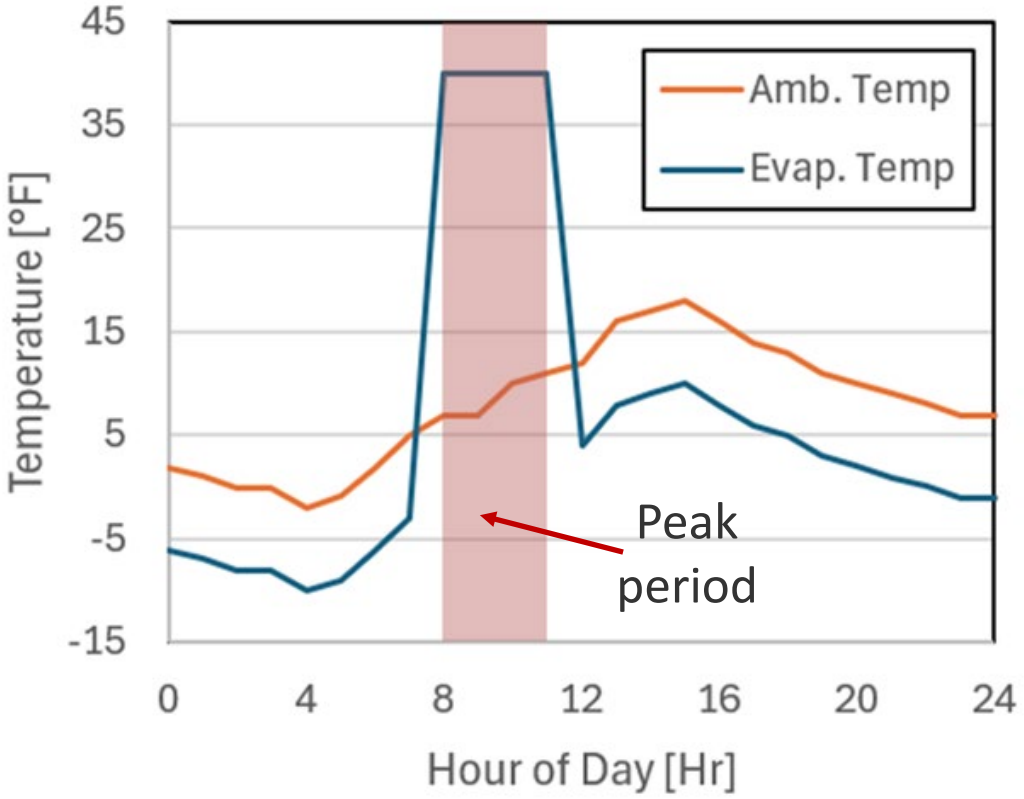
Outdoor Refrigerant/Glycol Module: Config 1 (Basic)



Space Heating w. TES Discharge

During peak TOU rates the HP can switch its heat source from ambient to TES and reduce compressor power





Progress and next steps

- 2025/2026: Design proof of concept prototype (funded by DOE)
- 2026: Build and test proof of concept prototype with partner Copeland using off-the-shelf components (funded by DOE)
- 2027: Build and test Gen-2 prototype with new thermal storage and advanced controls (funded by DOE)
- 2028: Field demonstrations (not yet funded; looking for partners)

3. **HVAC Technology Challenge: Cold-climate heat pumps for commercial buildings (TRL ~ 7)**

PI: Michael Deru

Commercial HVAC Technology Challenge

The Challenge works with HVAC manufacturers and building portfolio owners to bring about the next generation of RTU technologies.

HVAC Manufacturer Partners

AAON, BOSCH, Carrier, DAIKIN, LENNOX, LG, Rheem, TRANE TECHNOLOGIES

Represent 80% of the RTU market

Key challenge activities:

- Develop a performance specification
- Evaluate prototype RTUs in the lab
- Verify prototype RTUs with building owner partners

Building Owner Partners

amazon, Columbia Association, target, IKEA, LIFE TIME, PROLOGIS

Collectively own ~400,000 RTUs

Photo by Sam Petty, US DOE

Challenge Objectives

Maintain capacity and efficiency at low ambient temperatures

HP RTU	Cooling Capacity @ 95°F (ton)	Heating Capacity (ton)		
		47°F	5°F	-10°F
Standard	10	9.5	4.5	NA
Challenge	10	10	10	7
Improved Cold Climate (optional)	10	10	10	10

Additional considerations

- Minimize electrical capacity upgrade requirements
- Minimize peak demand impacts
- Enable dual fuel operations
- Implement load flexible controls

Photo by Sam Petty, US DOE

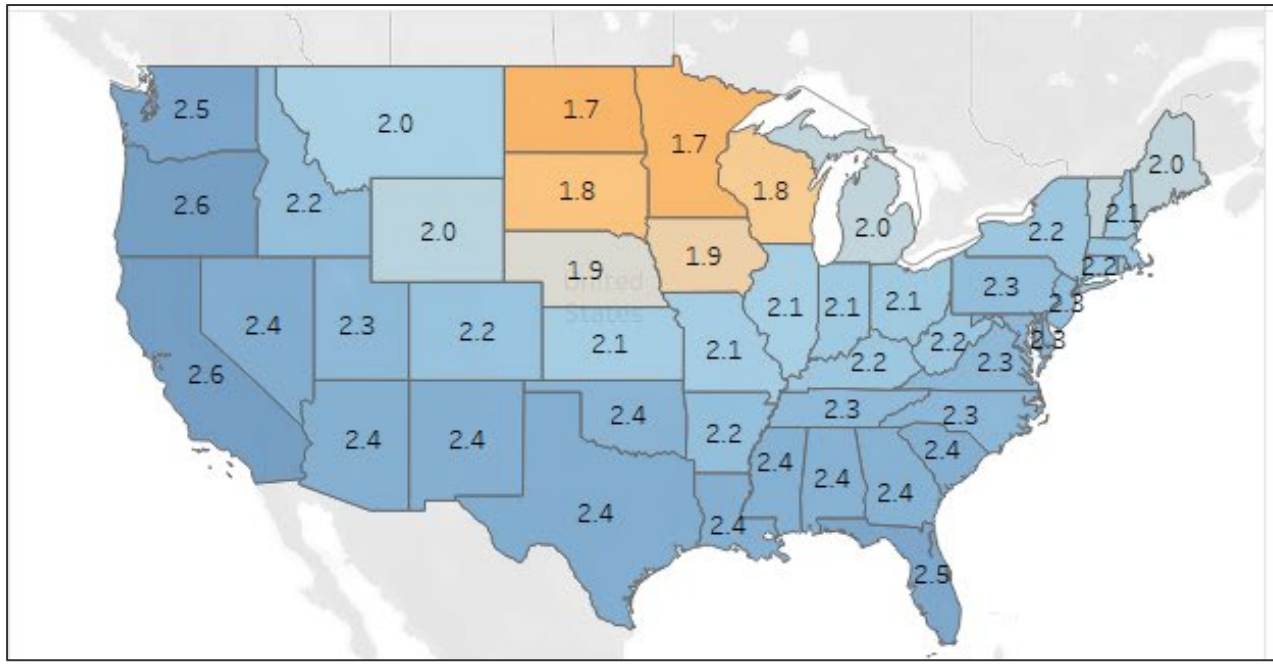
Full Specification: https://betterbuildingssolutioncenter.energy.gov/resources/commercial-building-hvac-technology-challenge-specification

Efficiency Improvements

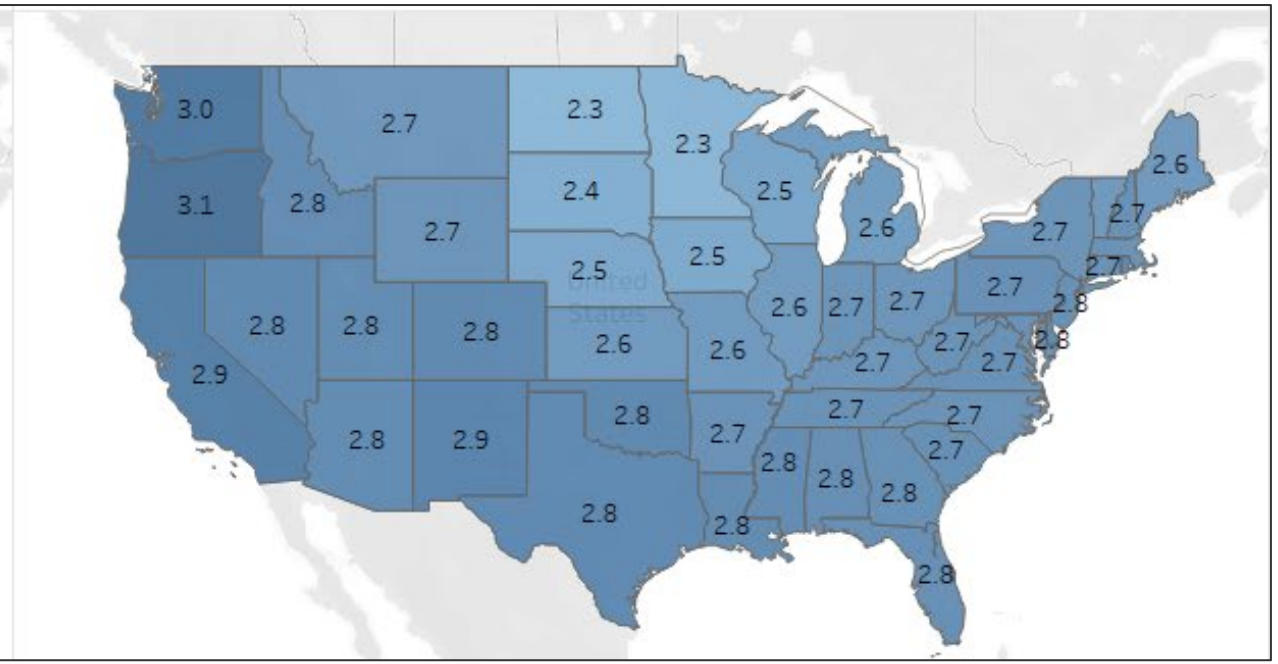
Draft - Not for Public Distribution

Median of annual average total heating COPs by state

Standard Performance



HVAC Challenge Spec Performance



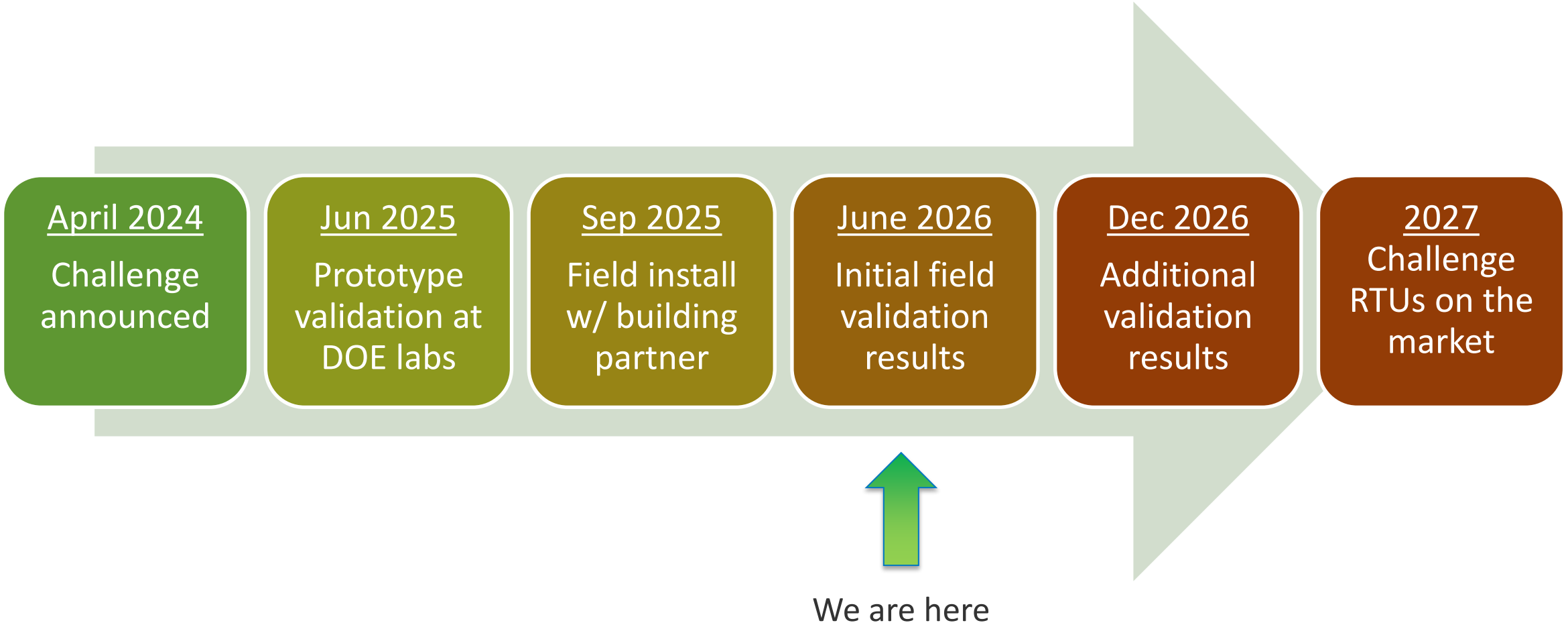
COPs presented include impacts of supplement heat, crankcase heat, and reverse-cycle defrost, but not supply fan.

Efficiency improvement of the overall performance of the heat pump through reduced runtime of the backup heat and better COP of the vapor compression cycle

Source: CaraDonna, C. (2025). *ComStock Measure Documentation: Heat Pump Rooftop Units Compliant With the Commercial Building Heat Pump Technology Challenge Specification*. https://www.nrel.gov/docs/fy25osti/92720.pdf

Challenge Timeline

Draft - Not for Public Distribution



4. **Cascade air-to-water HP for 160-180 F hydronic space heating (TRL ~ 5)**

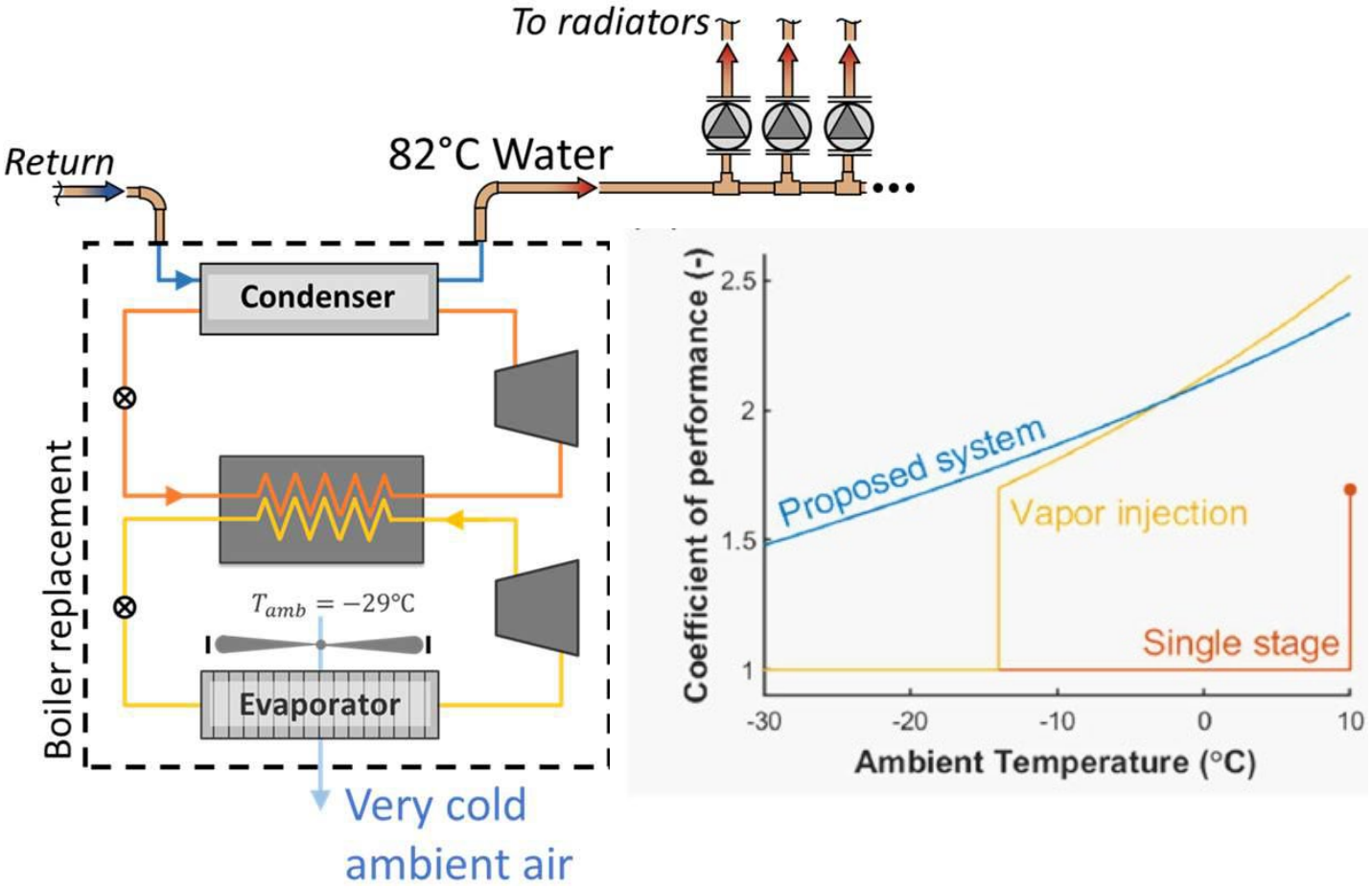
PI: Jason Woods

Hydronic heat pump: Achieving 180 F water in cold climates

10-ton cascade heat pump for 180 F water at -20 F ambient

- "Cold climate heat pumps" typically refer to air-to-air systems to replace forced-air furnaces (heat delivery ~120 °F)
- Available heat pumps are not suitable for hydronic systems requiring 180 °F water.

Hydronic heat pump: Achieving 180 F water in cold climates



- "Cold climate heat pumps" typically refer to air-to-air systems to replace forced-air furnaces (heat delivery ~120 °F)
- Available heat pumps are not suitable for hydronic systems requiring 180 °F water.

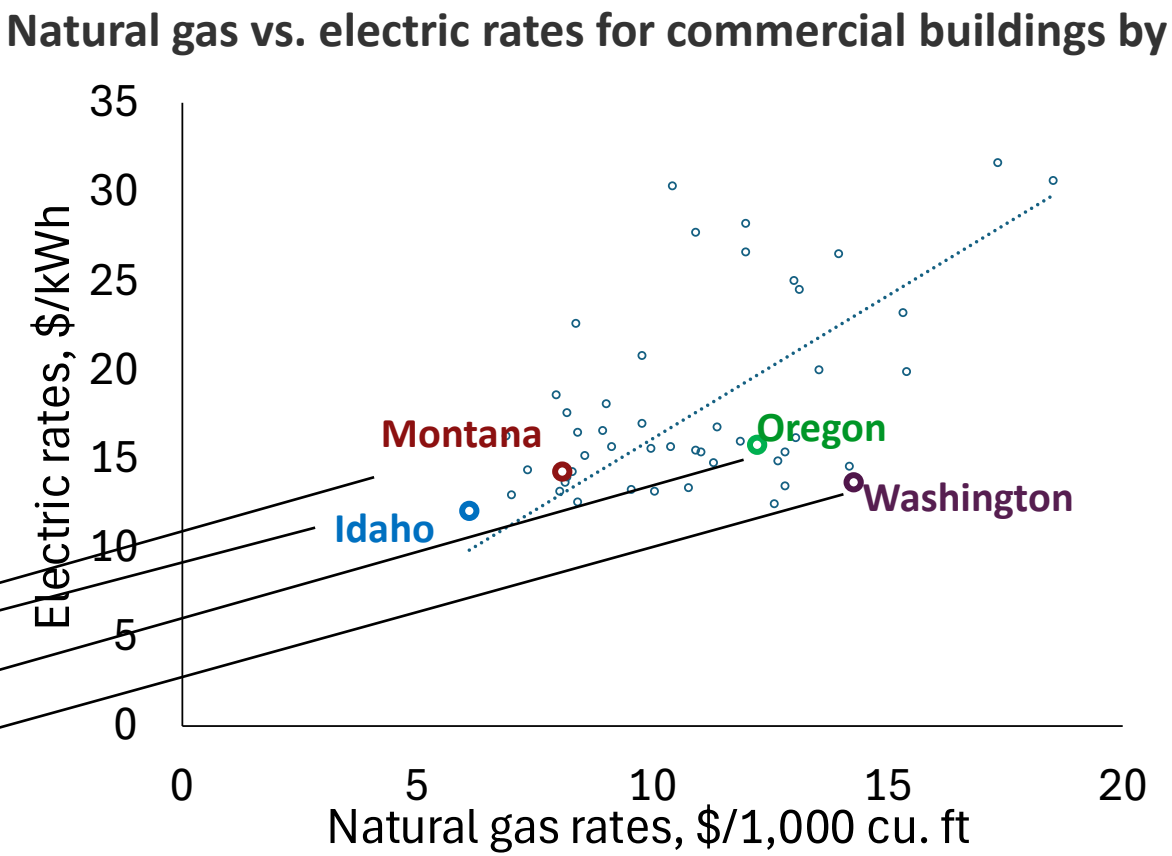
10-ton cascade heat pump for 180 F water at -20 F ambient

Does electric heating make sense for 180 F heat?

Buildings that adopt this heat pump for hydronic system replacement could lower utility bills, especially in Washington and Oregon

Cascade system annual savings vs. boiler

Gas rate \ Electric rate	Low	Med	High
Low	1%	-98%	-197%
Med	50%	1%	-49%
High	67%	34%	1%



Progress and next steps

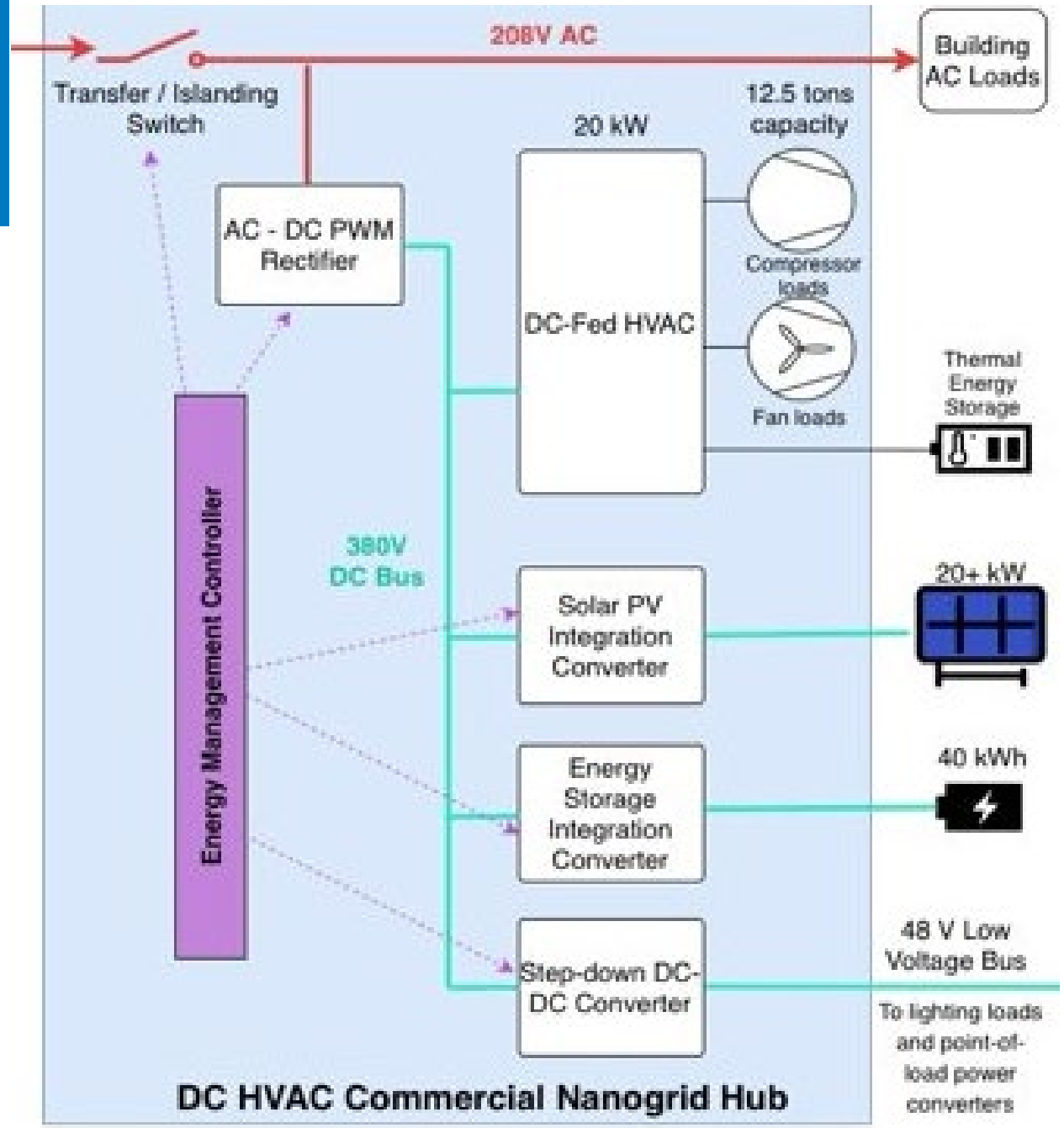
- 2025/2026: Initial prototype lab testing; modeling shows potential performance and guides gen 2 design (DOE and partner funded)
- 2026: Gen 2 prototype testing (partner funded)
- 2026/2027: Potential field demonstrations (not yet funded; looking for partners)

5. **DC Nanogrid Heat Pump (TRL ~ 4)**

PIs: Ramin Faramarzi, Omkar Ghatpande

DC-Backbone HVAC Nanogrid Hub

- **Develop a DC-backbone powered RTU HVAC system** to integrate with solar photovoltaics and energy storage that:
  - **Increases energy efficiency by 18%** by reducing system conversion losses (AC to DC and then DC to AC)
  - **Enhances** load **flexibility, affordability, and resilience** by shifting HVAC loads to off-peak hours using **electrochemical** and **thermal batteries**
- **Work with a RTU manufacturer to produce** a factory-ready **nanogrid hub**
- **Incorporate the lab's facilities** for capability testing and field evaluation of the proposed solution.



6. **Heat pump dedicated outdoor air system (TRL ~ 4)**

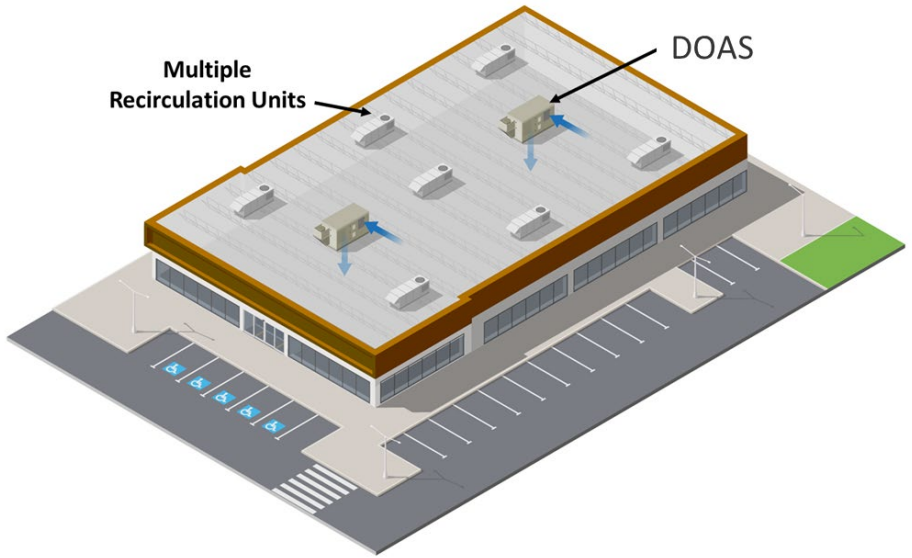
PI: Eric Kozubal

Dedicated Outdoor Air Systems

Ventilation air accounts for between >90% of commercial building heating loads

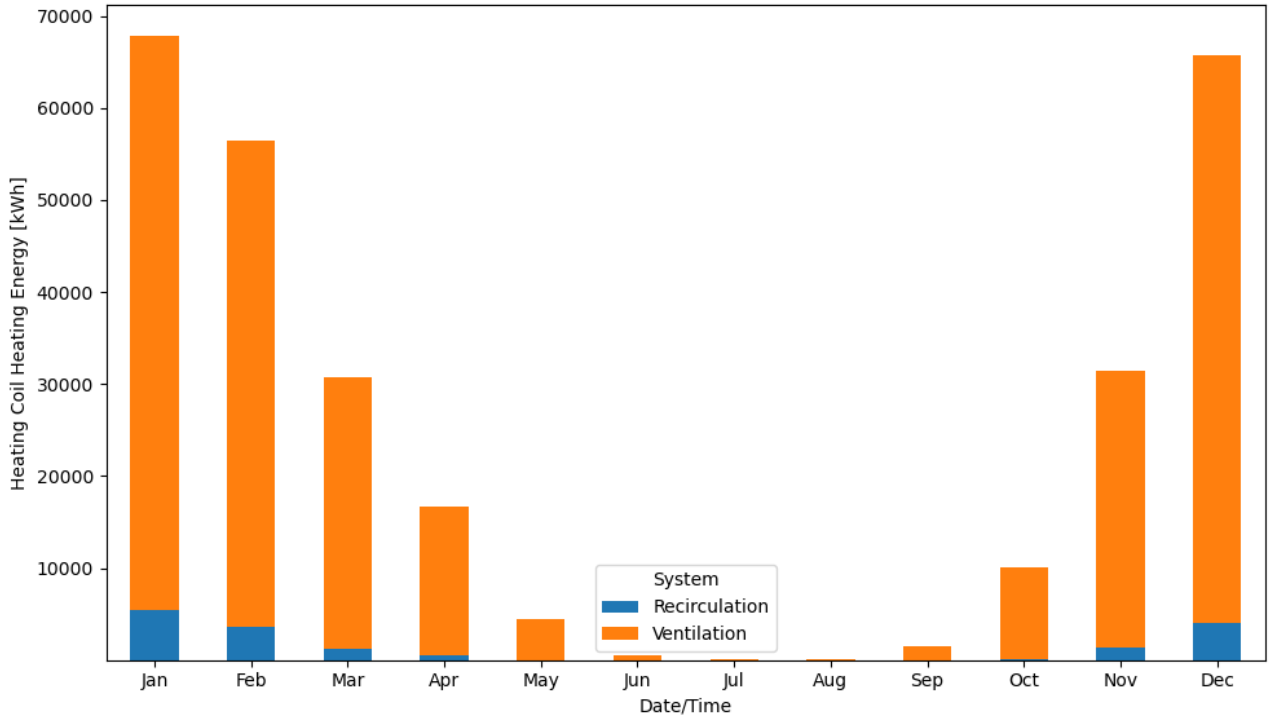
Current DOAS Technology

- Mainly gas heating
- Heat pump options have low efficiency
- No options for grid interactivity (on-demand)
- HFO refrigerants only



Ventilation vs recirculation heating load by month

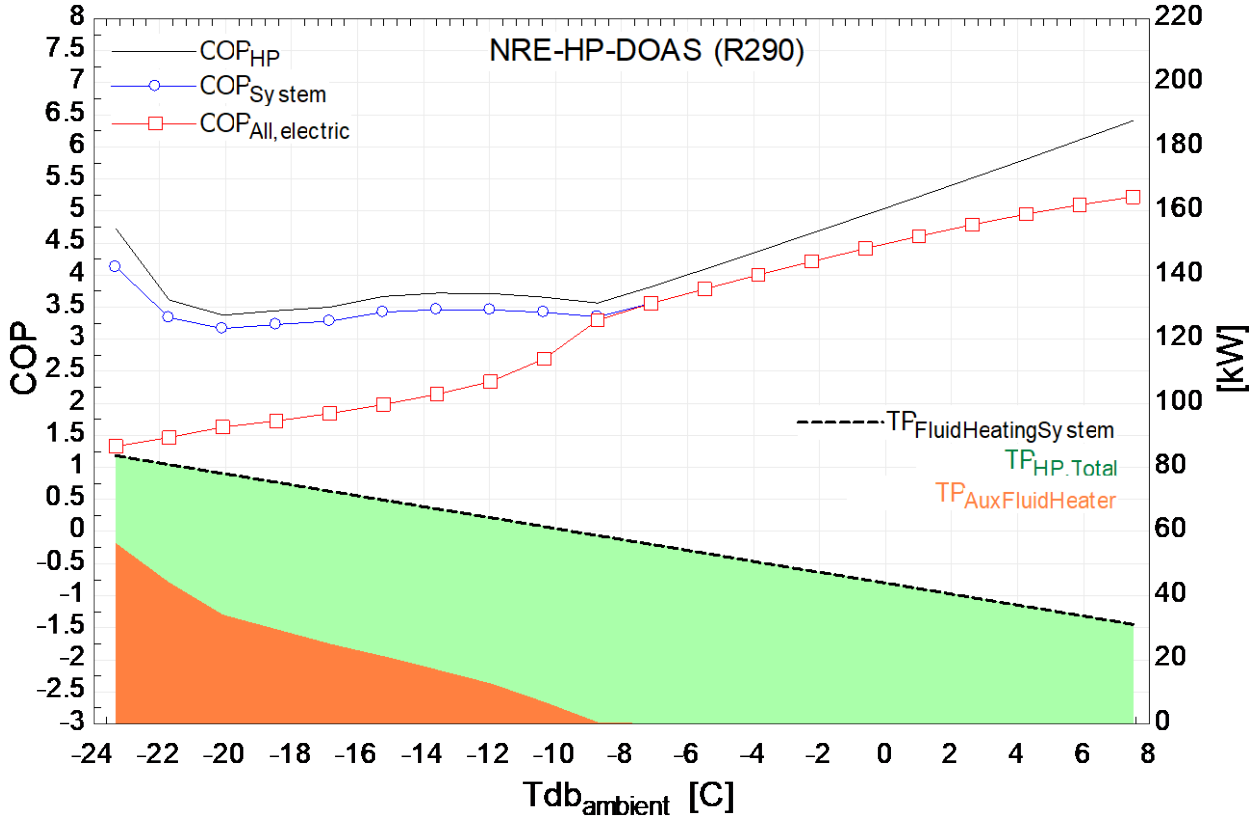
Chicago, IL (Supply Air = 18 °C / 64 °F)



Cold-Climate Heat Pump DOAS: Efficient, Affordable, Grid-Ready

NREL's cold-climate HP DOAS design:

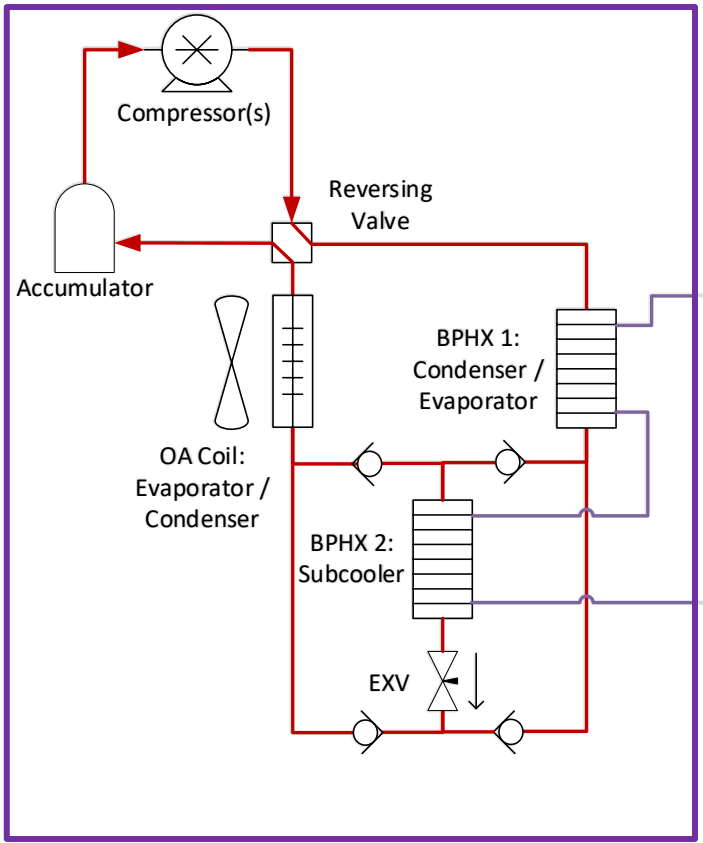
- Estimated 50% lower energy cost vs today's DOAS
- 2–6 hour load shifting via integrated thermal storage
- Cold-climate operation to -30°C (-33°F)

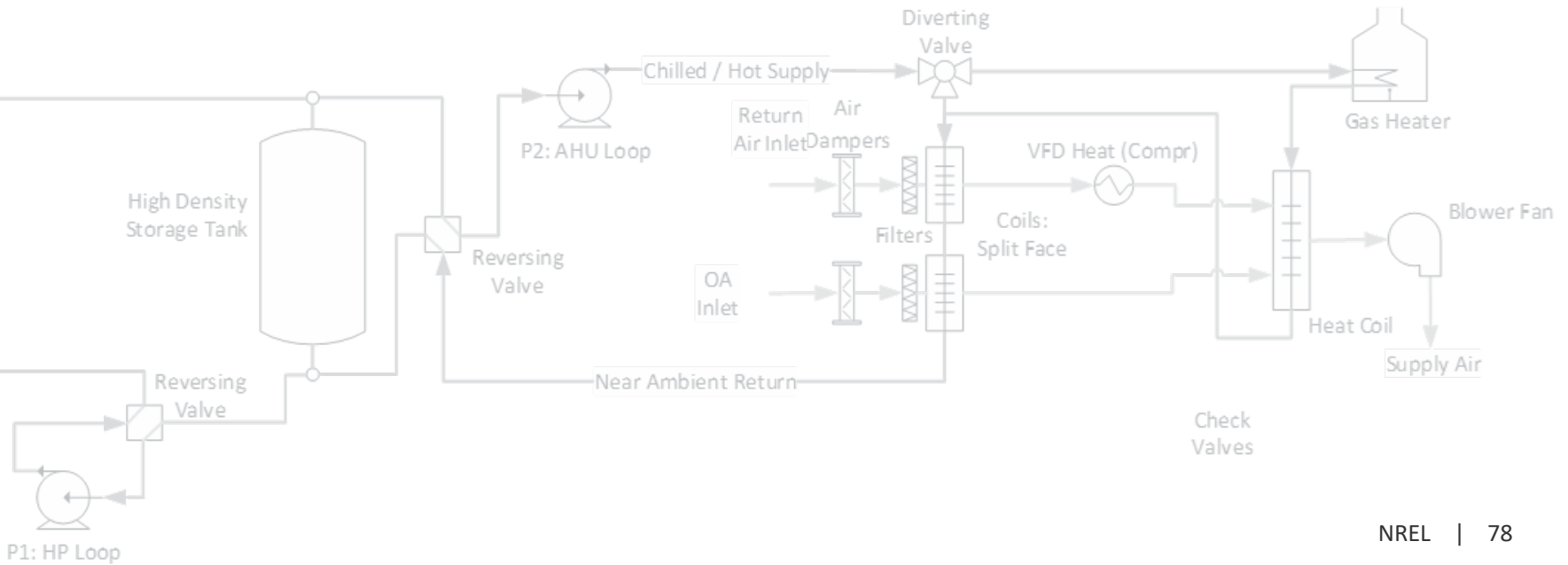


Mono-Block Heat Pump with Secondary Loop

Efficient and affordable operation at low ambient temperatures:

- -20 °C (-4 °F) with R454B
- -30 °C (-22 °F) with next generation refrigerants (e.g., propane, R454C)

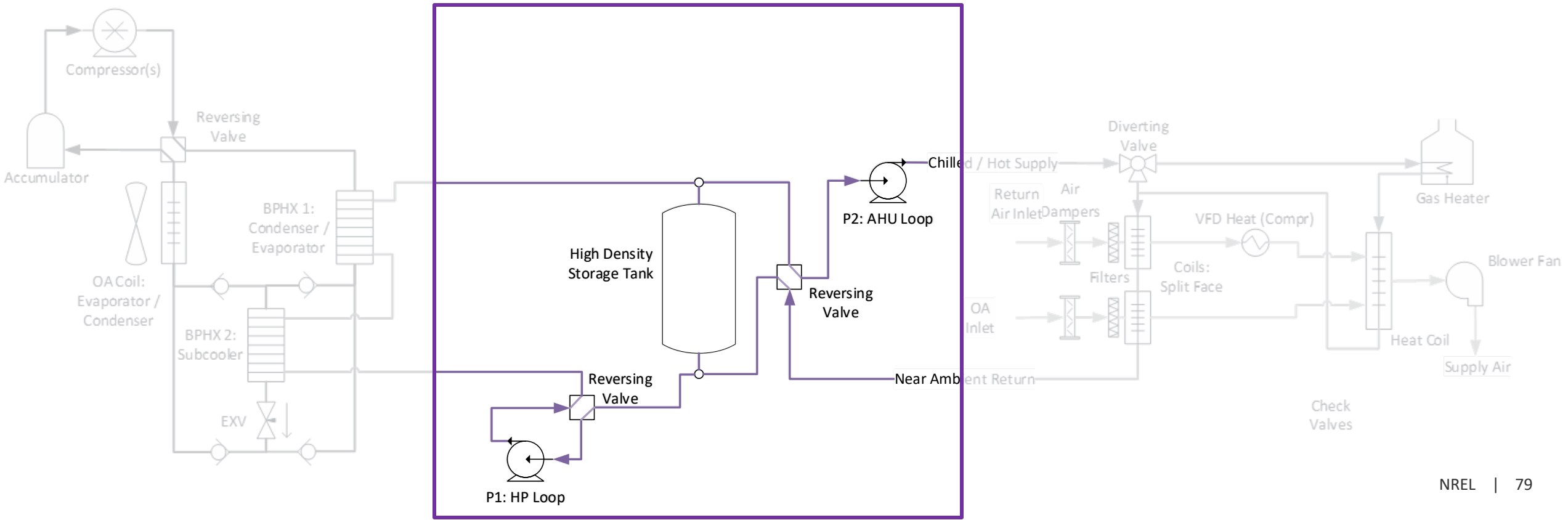




Integrated High Density Energy Storage

Low-cost sensible energy storage

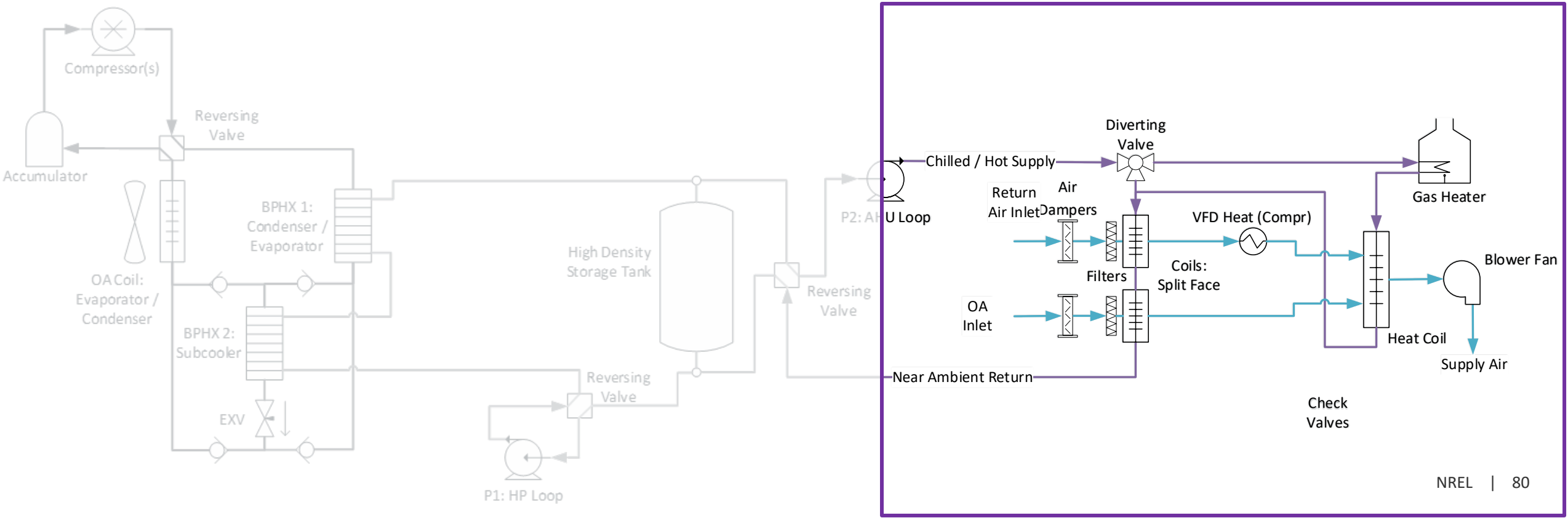
- 95% electric demand reduction up to 6 hours (200 gallons per hour of storage)



Air Handling Unit w/ Multi-HX Fluid Paths

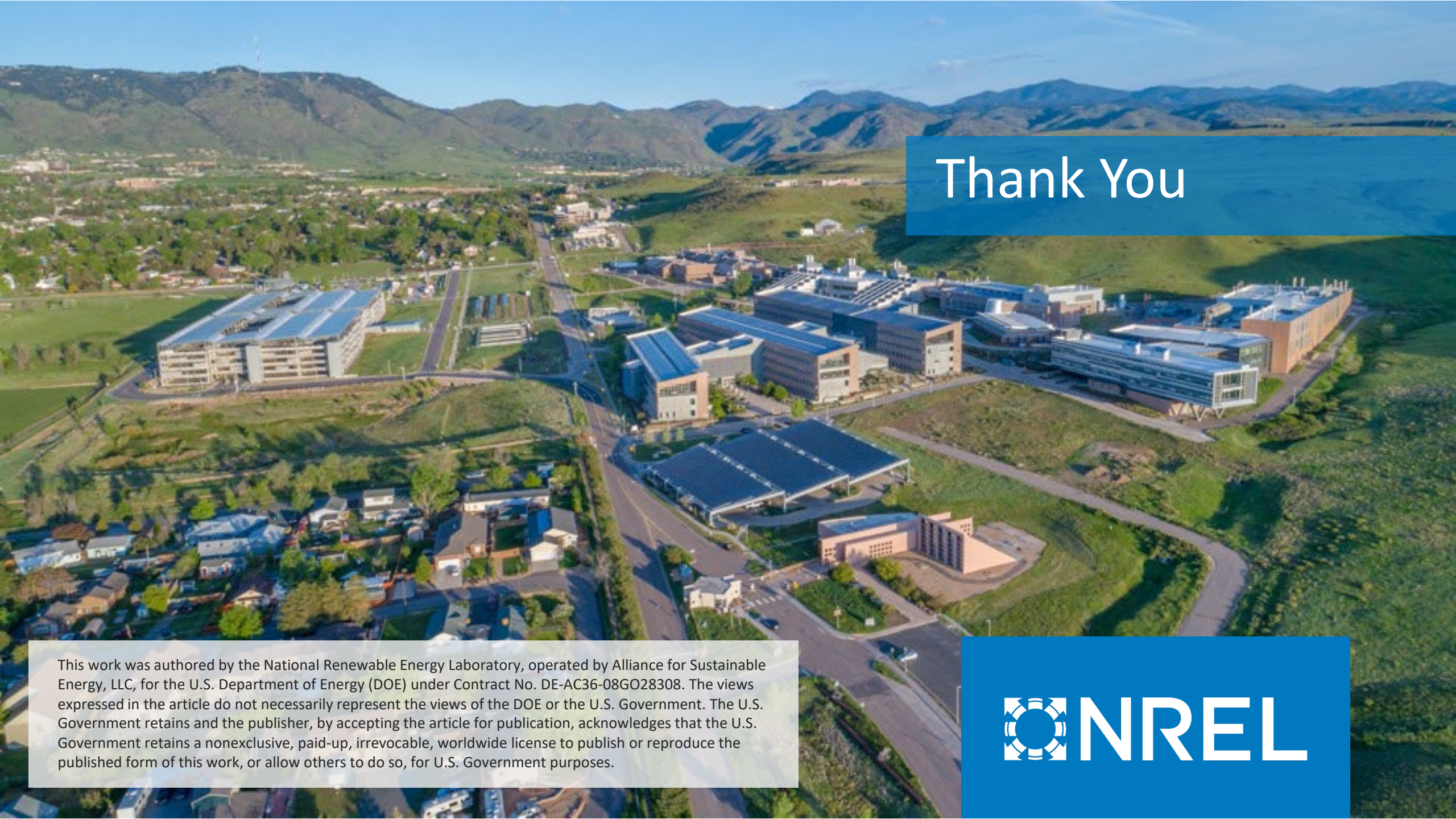
Heat provided with stored thermal energy:

- Always meets heating load, but can operate electric heat pump based on rate structure



Progress and next steps

- 2025/2026: Design of a heat pump DOAS, targeting ≥50% energy cost reduction. Partnering with DOAS manufacturers (funded)
- 2026: Proof-of-concept lab unit: Partner Blue Frontier fabricates and tests laboratory proof-of-concept prototype (partner funding likely)
- 2027/2028: Field Demo Units by DOAS OEMs: Commercial DOAS OEM partners build field demonstration units (not yet funded; looking for partners)



Thank You

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Closing

Open Discussion & Comments

Thank You!