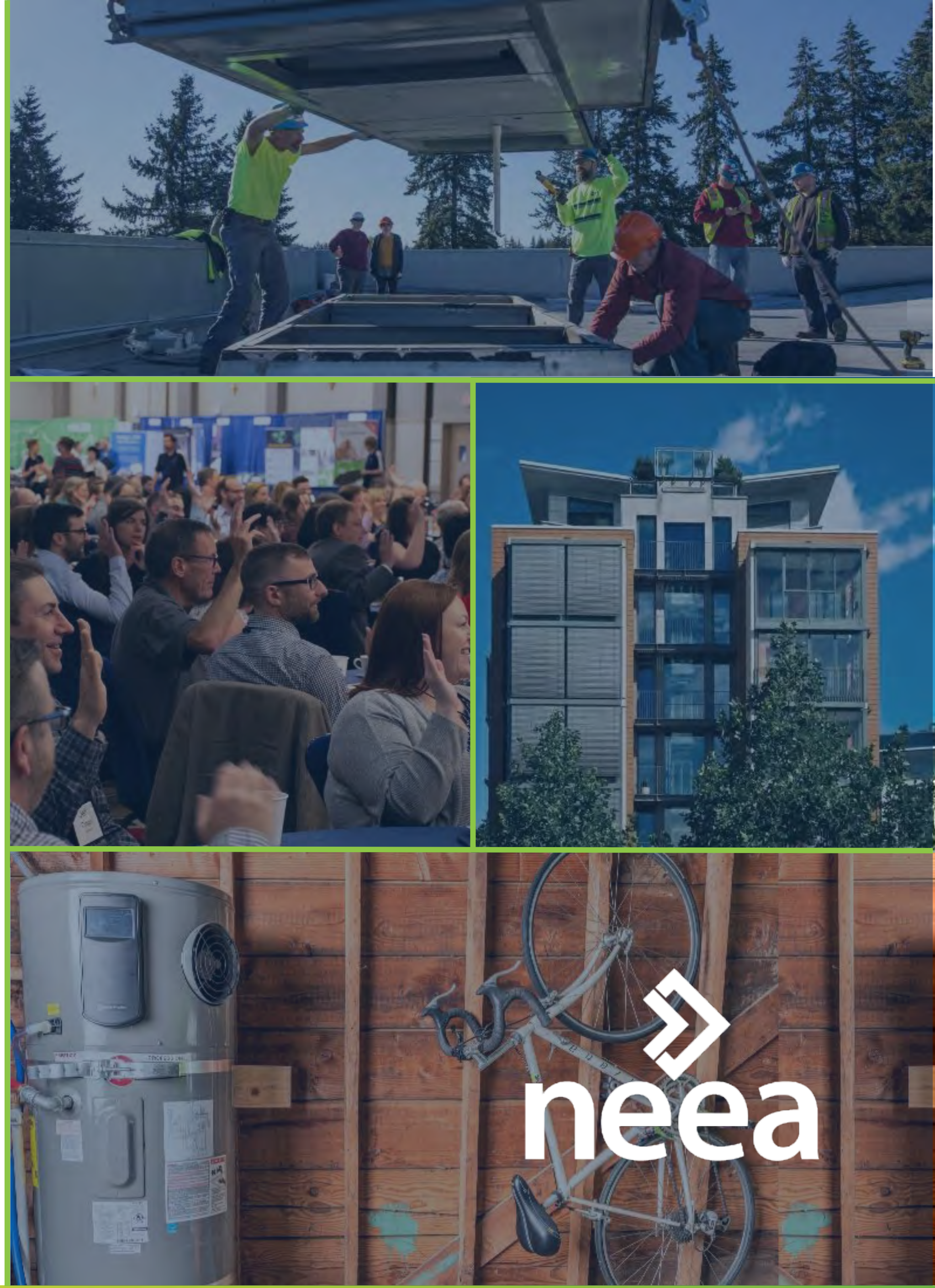
Regional Emerging Technology Advisory Committee (RETAC)

Northwest Energy Efficiency Alliance

Q2 2024 Meeting

June 27, 2024

8:30 a.m. – 1:00 p.m.

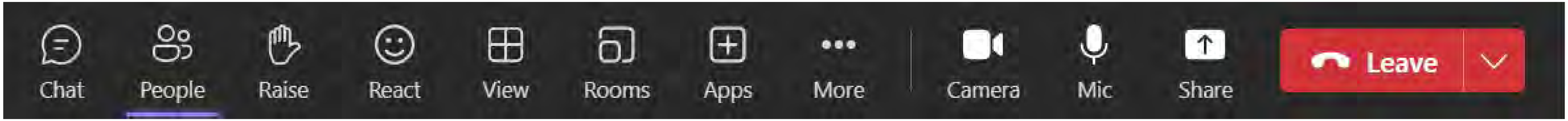


CLASSIFICATION LEVEL: PUBLIC

Navigating MS Teams Layout

Raise Hand

Camera & Microphone



Chat

Exit Call

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

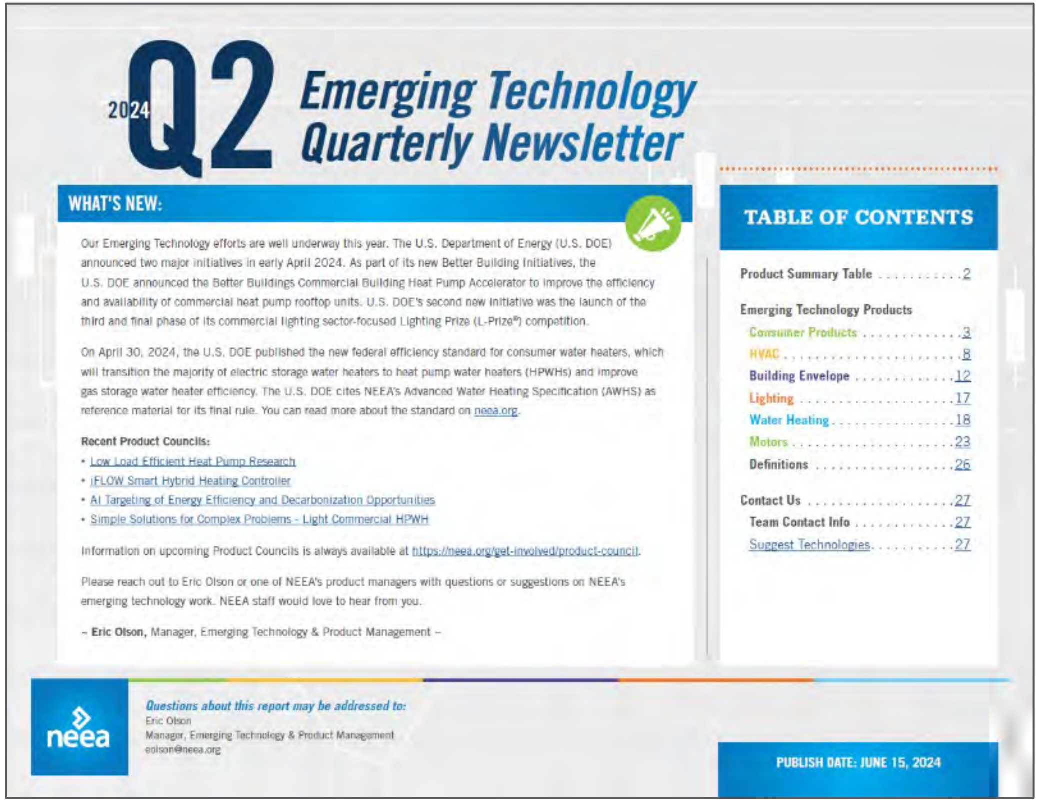
Name,
Title,
Organization
and …

When you were younger, what is one technology that you thought would be more widely adopted by now?

Agenda

8:30 am	Welcome and Announcements
9:00 am	*New!* ORNL Emerging Technology Update
10:30 am	*Break*
10:45 am	*New!* New Buildings Institute
11:45 am	*New!* Regional Room Heat Pump Field Study
12:00 pm	*Break*
12:15 pm	*New!* NW Power & Conservation Council
12:45 pm	Wrap-Up

Q2 2024 Emerging Tech Newsletter



2024 Q2 Emerging Technology Quarterly Newsletter

WHAT'S NEW:

Our Emerging Technology efforts are well underway this year. The U.S. Department of Energy (U.S. DOE) announced two major initiatives in early April 2024. As part of its new Better Building Initiatives, the U.S. DOE announced the Better Buildings Commercial Building Heat Pump Accelerator to improve the efficiency and availability of commercial heat pump rooftop units. U.S. DOE's second new initiative was the launch of the third and final phase of its commercial lighting sector-focused Lighting Prize (L-Prize®) competition.

On April 30, 2024, the U.S. DOE published the new federal efficiency standard for consumer water heaters, which will transition the majority of electric storage water heaters to heat pump water heaters (HPWHs) and improve gas storage water heater efficiency. The U.S. DOE cites NEEA's Advanced Water Heating Specification (AWHS) as reference material for its final rule. You can read more about the standard on neea.org.

Recent Product Councils:

- Low Load Efficient Heat Pump Research
- iFLOW Smart Hybrid Heating Controller
- AI Targeting of Energy Efficiency and Decarbonization Opportunities
- Simple Solutions for Complex Problems - Light Commercial HPWH

Information on upcoming Product Councils is always available at https://neea.org/get-involved/product-council.

Please reach out to Eric Olson or one of NEEA's product managers with questions or suggestions on NEEA's emerging technology work. NEEA staff would love to hear from you.

– Eric Olson, Manager, Emerging Technology & Product Management –

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neea

Questions about this report may be addressed to:
Eric Olson
Manager, Emerging Technology & Product Management
eolson@neea.org

PUBLISH DATE: JUNE 15, 2024

https://neea.org/resources-reports

- Selected Q2 Highlights
  - Recent Product Councils
    - Low Load Efficient Heat Pump Research
    - iFLOW Smart Hybrid Heating Controller
    - AI Targeting of EE and Decarb. Opportunities
    - Simple Solutions for Complex Problems – Light Commercial HPWH
  - U.S. DOE Published new efficiency standards for res. water heaters.

Other stuff we're doing…

- Nearing the end of testing of a Commercial Heat Pumps Dryer, the final report is expected in Q3.
- Final analysis on second regional laundry study is on-going. Final report also expected in Q3.
- Contracting is underway for testing RTUs with LLLC

2024 RETAC Meeting Dates

Q1	Thursday, March 28
Q2	Thursday, June 27
Q3	Wednesday, September 25
Q4	Thursday, December 12

 |

Conferences
Product Councils

Conferences

Past Conferences Conferences

- GTI Emerging Technology Program – April 2024
- Better Building, Better Plants Summit – April 2024
- Int'l Facility Management Assoc. OR and SW WA Symposium – April 2024
- Energy Solution Center Tech & Market Forum – April 2024
- LightSpec West – April 2024
- Utility Energy Forum – April 2024
- AEE West – May 2024
- Peak Load Management Conference – May 2024
- AIA Oregon Design Conference – May 2024
- Efficiency Exchange 2024 – May 2024
- Emerging Water Technology Symposium – May 2024
- IES DOE Research Symposium – May 2024
- Getting to Zero Forum – May 2024
- Association Society of Gas Engineers – June 2024
- CEE Summer Meeting – June 2024
- ASHRAE Summer Conference – June 2024
- Window and Door Manufacturers Association – June 2024

Conferences

Upcoming Conferences

- 2024 ACEEE Summer Study – August 2024
- IES 24 National Conference – August 2024
- Smart Buildings Exchange – August 2024
- BOMA Seattle – August 2024
- CEE Industry Partners Meeting – September 2024
- ENERGY STAR Partners Meeting – September 2024
- BOMA PNW Regional Conference – September 2024
- Street and Area Lighting Conference – September 2024

Q2 2024 Product Council Presentations

Presenter	Topic	Date Scheduled	Webinar Recording
Christopher Dymond with Cadeo Group	Low Load Efficient Heat Pump Research	4/2/2024	Northwest Energy Efficiency Alliance (NEEA) | Low Load Efficient Heat…
iFLOW	iFLOW Smart Hybrid Heating Controller	4/30/2024	Northwest Energy Efficiency Alliance (NEEA) | iFLOW Smart Hybrid…
Plentiful:ai	AI Targeting of Energy Efficiency & Decarbonization Opportunities	5/21/2024	Northwest Energy Efficiency Alliance (NEEA) | AI Targeting of Energy…
Cadeo Group	Simple Solutions for Complex Problems: Light Commercial HPWH	6/4/2024	Northwest Energy Efficiency Alliance (NEEA) | Simple Solutions for…
University of Oregon	Forest to Façade: Commercial Seismic, Daylighting, and Energy Retrofits	6/25/2024	Materials available soon!

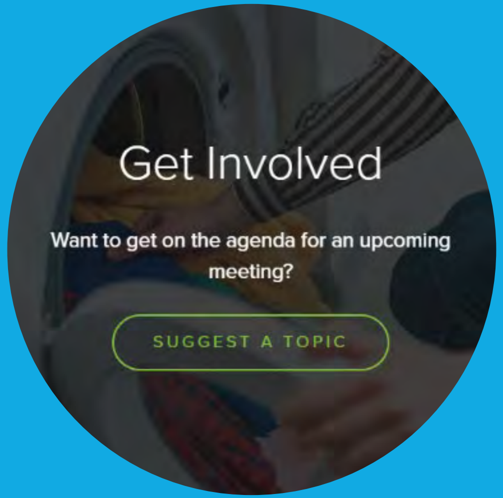
Have an idea for a Product Council?

Product Council is a great forum to:

- Share research & results from studies or field tests;
- Introduce technology or concepts that support the region's efficiency goals; or
- Solicit feedback on upcoming projects.

We have plenty of availability in Q3 & Q4, so let us hear from you!

Email productcouncil@neea.org or submit a request at neea.org/get-involved/product-council



ORNL Emerging Technology Update

ORNL Buildings Technologies Research Overviews

Kyle Gluesenkamp, Helia Zandi, Diana Hun, Bo Shen, Steve Kowalski, Brian Fricke

Oak Ridge National Laboratory

June 27, 2024

NEEA Q2 Regional Emerging Technology Advisory Committee Meeting

ORNL is managed by UT-Battelle LLC for the US Department of Energy

Agenda

5 min	• ORNL overview
10	• Thermal storage (**Kyle Gluesenkamp**)
15	• Smart connected neighborhood (**Helia Zandi**)
15	• Building envelope technologies (**Diana Hun**)
15	• Cold climate heat pump development (**Bo Shen**)
15	• High temperature heat pumps (**Steve Kowalski**)
15	• Low GWP refrigerants overview (**Brian Fricke**)
	• Wrap up

Agenda from Q1 meeting, March 2024

- ORNL history
- Overview of current Buildings research at ORNL
- Specific projects
  - Thermal storage integrated with heat pump
  - Dual fuel heat pump
- Collaboration mechanisms and brainstorming on joint opportunities
  - For next time:
    - Refrigerants
    - Envelope technologies
    - You name it!

I'll pause for discussion after each main agenda item

Oak Ridge National Laboratory

ORNL facts and figures

$2.7B
annual expenditures

~6,040
employees

$750M
modernization investment

Nation's most diverse energy portfolio

3,200
research guests annually

Nation's largest materials research portfolio

Forefront scientific computing facilities

World's most intense neutron source

World-class research reactor

2,511
journal articles published in FY21

Managing major DOE projects: US ITER, exascale computing

241
invention disclosures in FY21

52
patents issued in FY21

Building Technologies Research & Integration Center (BTRIC)

Demonstrating building energy efficiencies **since 1993**

60,000+ ft² of research space

Only DOE-designated user facility for building technologies

13 R&D100 AWARDS

125+ R&D PARTNERS

52 ACTIVE CRADAS

31 ASHRAE AWARDS

236 PUBLICATIONS

3,650+ VISITORS SINCE 2012

32 STRATEGIC PARTNERSHIPS

54 UNIVERSITY PARTNERS

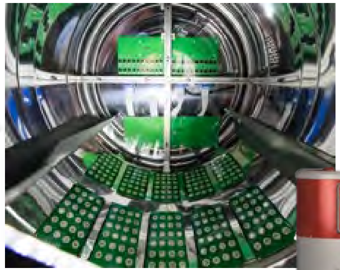
Deliver scientific discoveries and technical breakthroughs to accelerate building energy efficiency solutions

BUILDINGS-TO-GRID

- Low-cost wireless sensor technologies
- Transactive controls
- Power electronics
- Building energy models

HVAC&R AND APPLIANCES

- Develop affordable component and system technologies
- HVAC
- Water heating
- Refrigeration
- Appliances
- Energy storage



ENVELOPES

- Develop affordable technologies to address heat, air, and moisture flow
- Low-cost high R-value insulation
- Dynamic insulation
- Thermal energy storage
- Walls, roofs, attics, foundations, sheathings, membranes, coatings, and materials

INTEGRATION

- Performance characterization at the materials, component, system and whole-building levels
- Evaluate prototypes under realistic conditions
- Evaluate impacts of retrofit technologies

Grid-Interactive Efficient Buildings

OAK RIDGE National Laboratory

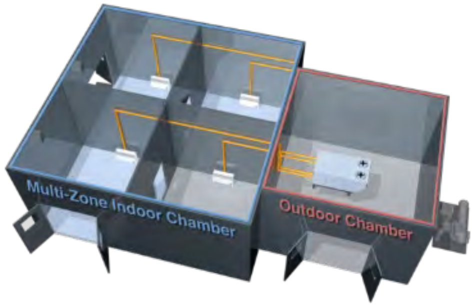
Equipment-related programs

- Equipment Research
  - Heating, Ventilation, and Air Conditioning (HVAC)
  - Water Heating
  - Refrigerants and Refrigeration
  - Hybrid Technologies
  - Modeling

- BEADS Research (Building Electric Appliances, Devices, and Systems)
  - Major electric appliances
  - Plug loads and miscellaneous electric loads
- TES Research (Thermal Energy Storage)
  - HVAC-integrated and envelope-integrated TES
  - PCM materials

Building Equipment Infrastructure

- 60,000 sq. ft. research footprint
- Multiple **environmental chambers**, capable of limited A2L and A3 quantities
  - Bldg 3170A: 8-ton, 20x40x18 ft, 2-room
  - Bldg 4020: 10-ton, 14x34x11 ft, 5-room
  - Bldg 5800: 20-ton, 40x20x14 ft, 2-room
  - Bldg 3144: 15-ton, 24x24x18 ft, 2-room (under construction)
  - Bldg 2500: 5-ton, 22x12x10 ft, 2-room (under construction)
  - Appliance: 3-ton, 7x7x8 ft, 1-room (under construction)
- Controlled field test sites (Yarnell Station house, two Flexible Research Platforms)
- Psychrometric sampling stations (ASHRAE 37-compliant)
- Air-side code testers (ASHRAE 37-compliant)
- Water conditioning systems (CFR UEF-compliant)
- Controlled refrigerant test loops
- Two compressor calorimeters





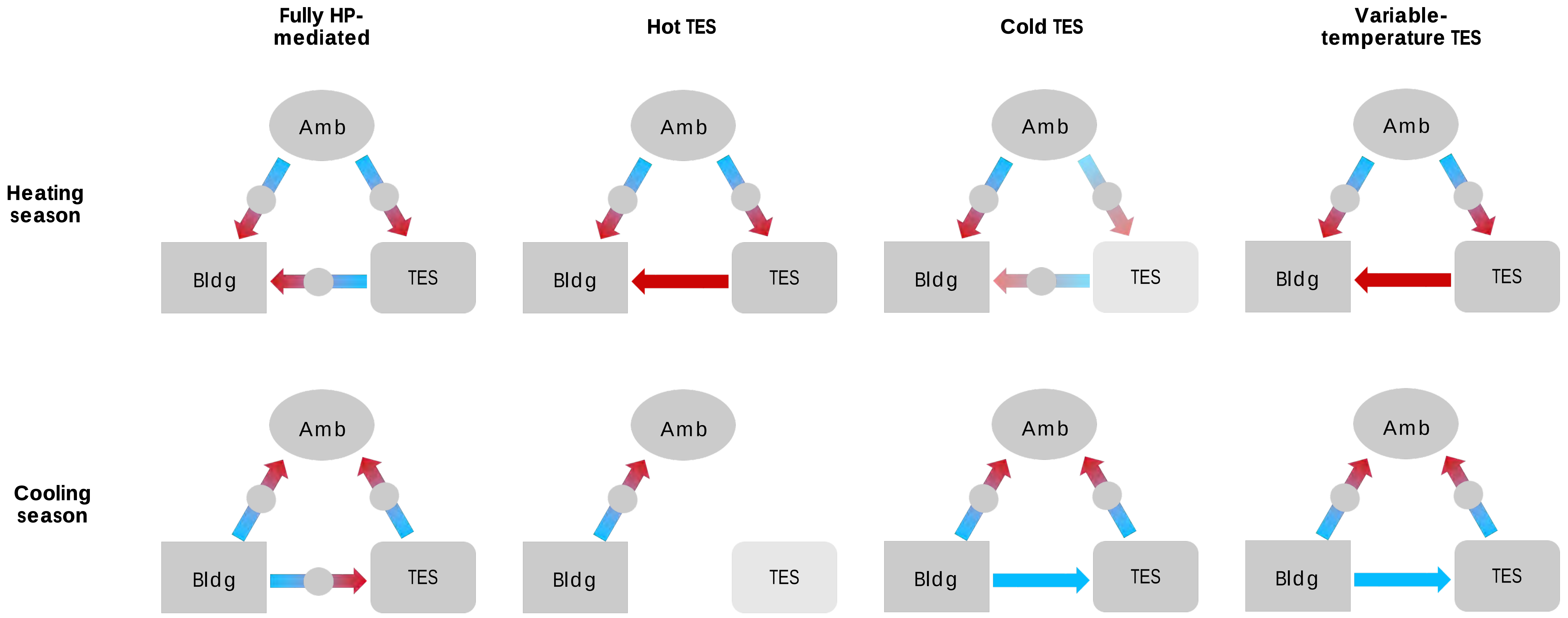




Thermal Storage in Appliances and Modular Equipment

- TES-integrated Heat Pumps
- Thermoelectric Dishwasher
- Desiccant Clothes Dryer
- GEB by ME

Thermodynamic options for TES-HP



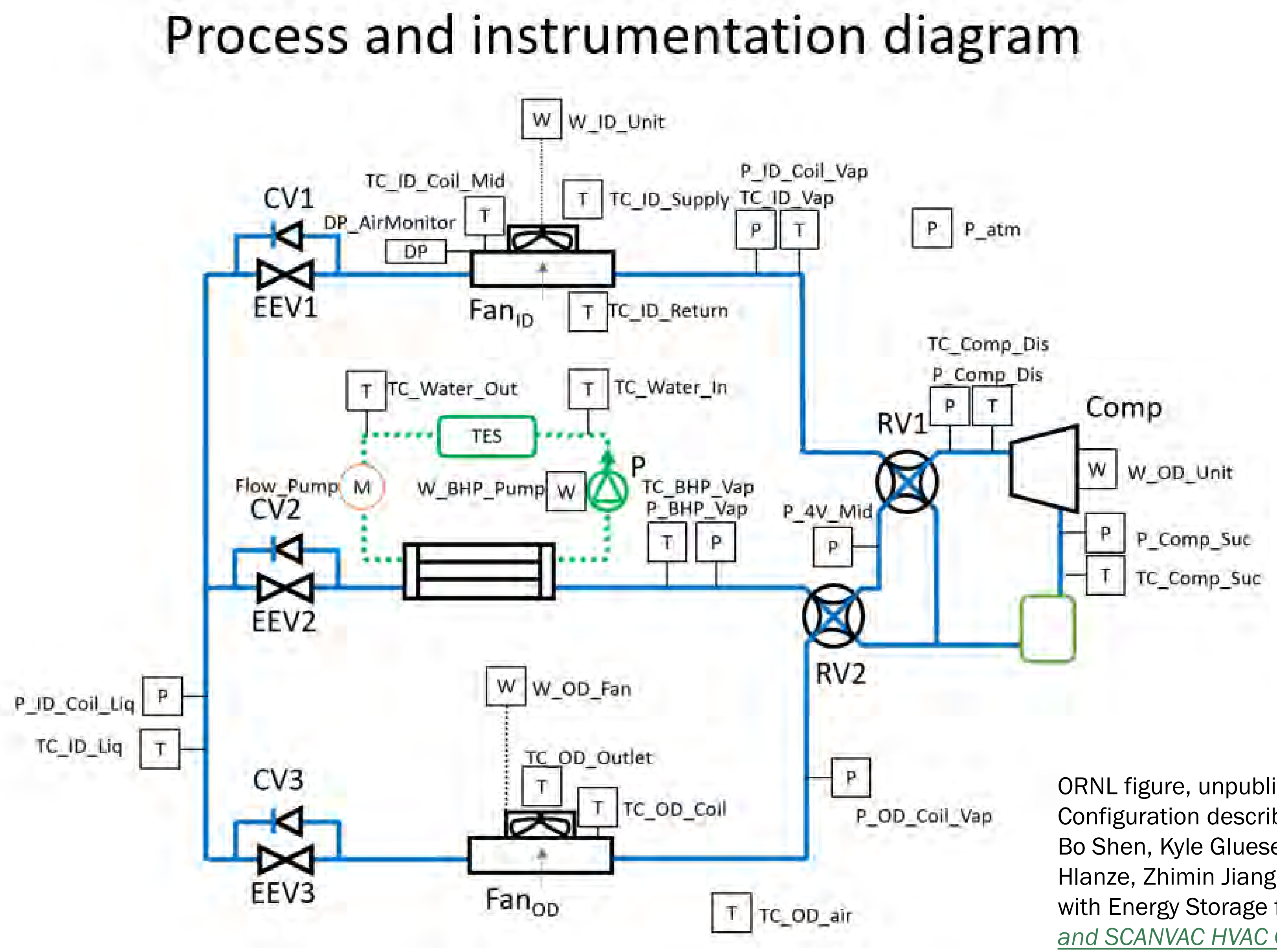
Useful winter and summer, but least demand reduction potential

Best winter demand reduction, but not useful in summer

Best summer demand reduction, but less useful in winter

Can be accomplished with sensible storage or two PCMs

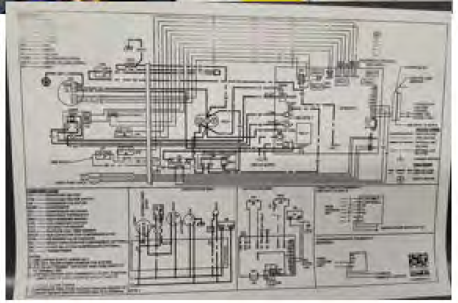
ORNL residential TES-HP prototype

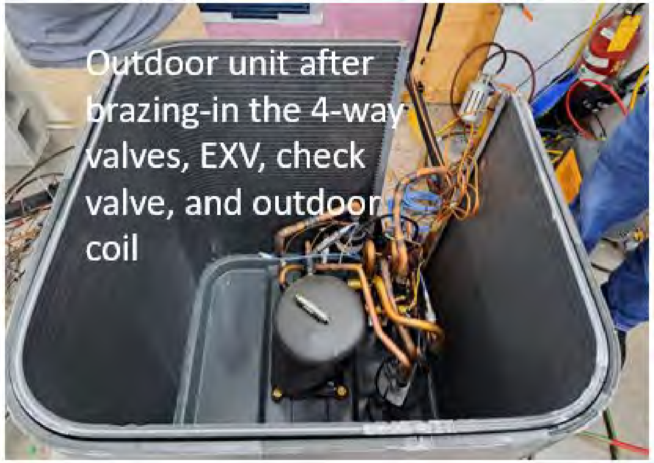


ORNL figure, unpublished.
Configuration described further in:
Bo Shen, Kyle Gluesenkamp, Zhenning Li, Jie Cai, Philani Hlanze, Zhimin Jiang "Cold Climate Integrated Heat Pump with Energy Storage for Grid-Responsive Control", *ASHRAE and SCANVAC HVAC Cold Climate Conference 2023*
Provisional Application 63/446,366

ORNL residential TES-HP prototype

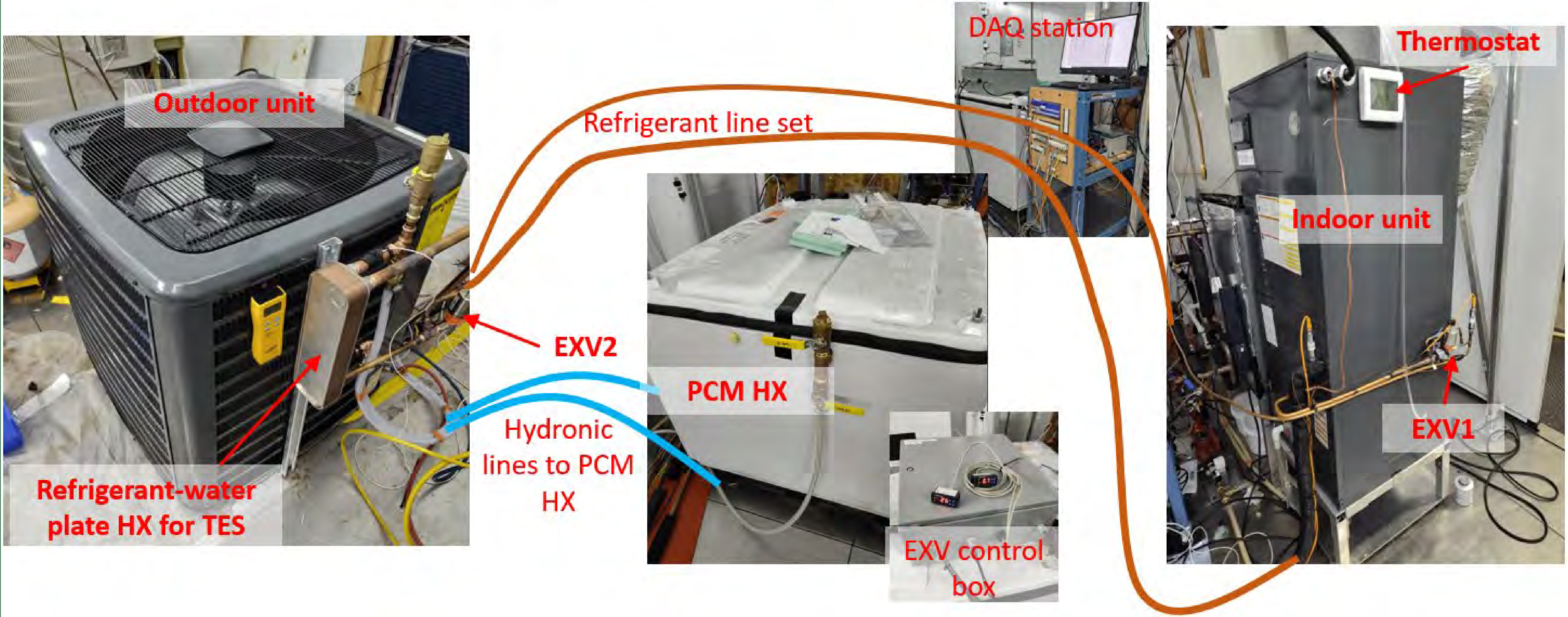
During modifications





ORNL residential TES-HP prototype

Complete system during shakedown operation



Appliances with thermal energy storage

Thermoelectric HP Dishwasher with Heat Recovery

Objective

- Develop pre-commercial thermoelectric (TE) heat pump dishwasher with heat recovery.
- Reduce energy consumption by 20% compared to conventional ENERGY STAR-rated resistance heater-based dishwasher.
- Improve drying performance by 60% compared to conventional ENERGY STAR-rated resistance heater-based dishwasher.

CRADA Partner: Samsung Electronics America, Inc.

common drying methods on the market today

This project →

	Drying speed	Dryness of plastic items	Energy consumption during drying phase	Impact on energy of whole cycle	Steam discharge
Passive method	Slow	Poor	0	Baseline	Okay
Heated dry method	Faster	Moderate?	High (800 W)	Bad	Okay
Door prop method	Faster	Poor	0	Neutral – maybe some efficiency gain	Bad
Fan method	Moderate	Poor	Low (10 W)	Neutral	Bad
TEDW goal	Fastest	Good? (TBD)	Moderate (200 W)	Improve efficiency via lower-T final rinse	Best (lowest)

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Desiccant Clothes Dryer with Heat Recovery

- Project status: awarded, establishing contracts
- ORNL, Samsung Electronics America, and the University of South Carolina will prepare a novel desiccant-based clothes dryer for commercial adoption.
- 120 V power facilitates replacing gas units.
- Energy storage capability enables drying operation on-peak with 75% less electricity consumption than conventional electric dryer, re-charging during off-peak times.

GEB by ME: Grid-interactive Efficient Buildings by Modular Equipment

GEB by ME: Novel Modular HVAC Product Ecosystem

New Modular *Product Ecosystem*

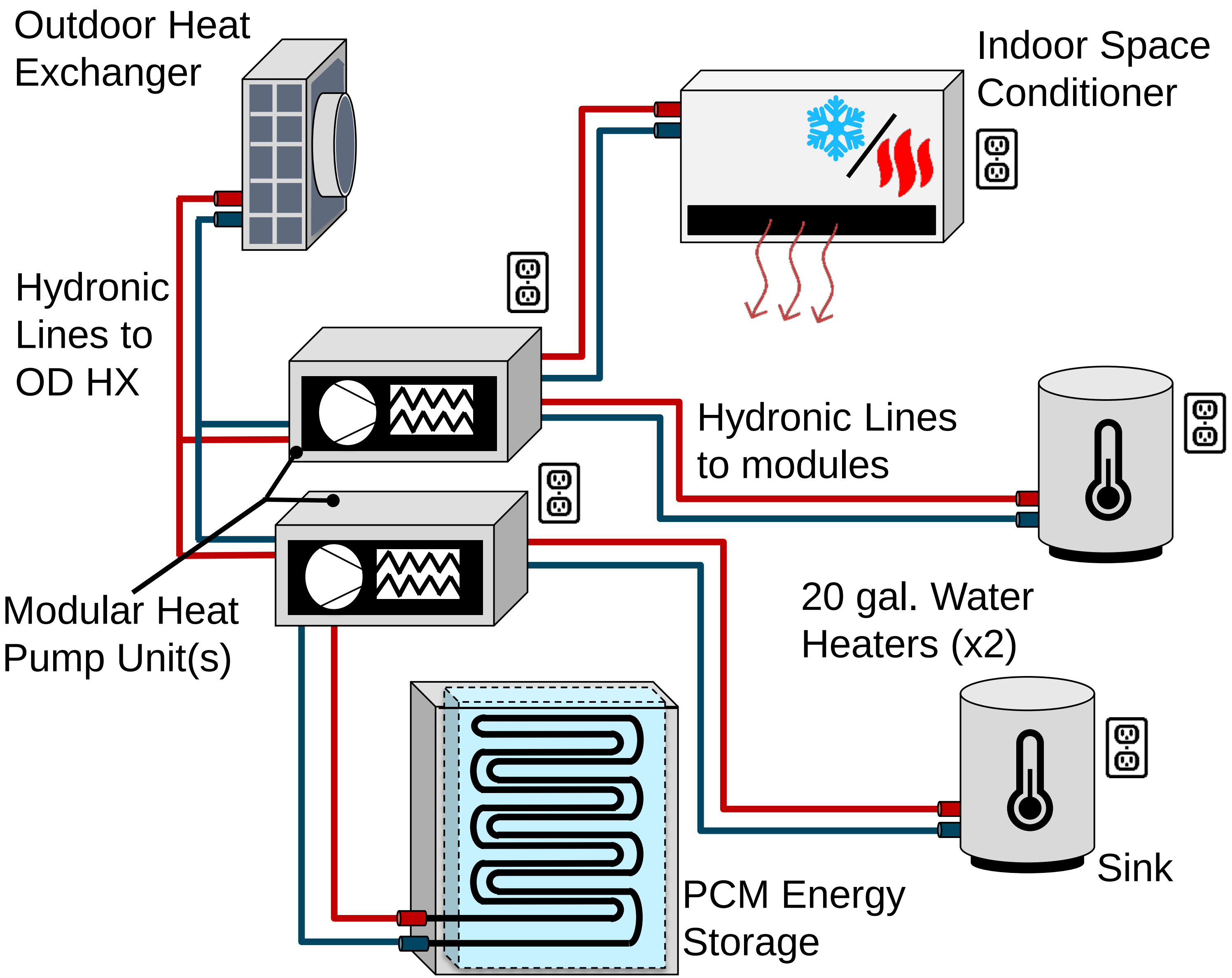
- Modular heat pump units create thermal energy interconnection
- Consumers can upgrade their HVAC system selectively without professional installation

Minimum Viable Product Set

- 1x Modular Heat Pump Unit
- 1x Outdoor Heat Exchanger
- 1x Indoor Unit (water heater or space conditioner)

Plug-and-play & Grab-and-go

- 120 V power source like other consumer products
- Hydronic connections between units allow for DIY assembly/disassembly



Approach

Water Heater Development

- Development and assembly of new modular 20-gal HPWH
- HPWH will be new technology; performance validation needed as Go/No-go milestone

Build Minimum Ecosystem

- Development and assembly of modular reversible heat pump and PCM storage
- Reversible heat pump is centerpiece of ecosystem, PCM storage is main load shifter
- Confirm sustained HPWH performance with heat pump and storage ecosystem

In-House Performance Testing

- Field demonstration of individual components in ORNL test home
- Field demonstration of final modular ecosystem in ORNL test home
- Development and validation of grid-responsive controls with ecosystem

Smart Connected Neighborhood

Helia Zandi, Ph.D.
R&D Staff
Computational Science and Engineering Division
zandih@ornl.gov

Motivation - Opportunity space

Facilities or large critical loads require microgrids to cost-effectively meet continuity of operations and resilience requirements	Potential to develop methods for managing on-site generation and load synergistically	Buildings have the potential to reduce their consumption by 20%-30% through advanced sensors and controls	Significant advantages in co-optimizing microgrid generation & neighborhood-scale consumption/residential loads	Significant need in scalable control and automation techniques for improving resilience and situational awareness

Source: Georgia Power

Reduce Energy Intensity and Increase Energy Efficiency

Increase Load Flexibility and Improve Grid Resiliency

5.5 million commercial, 118 million residential, projected to be 80% of load growth through 2040

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Southern Company Smart Neighborhood Initiatives

Understanding tomorrow's home today

Two first-of-a-kind smart home communities at the intersection of energy efficiency, distributed energy resources & buildings-to-grid integration and the traditional utility model

Georgia Power Smart Neighborhood™

- 46 townhomes
- Atlanta, Georgia
- Homeowner owned solar + storage
- Grid integration of solar, storage, HVAC, water heating & EV charging

Alabama Power SMART NEIGHBORHOOD®

- 62 single-family homes
- Birmingham, Alabama
- Utility owned, grid-connected microgrid
  - → 330 kW solar
  - → 680 kWh storage
  - → 400 kW NG generator
- Grid integration of microgrid, water heating & HVAC

Major Research Partners

Electric Power Research Institute and U.S. Department of Energy's Oak Ridge National Laboratory

Key Vendor Partners

LG Chem, Delta, Carrier, ecobee, Rheem, SkyCentrics, Flair, Vivint, Pulte Homes, Signature Homes

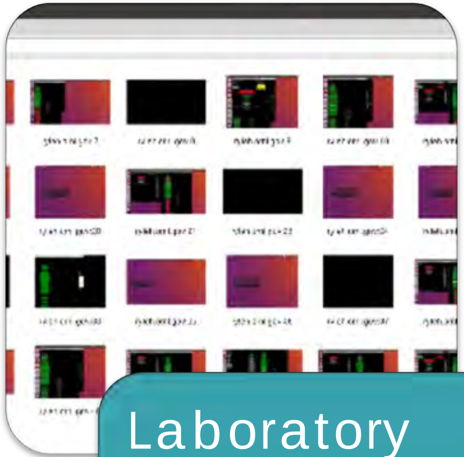
Key Results

Homes are 30-40% more efficient
EV makes up 15-20% of total usage
Successful microgrid islanding
New business opportunities deployed

Oak Ridge National Laboratory   Southern Company

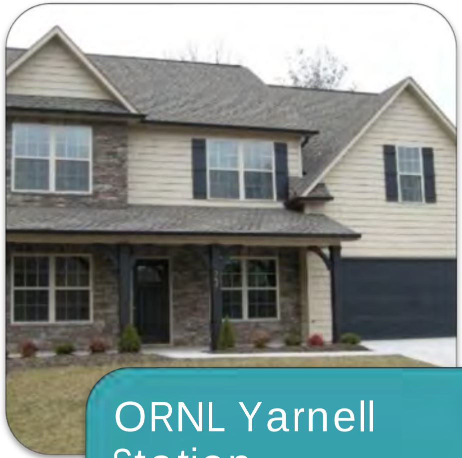
This work was funded by the U.S. Department of Energy, Energy Efficiency and Renewable Energy, Building Technology Office under contract number DE-AC05-00OR22725.

Phased Testing Approach



Laboratory

- Simulation-based Testing
- Software as Deployed



ORNL Yarnell Station

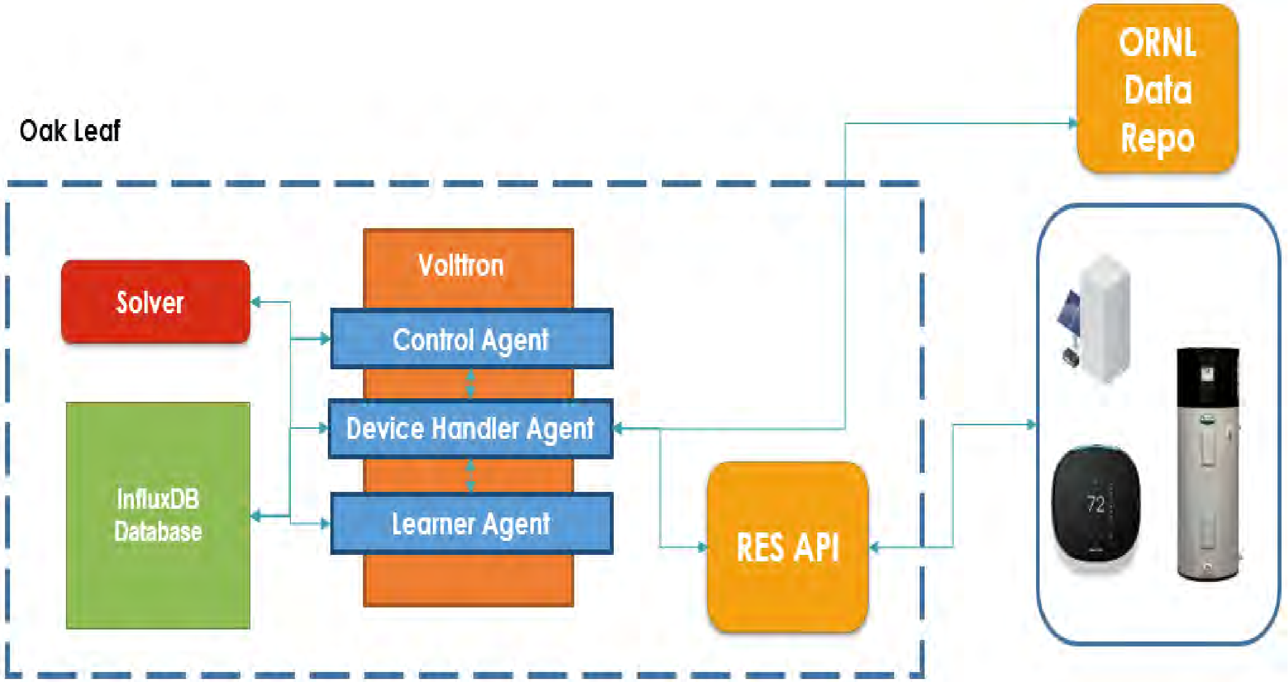
- Unoccupied Research Home in West Knoxville
- Development Testing

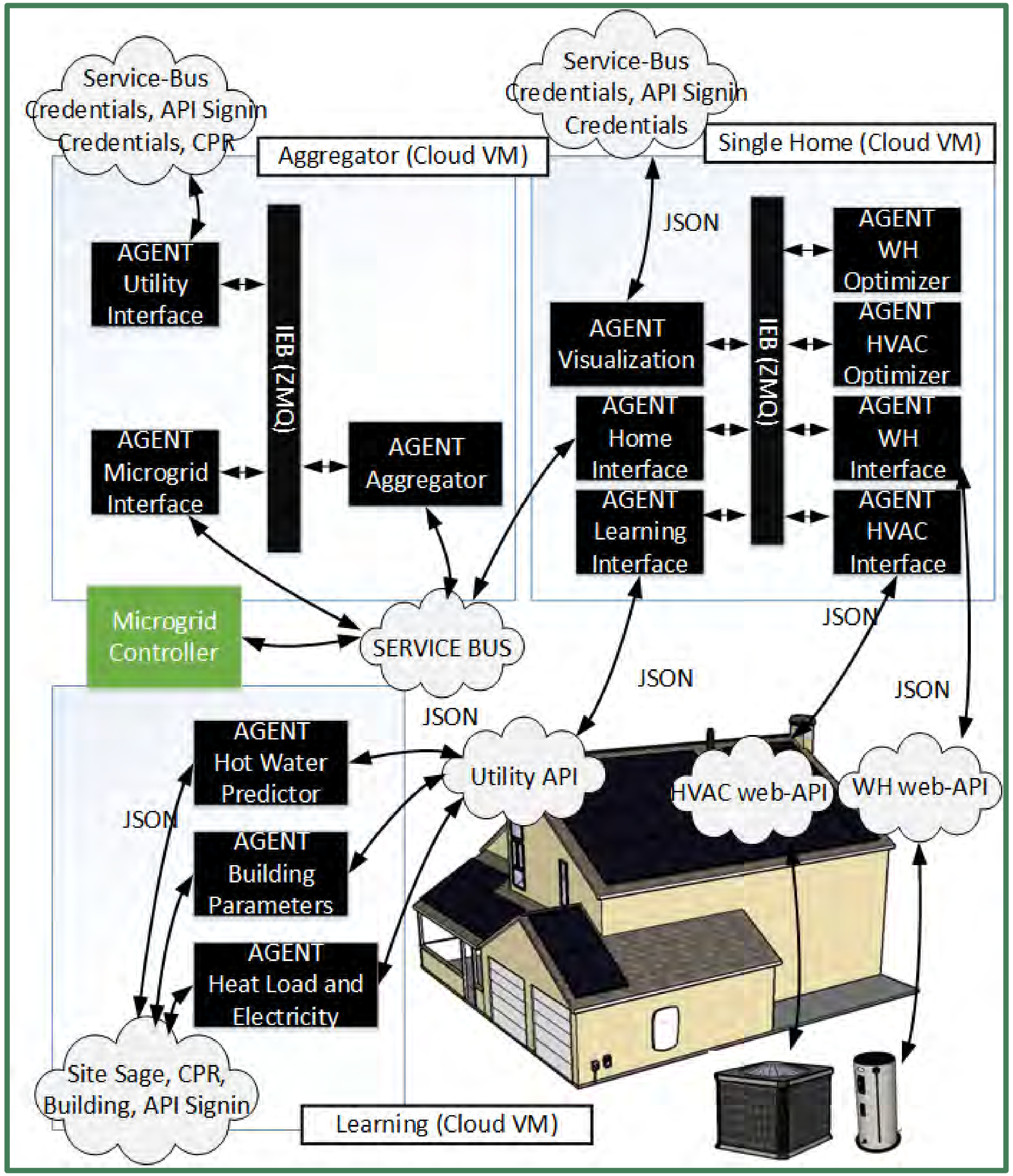
Southern Company Idea Home

- Southern Company Development Environment
- Unoccupied Research Home at Reynold's Landing
- User Acceptance Testing (UAT) Phase

Oak Ridge National Laboratory   Southern Company

Software Architecture





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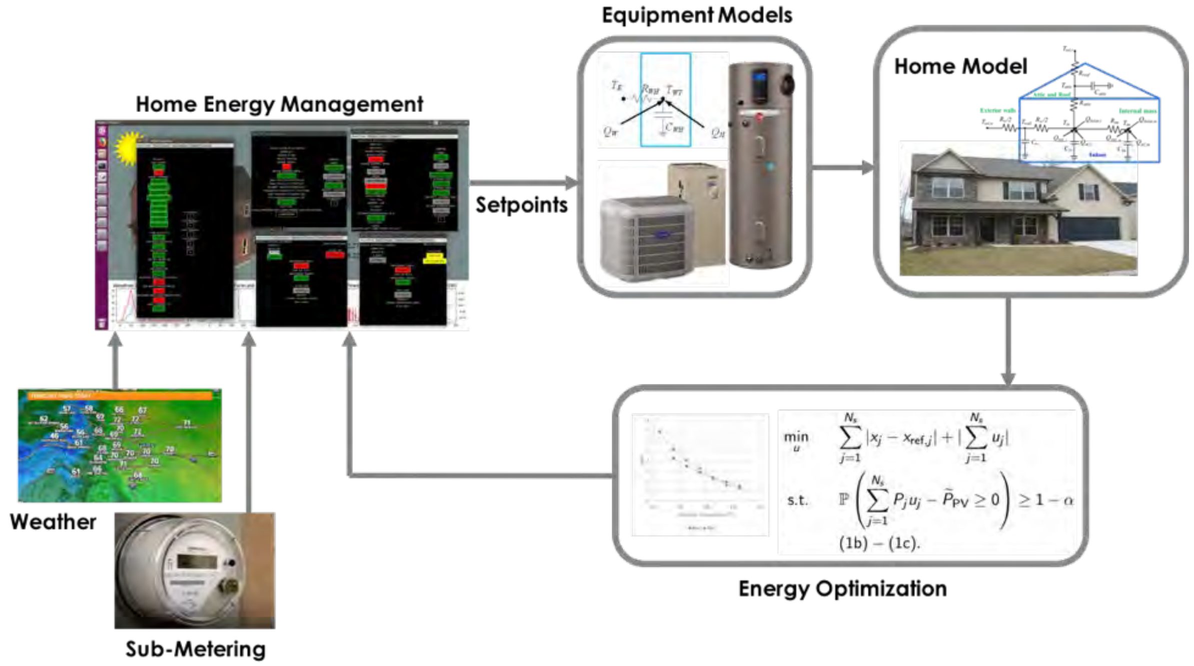
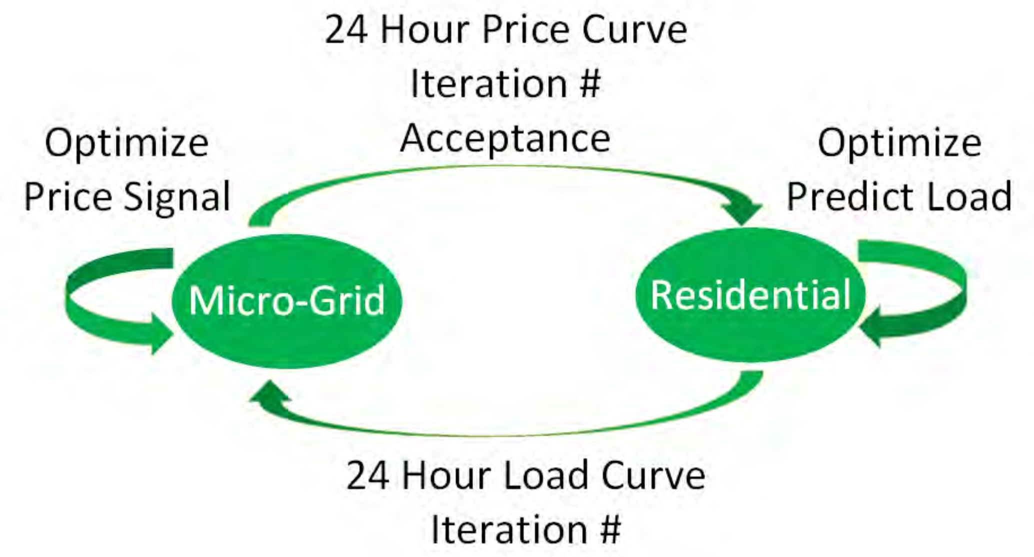
Neighborhood performing two-levels of optimization

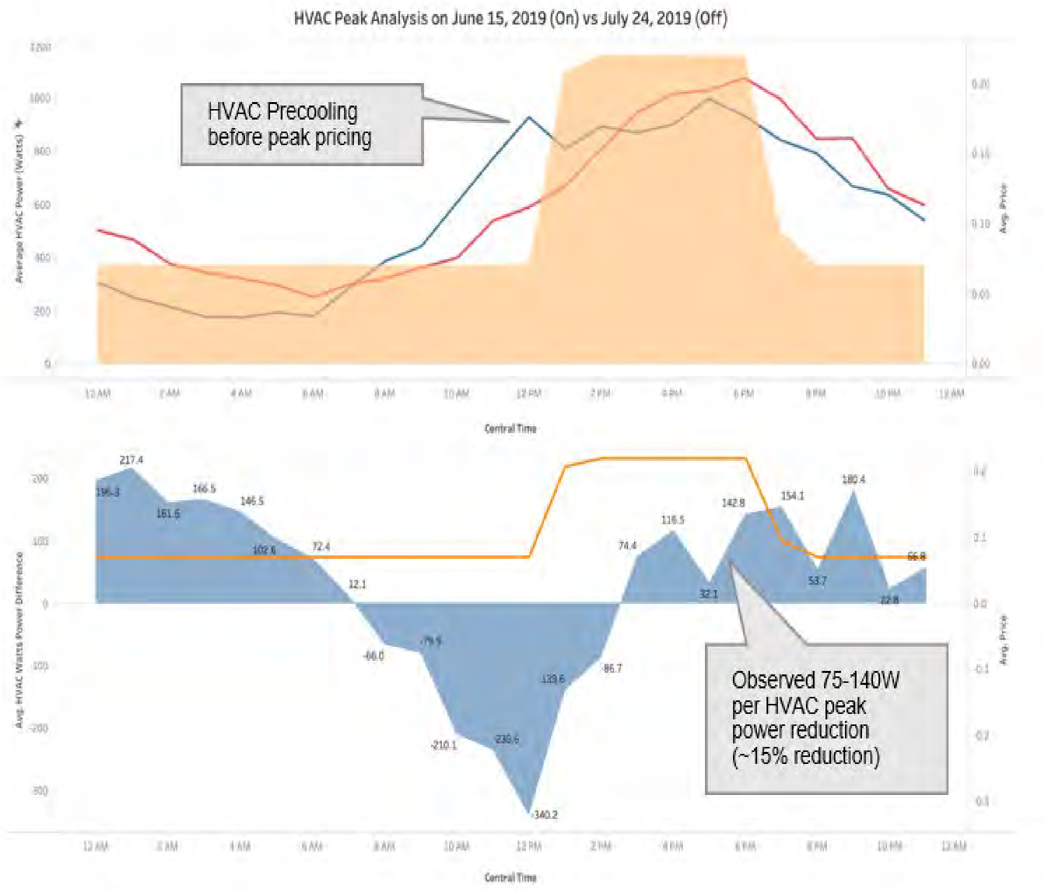
Residential-Level Optimization



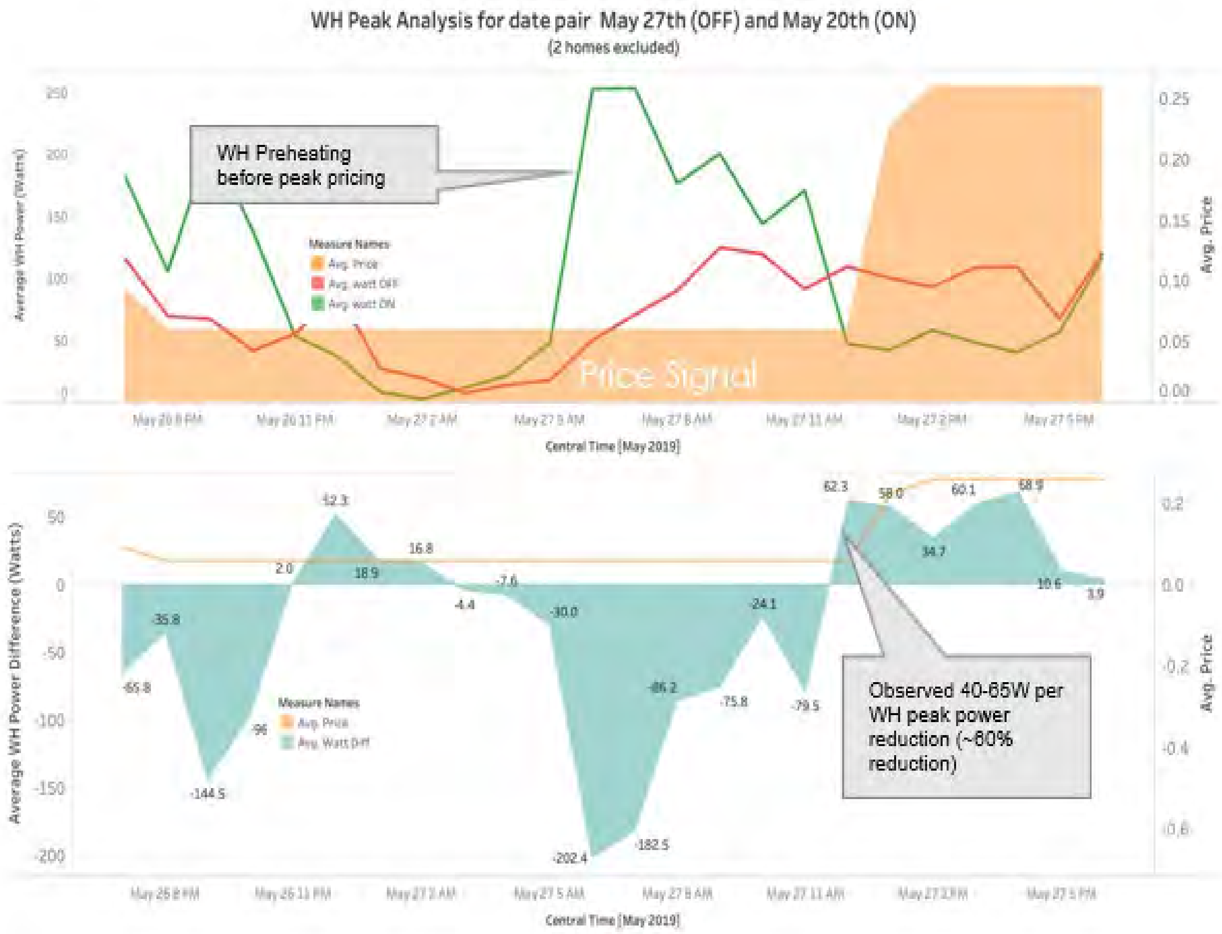
Neighborhood-Microgrid Optimization



HVAC Peak Analysis



WH Peak Analysis



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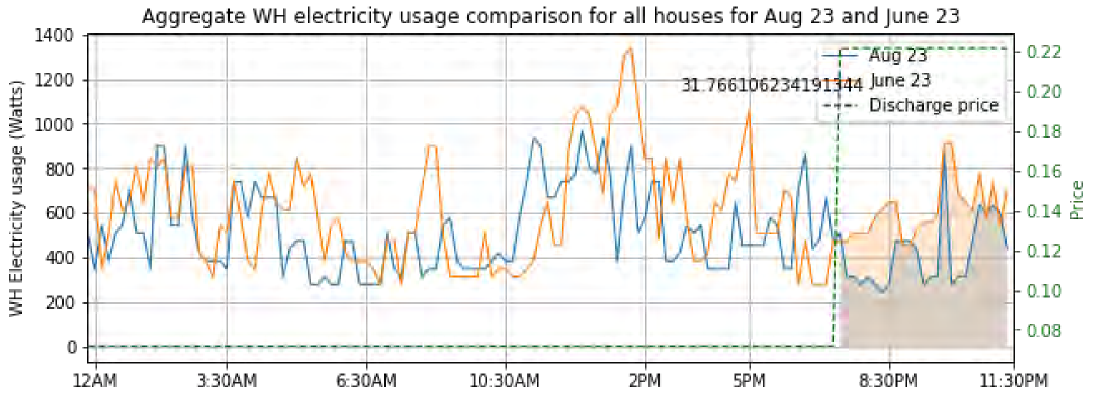
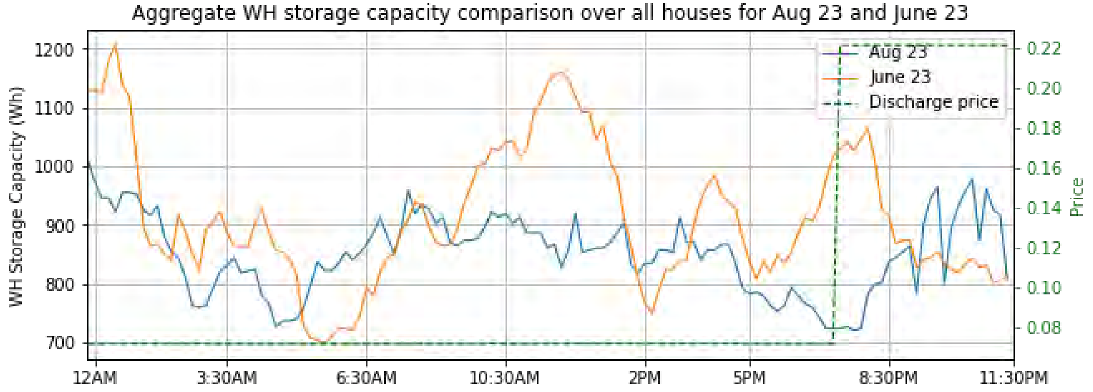
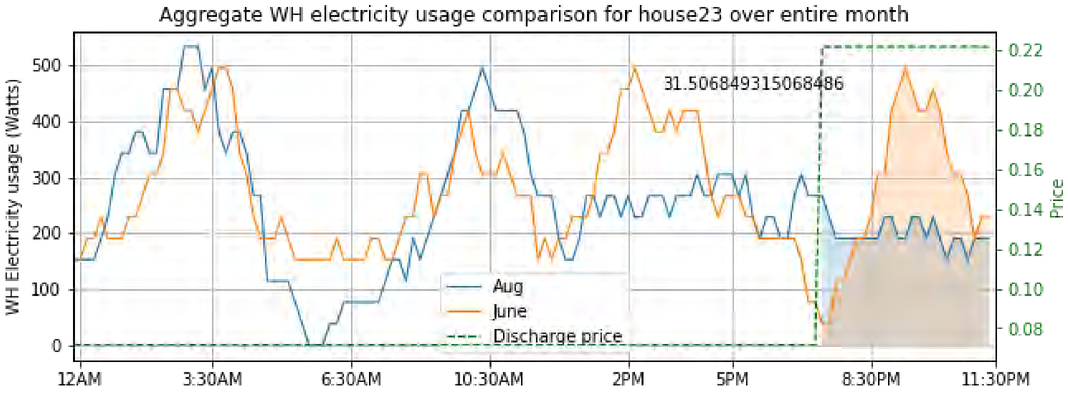
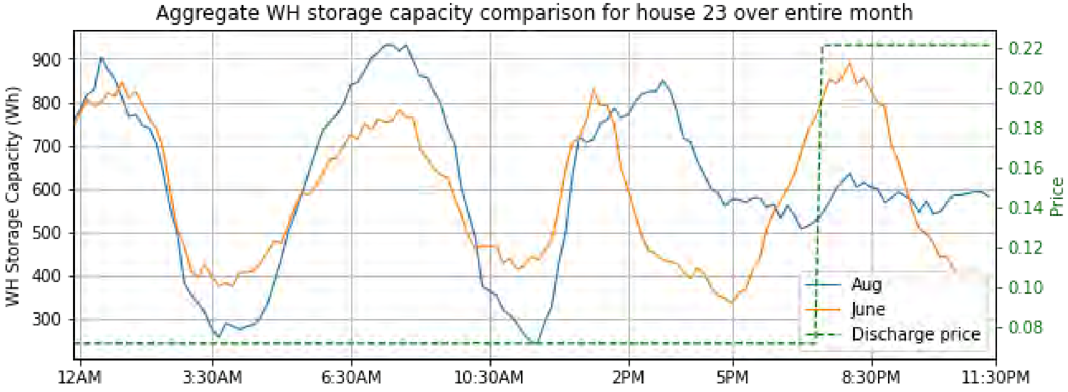
Water Heater – Summer month comparison

- Optimization dispatched – all weekdays in August 2023
- Aggregate plots – over the entire neighborhood





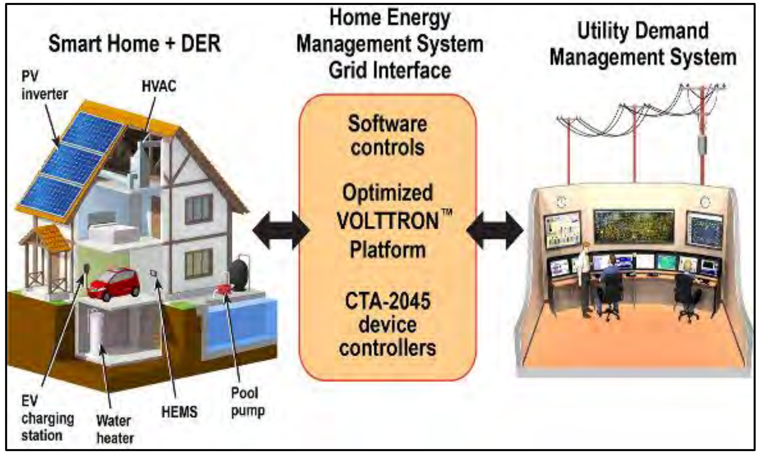




Control Deployment in Low-Income Multi-Family Housing

- **Objective**: Extend the core capabilities of Home Energy Management System to an application in a low-income MF housing community

- **Impact:**
  - Demonstrate how MF housing occupants can benefit from energy efficiency and incentives for participating in DR programs while simultaneously reducing the stress on local electric grids
  - Perform scale-up impact analysis of such a system based on measured data and simulated



Location: Murfreesboro, TN

Key Partners:
- o Oak Ridge National Laboratory
- o Tennessee Valley Authority
- o Middle Tennessee Electric
- o Murfreesboro Housing Authority
- o Ace IoT Solutions
- o Smartmark Communications

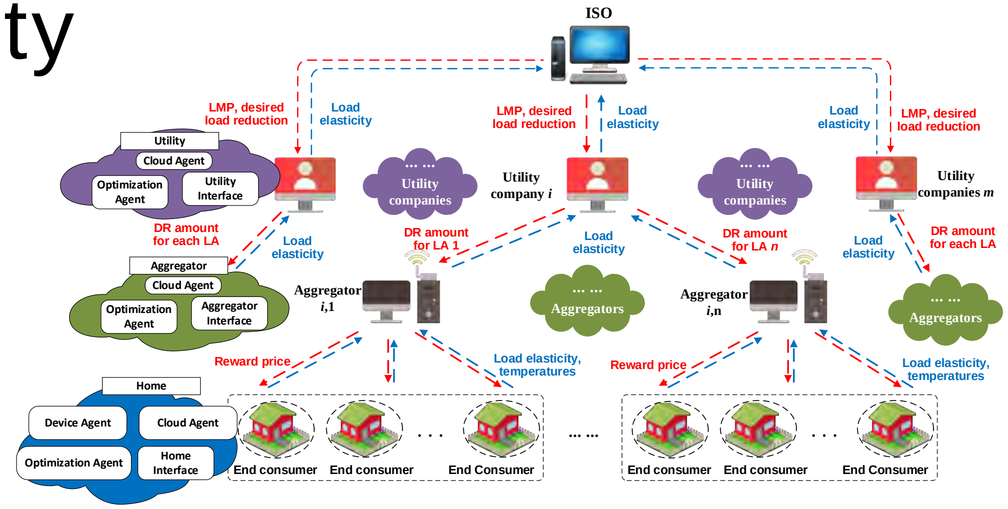
Connecting MHA, Source : https://www.tva.com/energy/technology-innovation/connected-communities/connected-communities-pilots/residential-demand-response-through-connected-mha

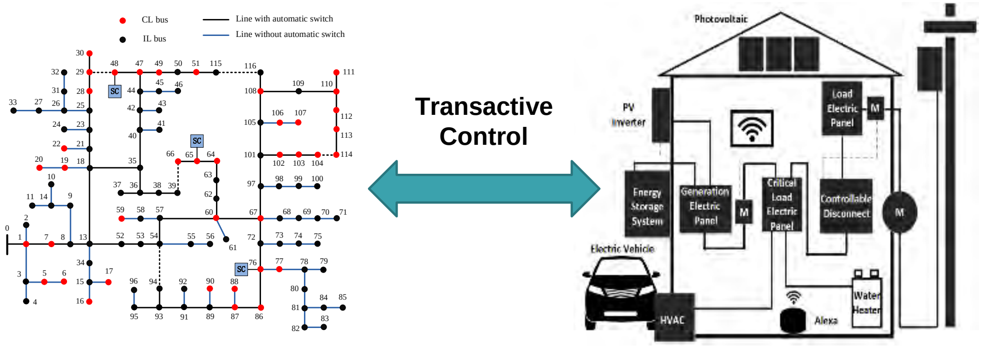
Oak Ridge National Laboratory

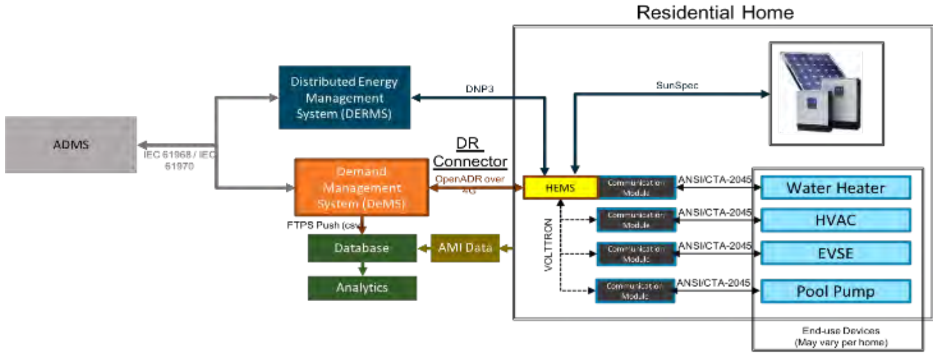
ORNL work was funded by the U.S. Department of Energy, Energy Efficiency and Renewable Energy, Building Technology Office under contract number DE-AC05-00OR22725.

Key Advances to Address Scalability

- **System Integration** – Overlay Architectures
  - Diverse set of requirements in these two domains
  - Integration – System of systems
- **Models -** Online learning-driven models
  - Characterize devices based on available sensor data
  - Forecast energy-use based on disturbances and constraints
- **Controls** - Grid-interactive Building Controls
  - Optimize resources for demand reduction and grid support
  - Coordinated control strategies for a large number of EVs to improve grid-Interactivity and resilience







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Thank you!

Helia Zandi
zandih@ornl.gov

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Overview of Building Envelopes Research

NEEA | June 27, 2024

Diana Hun, PhD, PE (inactive)
Group Leader | Building Envelope Materials Research
Subprogram Manager | Building Envelopes

ORNL is managed by UT-Battelle LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Building Envelopes Program

Develop and deploy
affordable and sustainable building envelopes
for new construction and retrofits
to enable DOE's decarbonization goals

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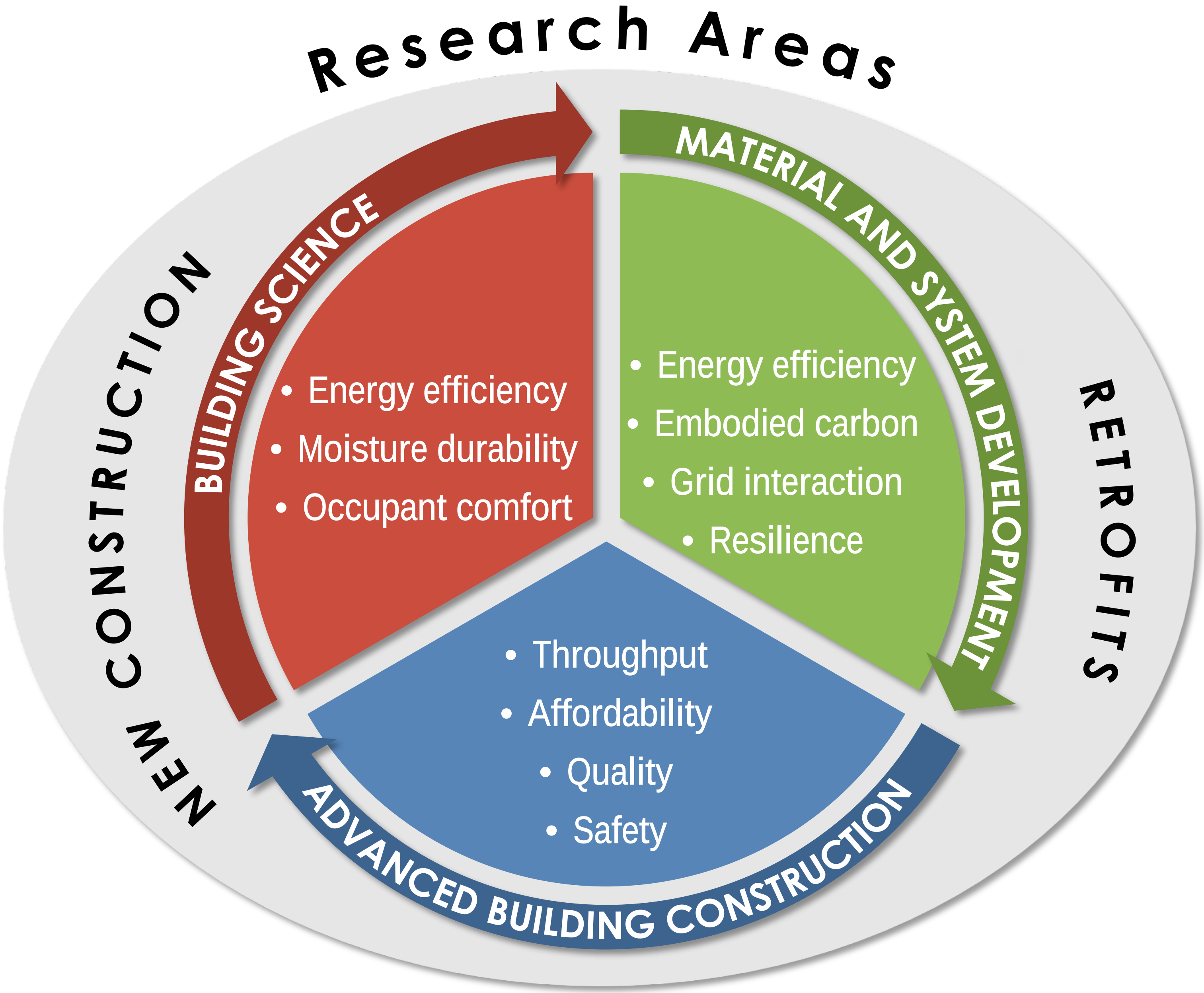

Research Areas
NEW CONSTRUCTION
BUILDING SCIENCE
• Energy efficiency
• Moisture durability
• Occupant comfort
MATERIAL AND SYSTEM DEVELOPMENT
• Energy efficiency
• Embodied carbon
• Grid interaction
• Resilience
RETROFITS
• Throughput
• Affordability
• Quality
• Safety
ADVANCED BUILDING CONSTRUCTION

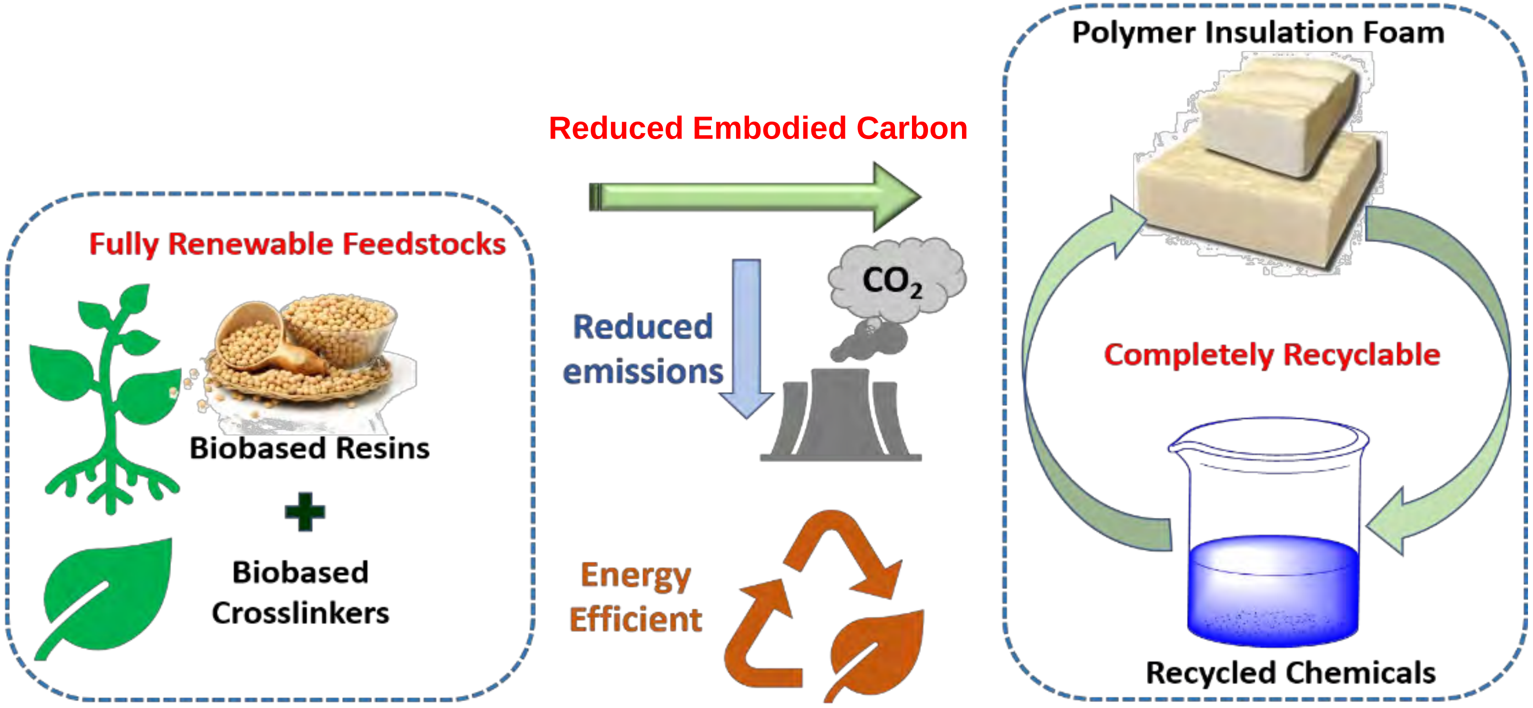
Low-Carbon Building Materials

Thermal Insulation

Non-Isocyanate, Low-Carbon, Biobased Foam Insulation

Goal: Improve safety and reduce embodied carbon of thermoset foam insulation

- Eliminate isocyanate from the formulation
- R-value ≥6/inch and meet common performance metrics
- ~50% lower embodied CO_2 than PU foam with low GWP blowing agents
- Recyclable through low energy thermal processes
- Patent application #63/461,646



Preliminary Prototype of Non-Isocyanate Biobased Foam Insulation

- ~85% biobased polymer content
  - Acrylated Epoxidized Soybean Oil
- Low GWP blowing agent
- Current: non-optimized ~R4.3/in
- Next steps
  - Increase R/in by reducing pore size, improving pore structure, and increasing porosity
  - Develop sprayable formulation

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Spray Foam Insulation

State of the Art

Automate Foam Installation

- **Goal:** Increase safety, improve quality, reduce waste, lower installation cost
- Autonomous spray foam installer
  - Autonomously locate and fill wall cavities using LIDAR and Vision systems
  - Omnidirectional base motion
  - Five-degree-of-freedom robotic foam installation system
  - Monitor substrate, environment, and spray temperature to optimize foam composition and improve quality and installation consistency
  - Monitor foam thickness to ensure adequate thickness without overfill

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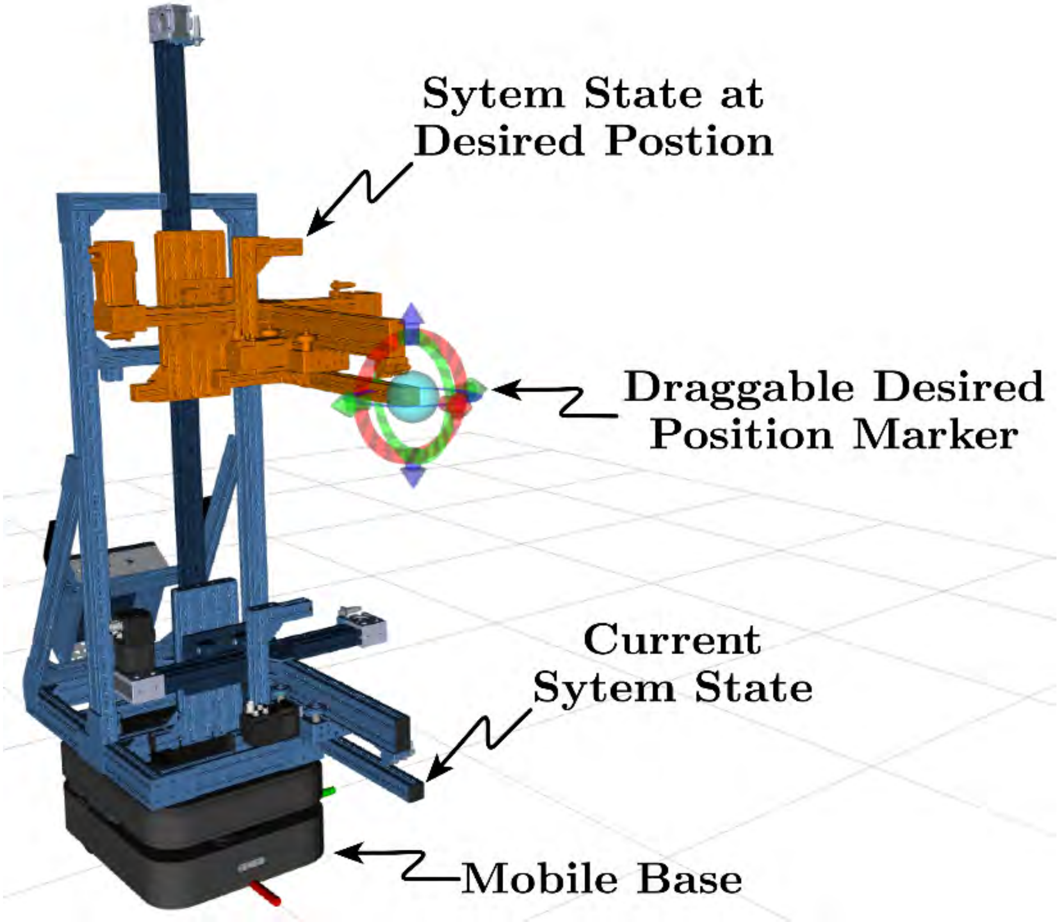
Autonomous Spray Foam Installer Concept



- Guarantee consistent quality and hence achieve the target R-values
- Reduce labor costs by 50%
- Improve installation safety
- Increase yield of installed foam by 10%
- Reduce overall cost by 20%

Autonomous Spray Foam Installer

Non-Isocyanate Spray Foam

Higher throughput

Lower embodied carbon

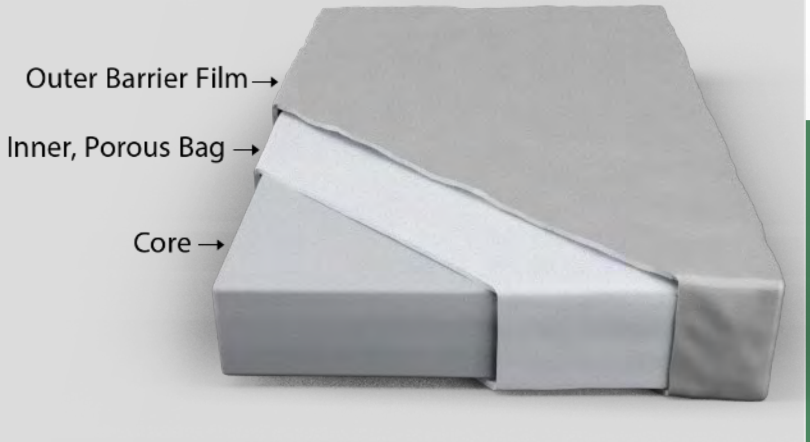
Lower cost

Higher quality

Non-toxic

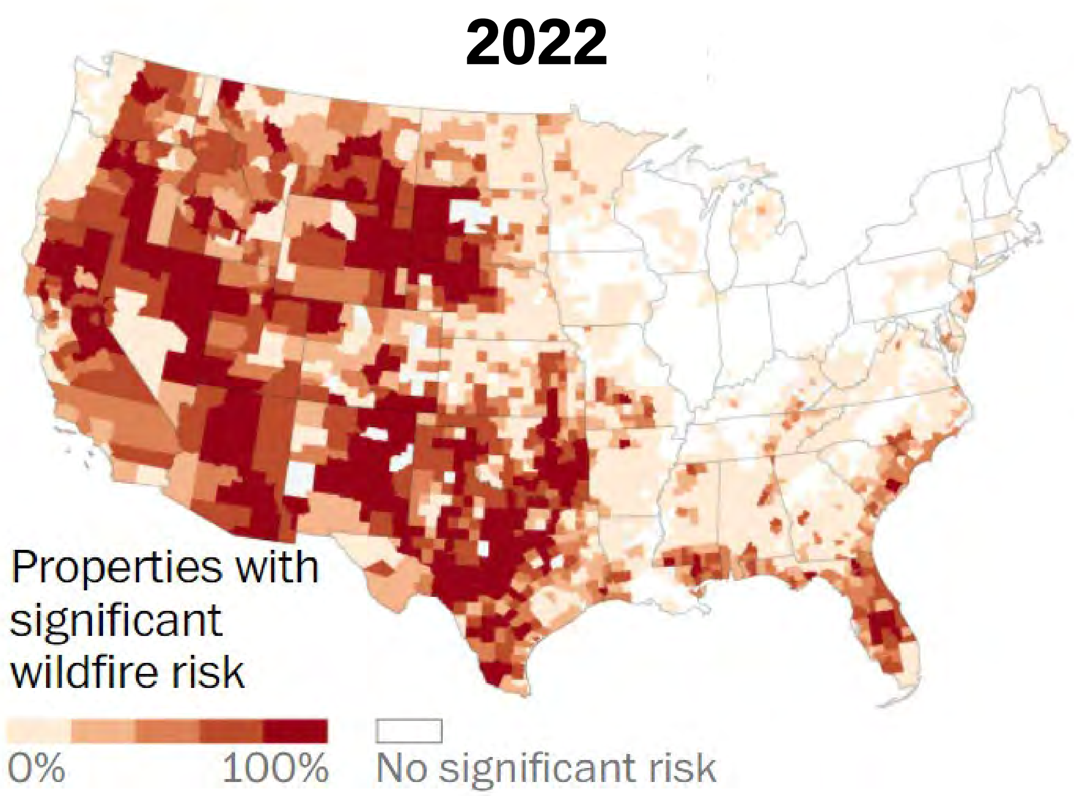
Low-Cost, Low-Carbon Cores for Vacuum Insulation Panels (VIPs)

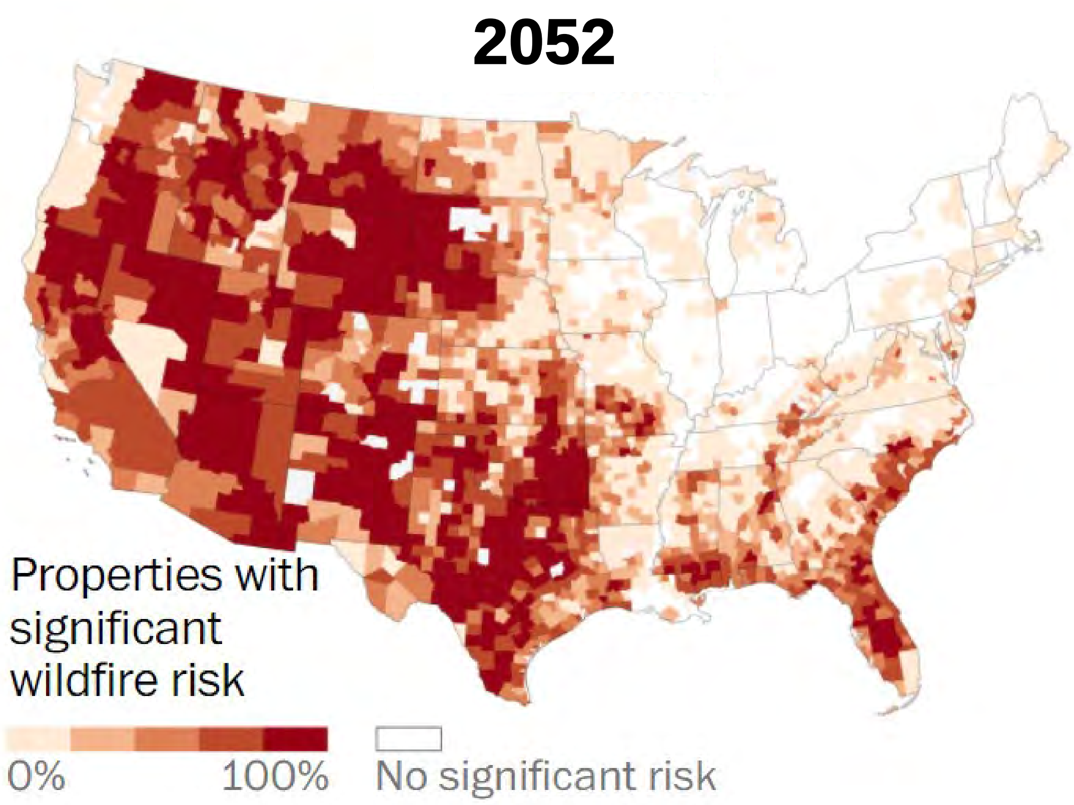
- **Goal:** Reduce cost and embodied carbon of VIPs
- Main cost and carbon contributor is the core material
- Alternatives to fumed silica and glass fibers
  - Natural fibers
  - Recycled glass fibers
  - Current results: reduce overall VIP cost by ~20%



Fire Resilience

Increases in Wildfire Risk



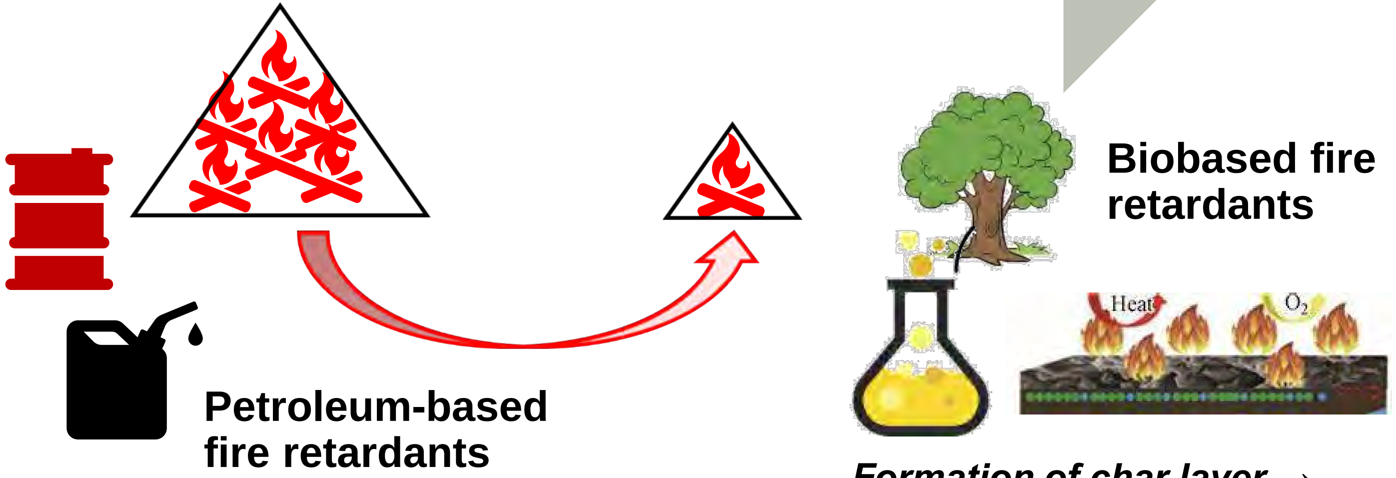


Low-Carbon, Fire Retardants with Lower Toxicity

Material Science + Cone Calorimeter

Approach

- Use biobased feedstock (resin)
- Functionalize with new moieties
- Reduce flame spreading of low-carbon building materials



Formation of char layer → prevention of flame spreading

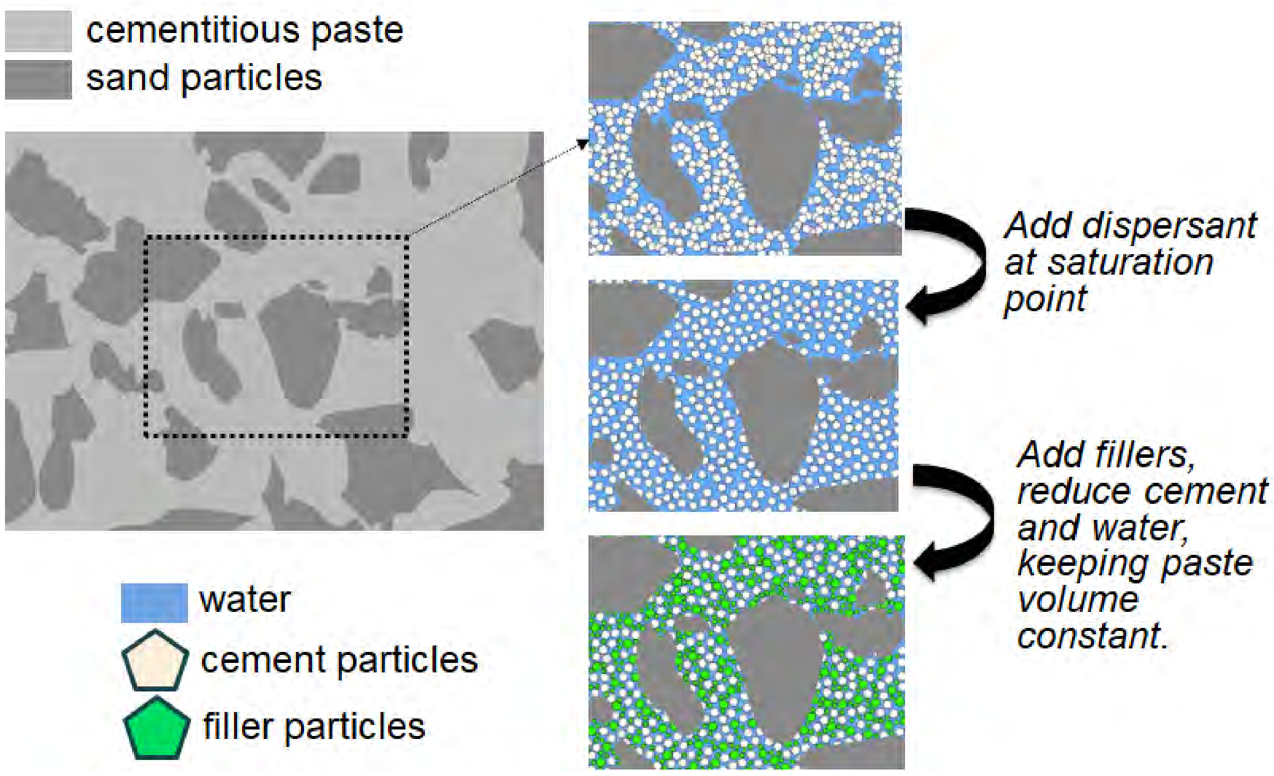
Formulations applicable to various building materials: foam and fibrous insulation, siding, and other materials

Concrete

High Filler, Low Water Concrete

Denise Silva, PhD

- Cement is responsible for ~8% of global anthropogenic CO_2
- **Goal:** reduce cement in concrete by >35%
  - Superior mechanical performance
  - Superior durability
  - Comparable cost
  - Minimal adjustments to current production practices
  - Minimal capital investment by producers



Latest Results

- Prototype mixes
  - Up to 50% lower embodied carbon
  - Meets mechanical property requirements for precast concrete
- Cost
  - ~10% increase because of current material cost volatility and premium price for finely ground limestone
  - Can be decreased with further optimization and supply chain adjustments for increased filler demand
- Upcoming large-scale trial at Gate Precast on 6/04/2024

Non-Destructive Diagnostic Tools

Air Leakage Through Building Envelopes

Problem

https://www.greenbuildingadvisor.com/article/measuring-natural-air-leakage

Energy penalty due to air leaks through the envelope

- ~4 Quads of energy per year
- ~4% of US primary energy

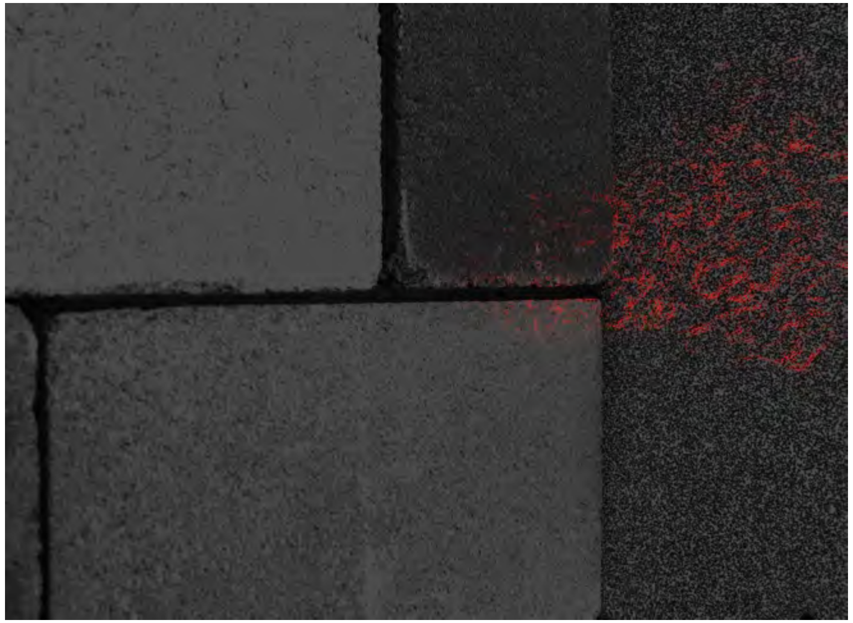
Locate leaks with a refraction-based detector

- Light refracted by air masses with density/temperature different than surrounding air
  - Scale of distortion depends on temperature differential

- Refraction-based air leak detector
  - Captures distortions for temperature differentials > ~2°C
  - Off-the-shelf cameras
  - Advanced software to process images, locate leaks, and quantify flow rate

Refraction-Based Air Leak Detector (ALD)

Proof of concept



Air leak detection using readily available cameras and advanced software

ALD in everybody's hands

Phone app will enable most homeowner to locate and seal air leaks and reduce their energy bill

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Discussion

Diana Hun, hunde@ornl.gov

ORNL Cold Climate Heat Pump Development

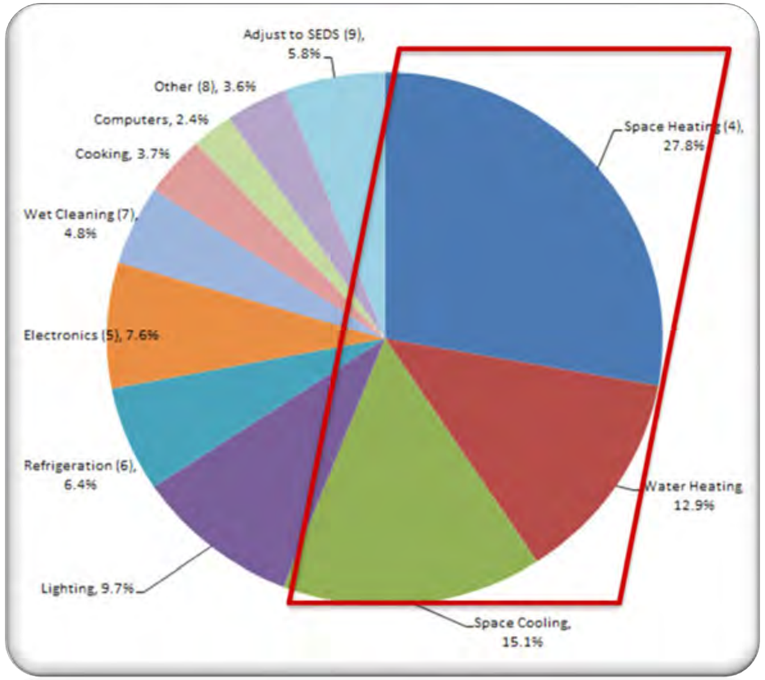
Bo Shen, Ed Vineyard

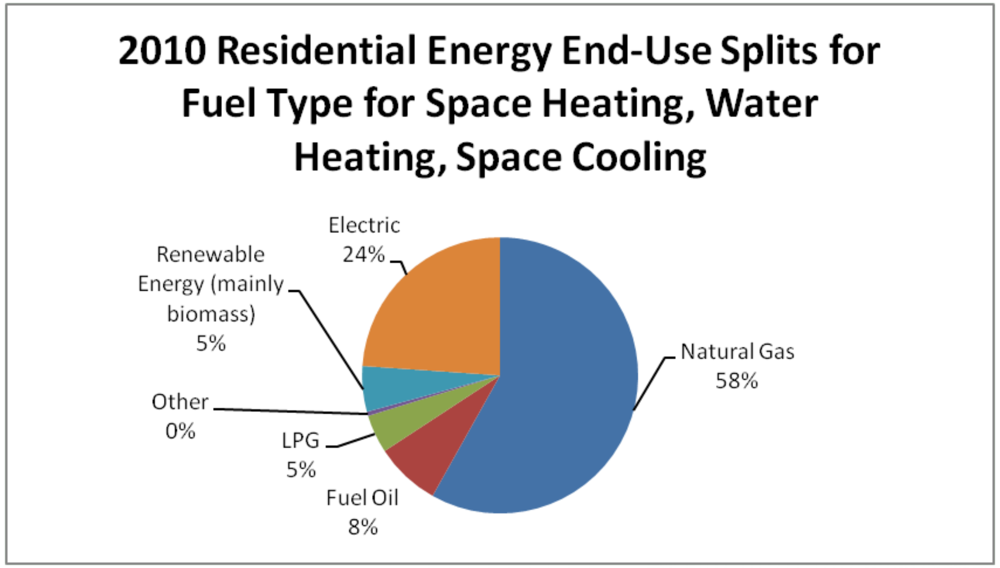
Content

1. Background
2. Three successful air-source cold climate heat pumps (DOE success story)
3. Summary

Background

- 2010 total consumption: 40.4 Quads
- Fossil fuel accounts > 58% heating

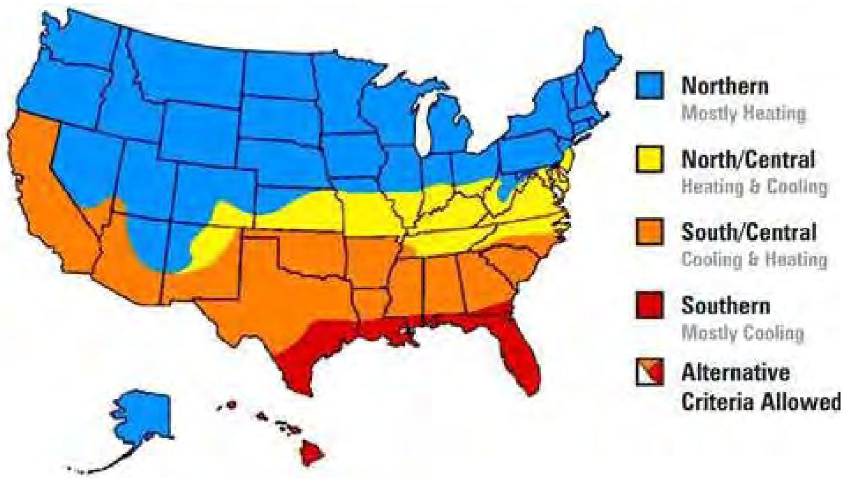




Current status of air-source heat pumps

Problem Statement:

- Typical ASHPs don't work well at low ambient temps due to very high discharge temp and pressure ratio
- Heating capacity not sufficient to match building load, if sized for cooling load.
- COP degrades significantly with ambient temperature



Target Market: Replace electric resistance heat and coal burning in cold climates.

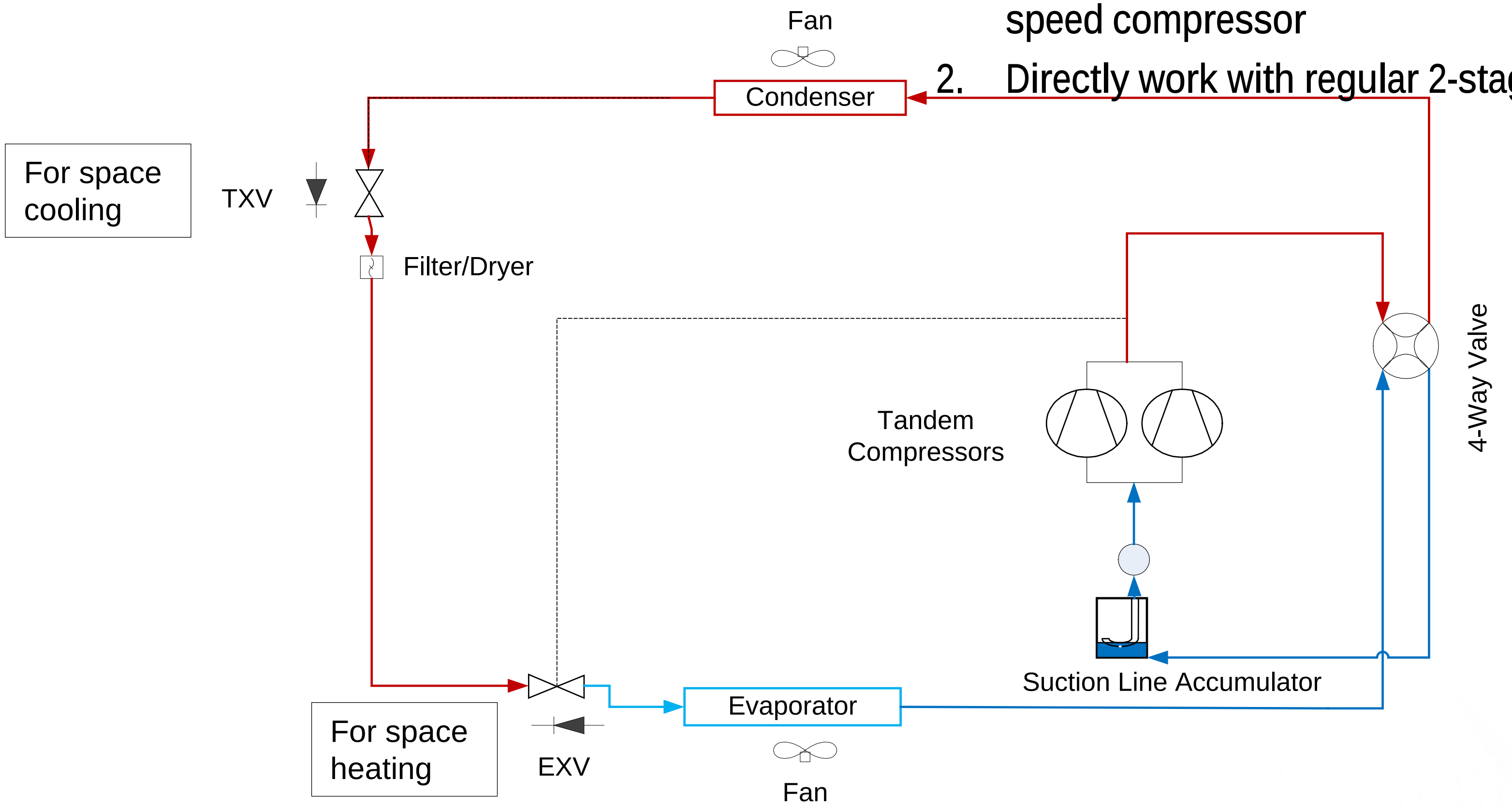
Technical Goals (Project outputs):

Develop a CCHP to minimize resistance heating

- COP@ 8.3°C/47°F > 4.0; HP capacity@ -25°C/-13°F > 75% of rated capacity@ 8.3°C.
- Maximize COPs at -8.3°C and -25°C with acceptable payback period.

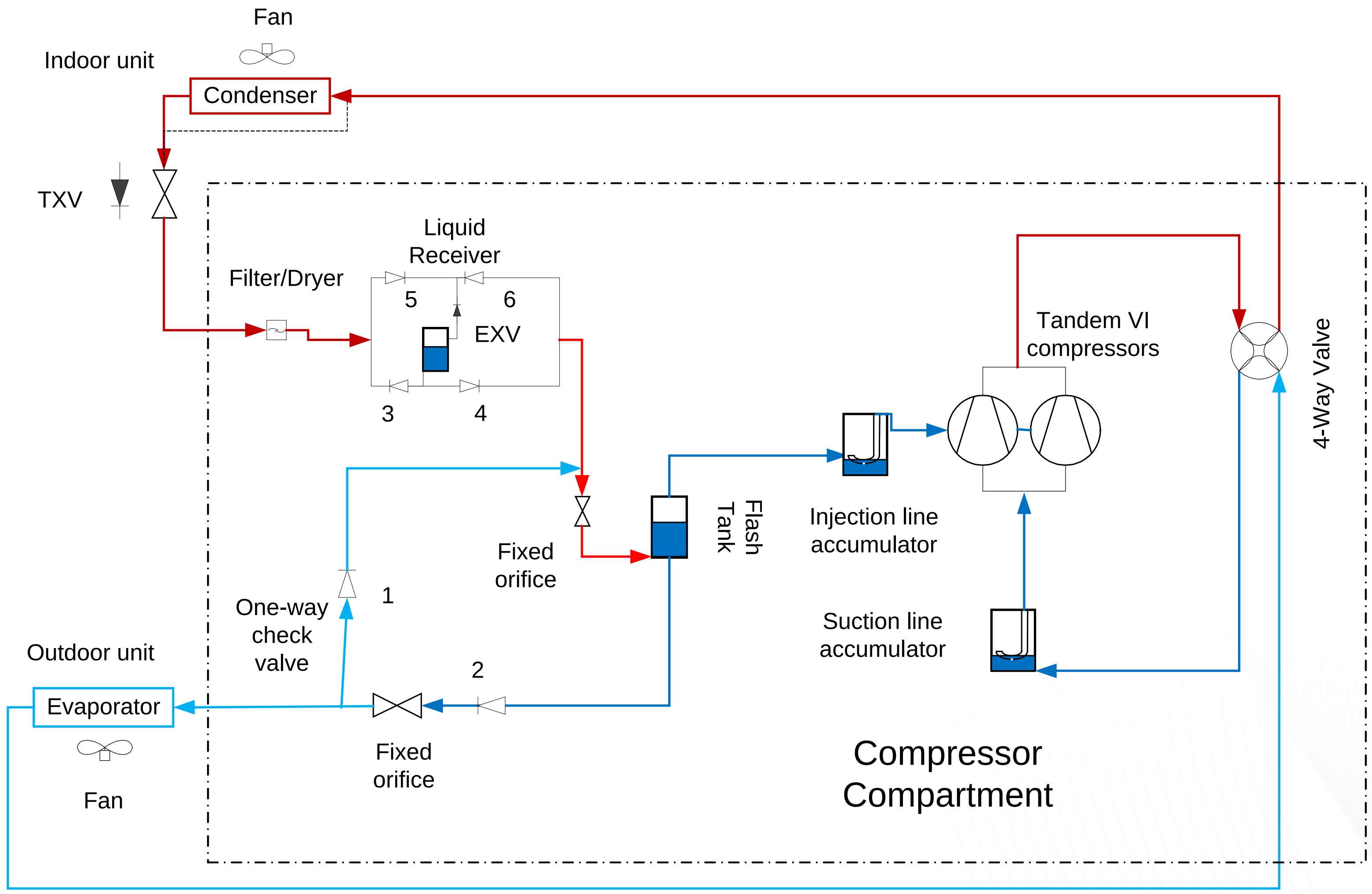
System I – tandem single-speed compressor

1. 30% less cost, and easier control than variable-speed compressor
2. Directly work with regular 2-stage thermostat



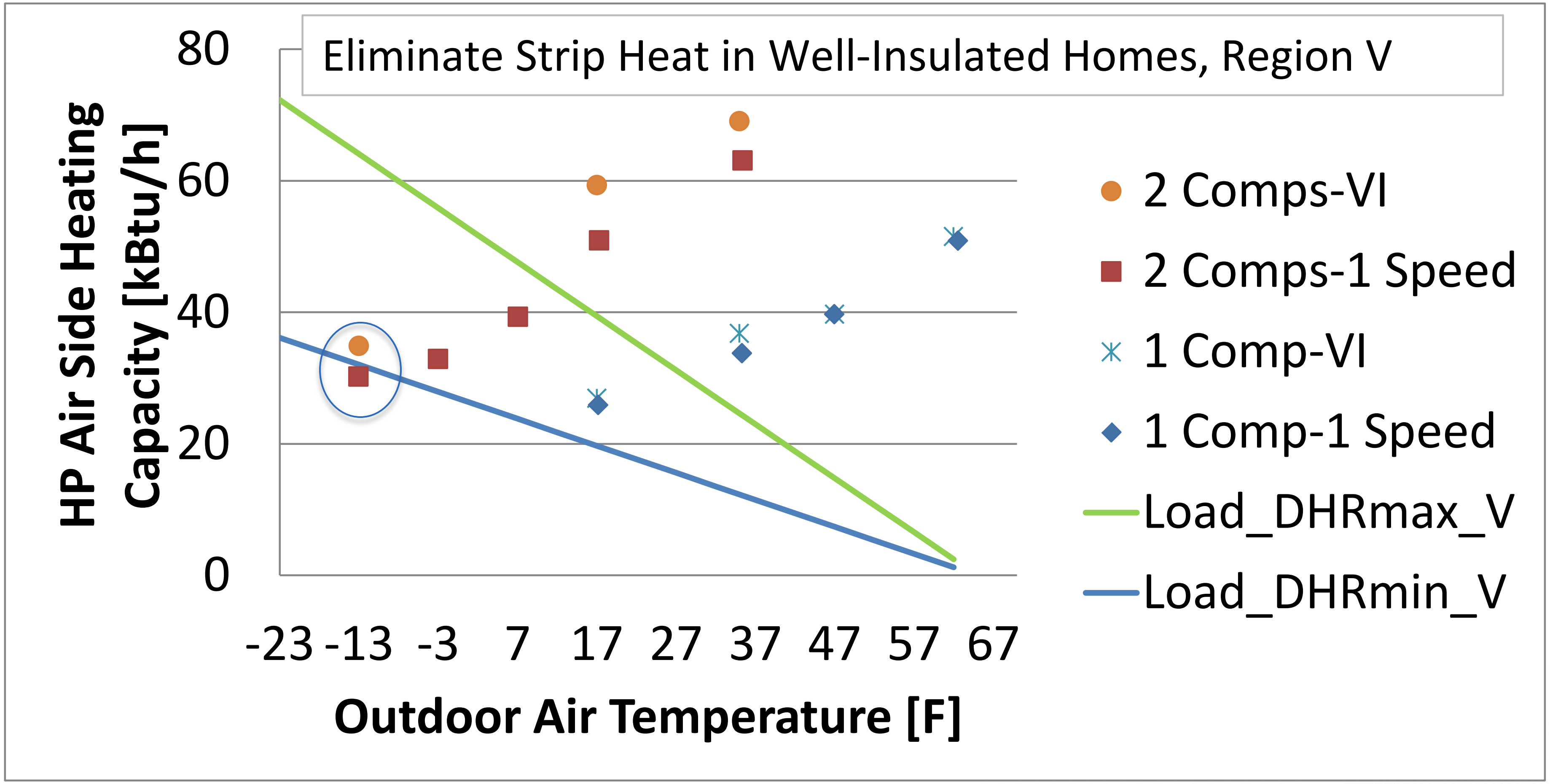
1. *Two identical, fixed-speed compressors, specially optimized for heating mode , tolerate up to 280°F /138°C discharge temperature.*
2. *A single compressor to match cooling load, and heating load at moderately cold temperatures, turn on both compressors at low ambient temperatures when needed.*
3. *(Suction line accumulator+ EXV discharge temperature control) facilitates charge optimization in a wide ambient temperature range.*

System II – tandem vapor-injection compressor



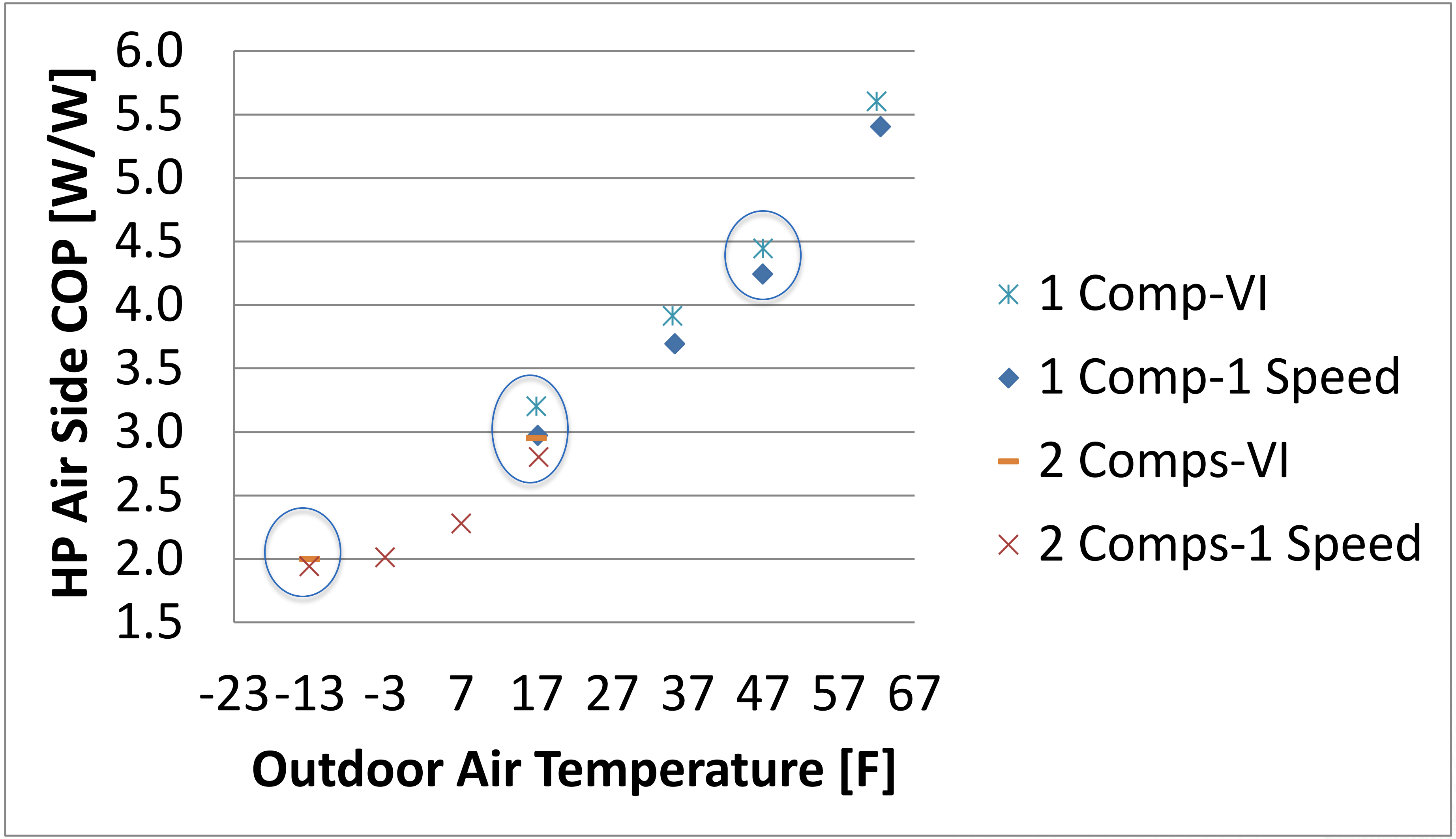
- *Equal Tandem, Vapor Injection Compressors + Inter-stage Flash Tank + EXV Inter-stage Pressure Control .*

Lab Measured Heating Capacities



- *CCHPs eliminate auxiliary strip heating down to -13°F /-25°C in US cold regions.*

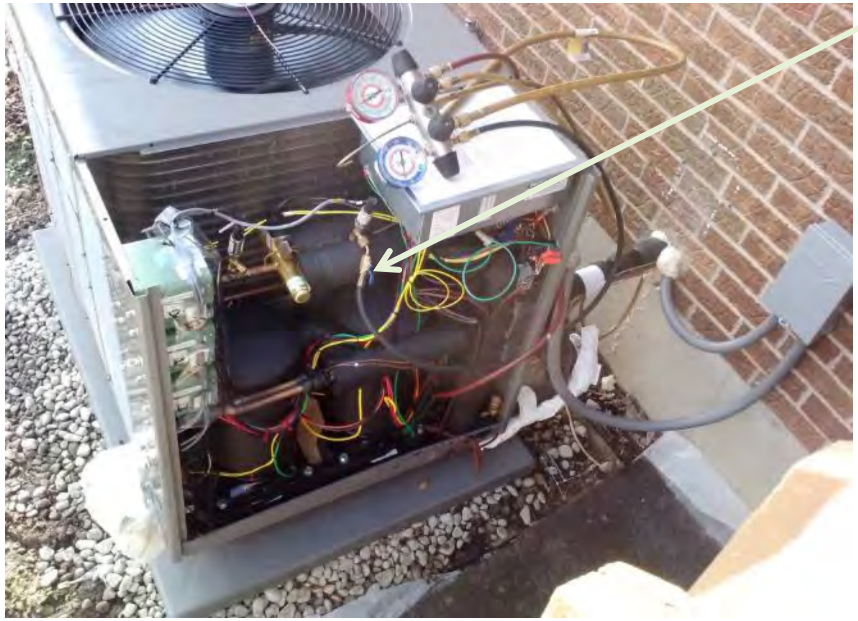
Lab Measured Heating COPs



- *The 'premium' system with tandem VI compressors achieved 5% better COPs than the 'more cost-effective' fixed-speed compressor version at various ambients.*

Field Prototype-tandem single-speed

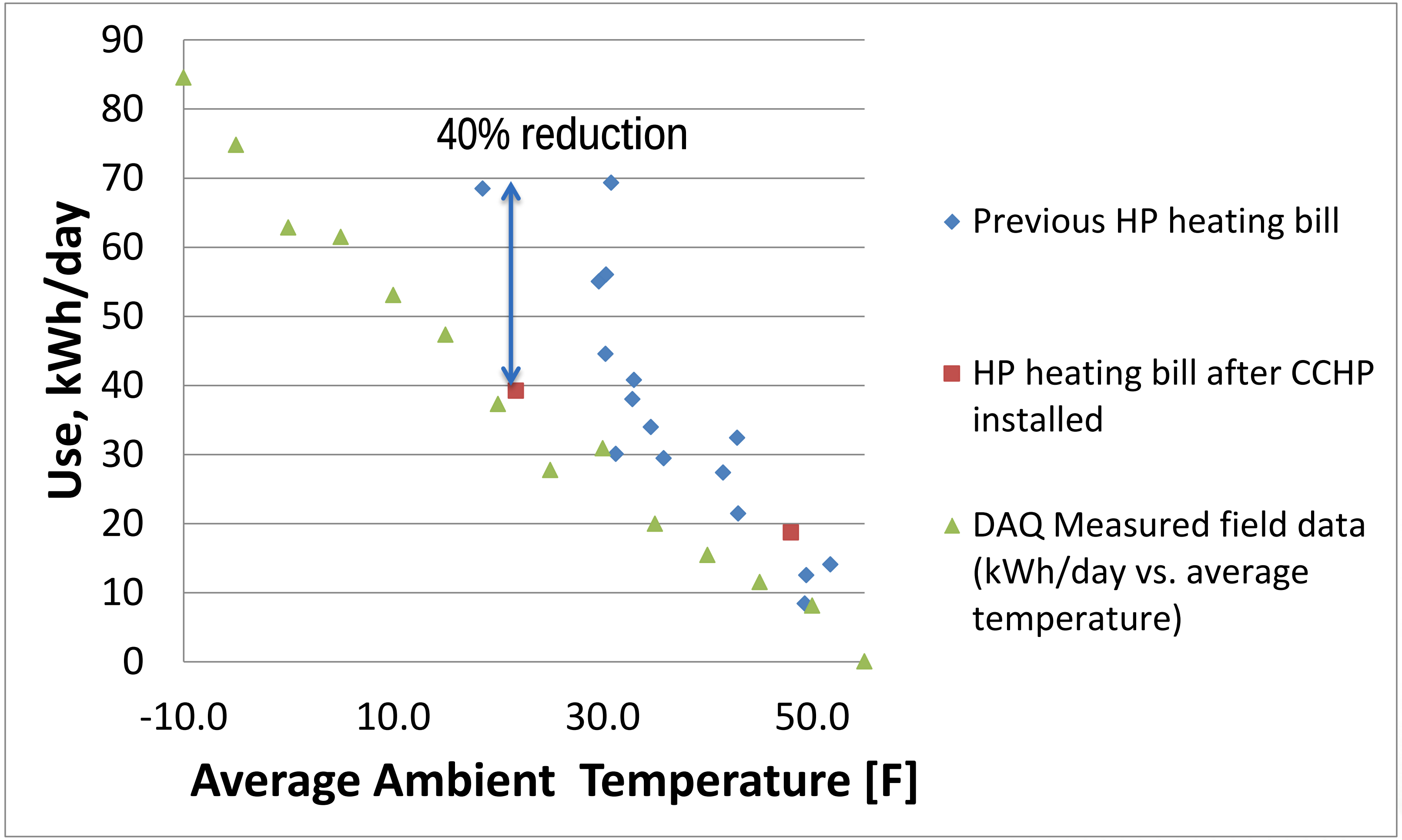
*Insulated compressors to minimize cold weather heat loss



Field testing in OH-outdoor unit, at a residential home having a design cooling load of 3-ton (10.6 kW)

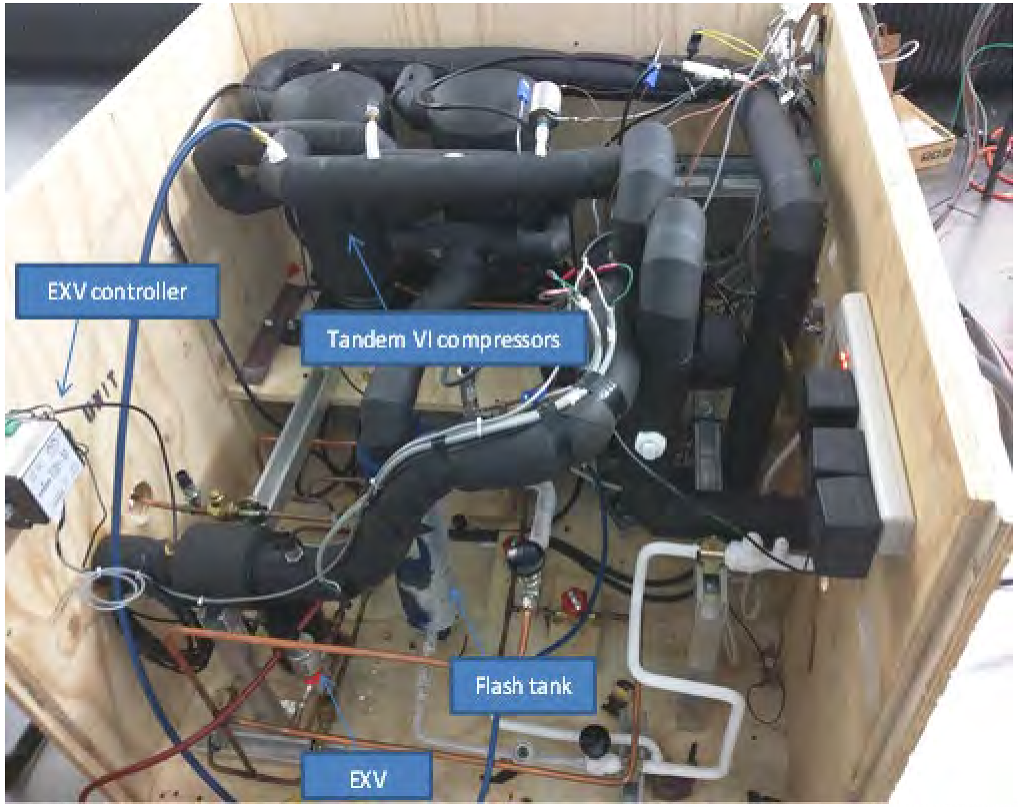
Indoor Unit and Data Acquisition, record data point every half minute.

Huge energy reduction in coldest months compared to previous conventional HP (13.0 SEER/8.0 HSPF)



>40% energy reduction vs. previous HP with similar average monthly temperatures of 20°F (-6.7°C).

Field test of tandem VI compressors (2016, in Fairbanks, Alaska)



Three boxes, put compressor box indoor.

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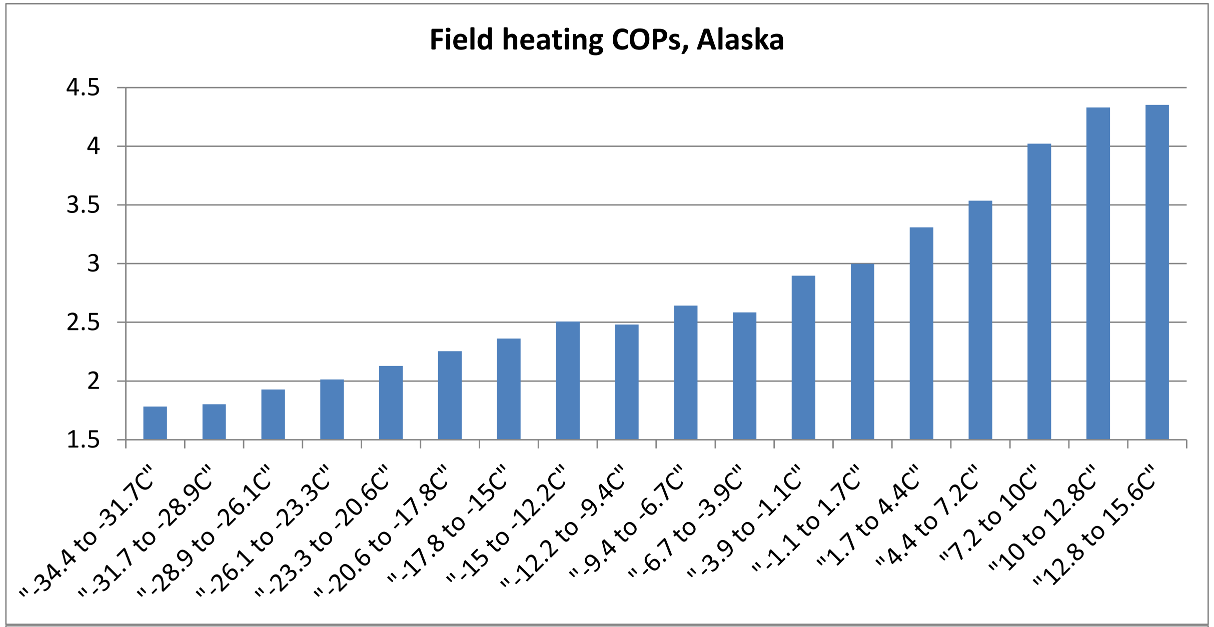
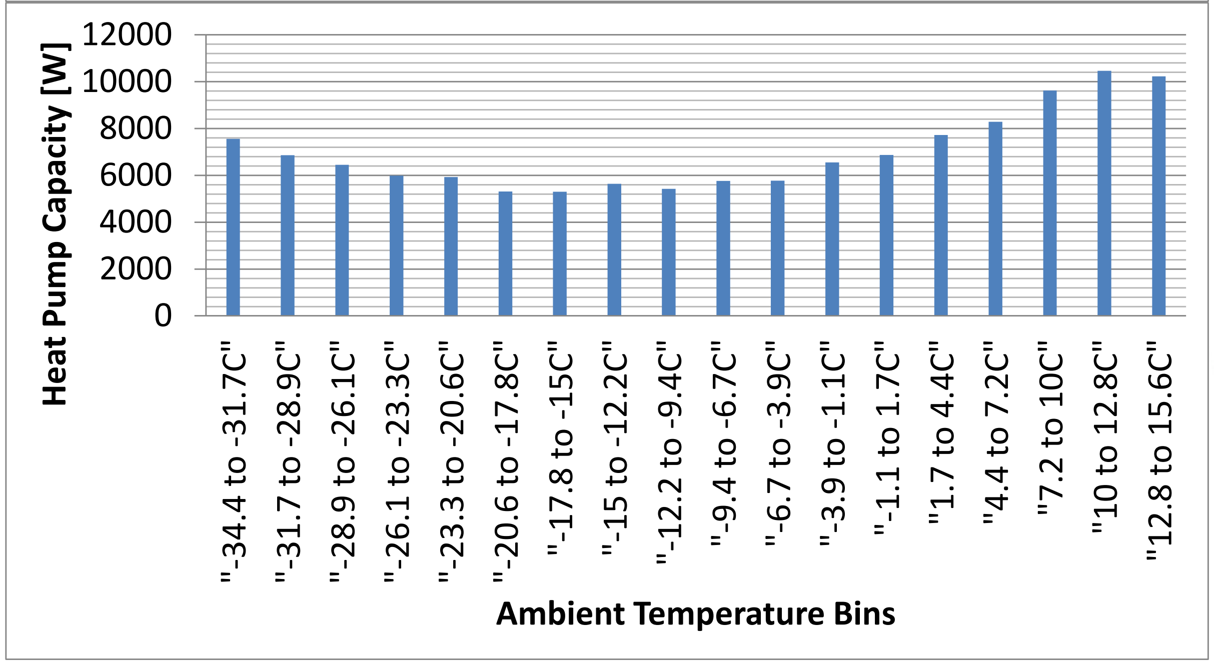
Field Heating COPs and Capacities, Alaska



- Work in most extensive and extreme ambient range.
- 1.6 COP at -30°F/-35°C.



- The second compressor turned on below 5°F/-15°C.
- Running two compressors provides 75% of rated capacity at -30°F/-35°C.

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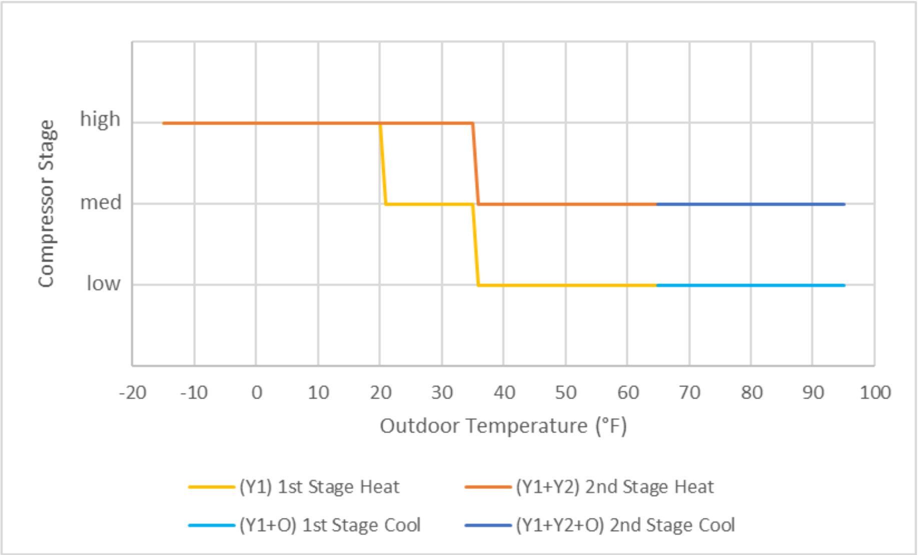
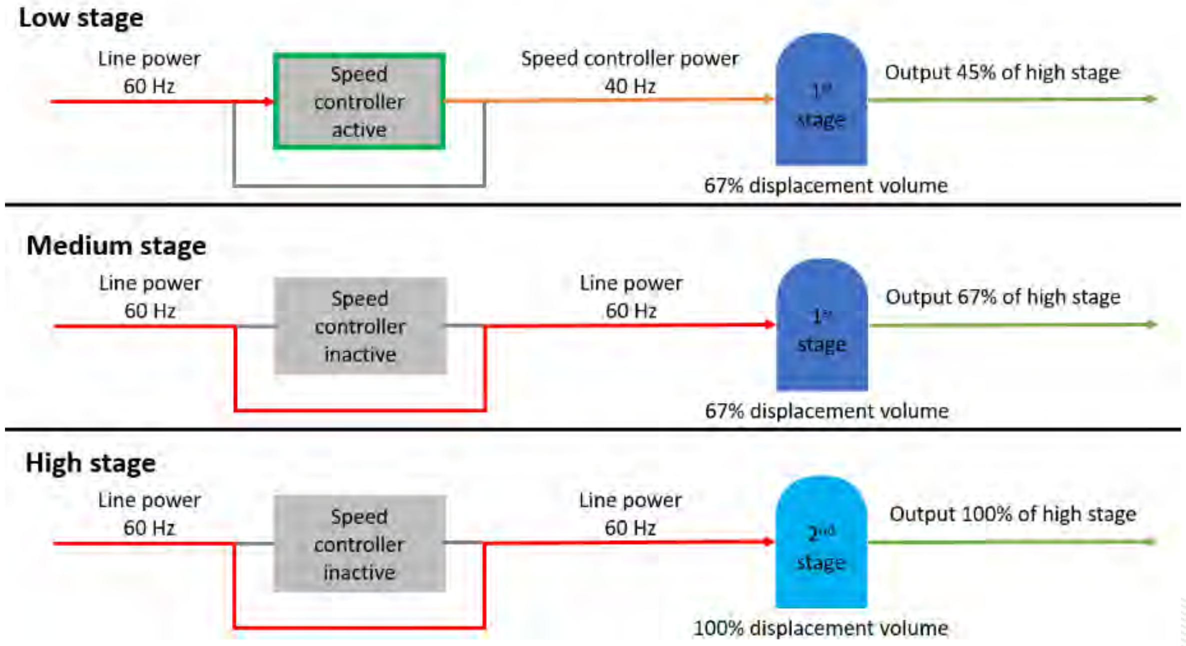
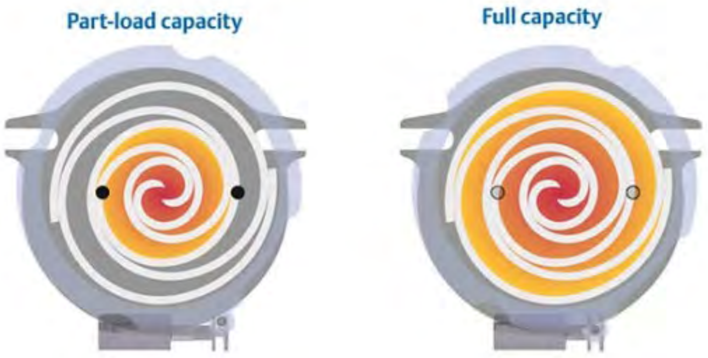
System III - Develop a CCHP using a single, 3-stage compressor

Low-Cost Capacity Modulation (30% lower than inverter-driven variable-speed compressor)

- 3-stage scroll compressor (100%/67%/45%) – an enhanced version of 2-stage UltraTech Compressor
- 67% is used for rated capacity of cooling mode, 100% capacity for enhanced heating at low ambient temperatures.
- Compatible with 2-stage thermostat





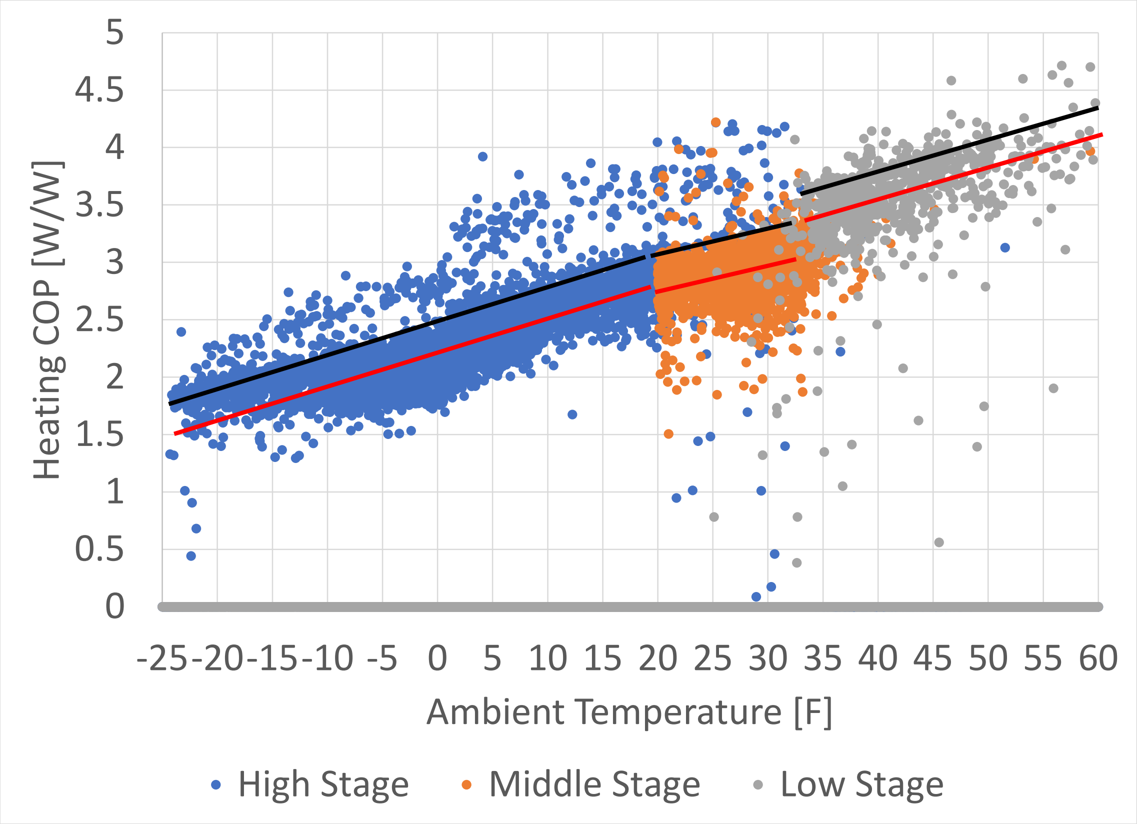


Improved from 2-stage compressor using mechanical capacity modulation

Progress

- Field trial in Fairbanks Alaska, started in 2021 winter – Cold Climate Heat Pump, completed in 2023

Operated to -25˚F,
Solid COPs > 2.0 down to -10˚F.



Field unit

Summary

Main points:
- Pioneer cold climate heat pumps while shorten U.S. industry learning curves
- ORNL is developing new heat pumps suitable for cold weather
- They were tested under harsh Arctic conditions and these learnings are being applied

Outcomes:
- Develop and deploy three prototype generations for field testing in Alaska's severe winters.
- 40% energy saving in peak heating months in one field test.
- BTO success story, 2014.
- U.S. manufacturers are applying the technical strategies, developed by ORNL, 10 years ago.

Next step:
Whole decarb package - cold climate multi-functional heat pump for space cooling, heating and water heating – seeking commercialization.

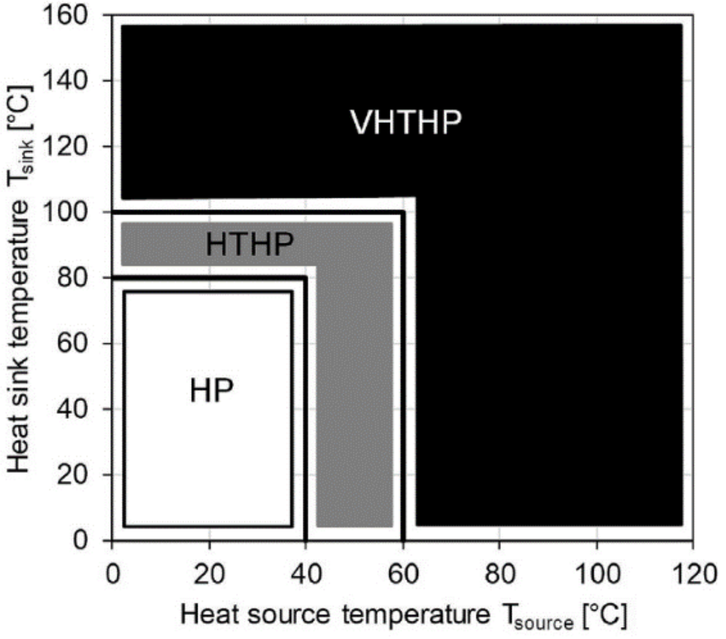
High Temperature Heat Pump Research at Oak Ridge National Laboratory

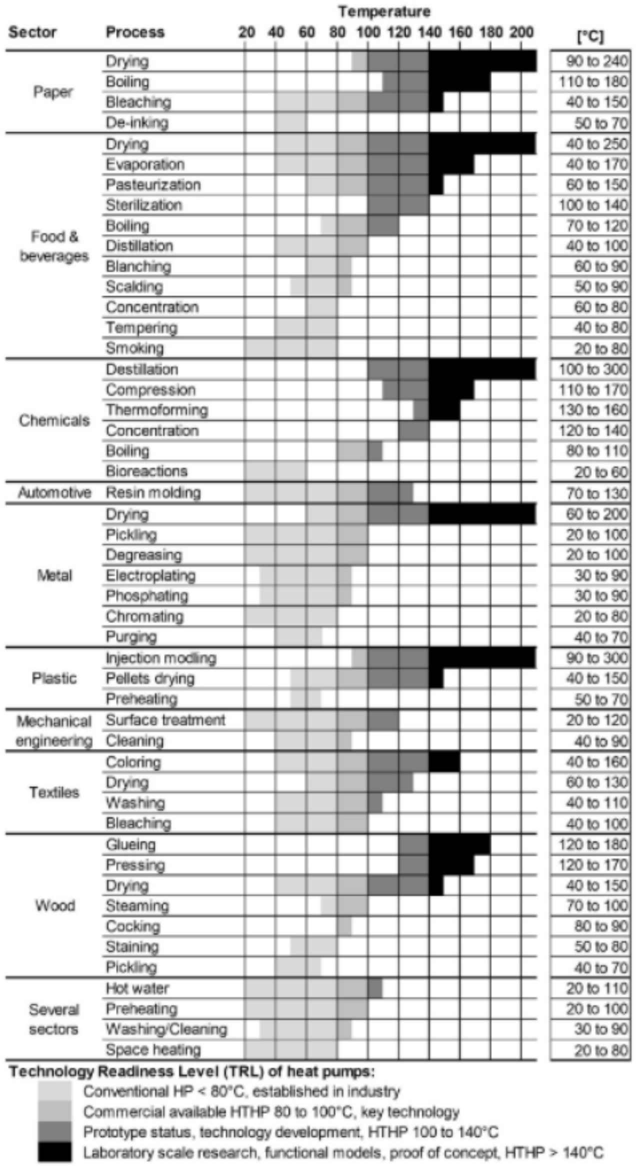
Stephen Kowalski

ORNL is managed by UT-Battelle LLC for the US Department of Energy

High Temperature (or Industrial) Heat Pumps

- Generating process heat, usually from fossil fuel combustion, accounts for a significant amount of energy usage for the industrial sector.
- Heat pumps can be a suitable technology to decarbonize the industrial sector but concepts to deliver sink temperatures at greater than 100°C are at low Technical Readiness Level (TRL).
- Key enabling technologies
  - Cycle
  - Compressor
  - Working fluid
  - Heat exchangers
  - Controls





Both figures from: C. Arpagaus, F. Bless, M. Uhlmann, J. Schiffmann, and S. S. Bertsch, "High temperature heat pumps: Market overview, state of the art, research status, refrigerants, and application potentials," *Energy*, vol. 152, pp. 985–1010, Jun. 2018, doi: 10.1016/j.energy.2018.03.166.

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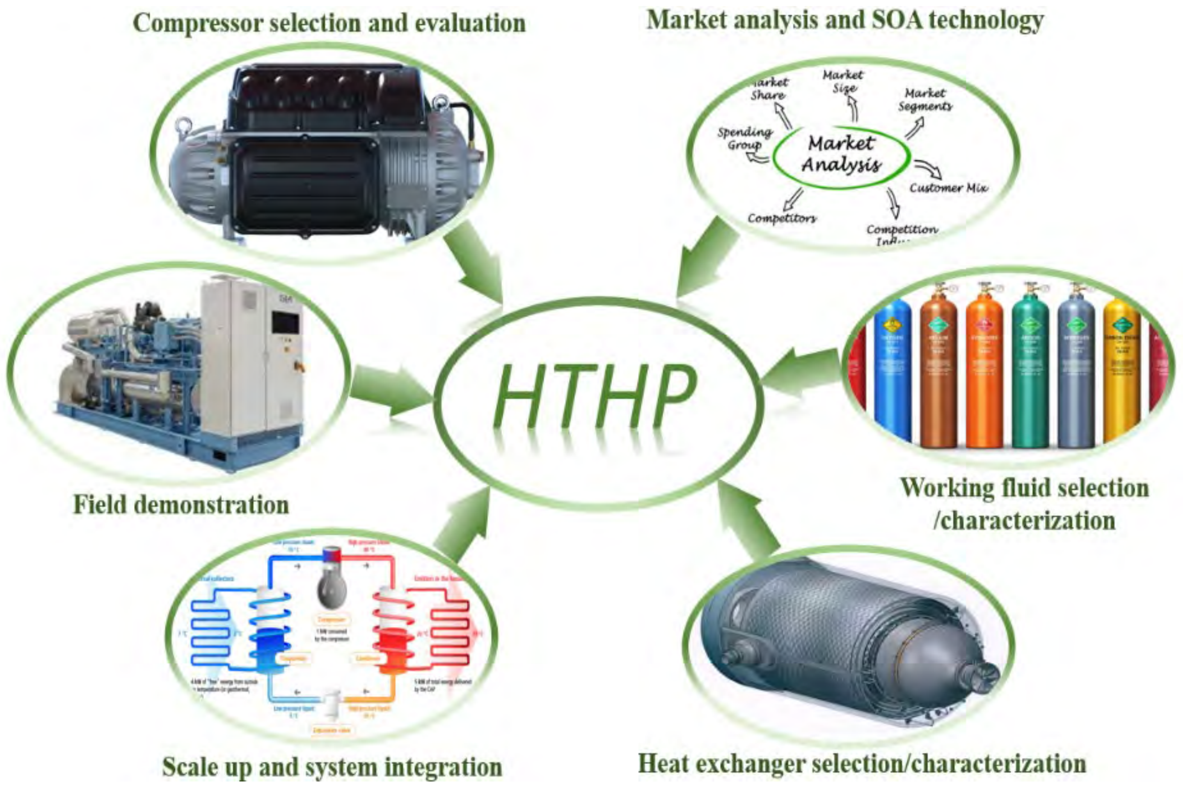
High Temperature Heat Pump for Commercial Space and Water Heating

Objective and Outcome

- **Problem**: Processes in buildings and industrial applications account for 60% of direct and indirect CO_2 emissions. More than 1.8 quads of energy are used annually in gas-fired equipment for commercial heating applications, accounting for more than 94 MMT of CO_2 emissions in 2021. Heat pumps can provide a resilient and sustainable replacement for gas-fired equipment.
- **Objective**: The project is focused on the development and performance optimization of high-temperature heat pumps for space and water heating for commercial buildings. The team intends to design and demonstrate a 50 kW or higher capacity heat pump that can provide at least 93°C sink temperature with acceptable COP while deploying a low GWP refrigerant.

National Impact

- A direct replacement for gas-fired technology for commercial buildings' heating while ensuring at least 50% reduction in direct CO_2 emissions
- Process integration and optimization for simultaneous air and water heating
- Demonstration of acceptable COP at various operating conditions and potential for scaling up the technology for large-scale deployments



ORNL team is developing a comprehensive Research, Development and Demonstration framework for commercial/industrial HTHP. The scope of the study includes aspects related to market evaluation, techno-economic analysis, and life cycle cost analysis.

Research activities:
Establishment of CRADA partnership with industrial partners.
Design and fabrication of the test facility for sink temperature >100°C
Design and procurement/fabrication of key components
Lab and field demonstration of the 50 kW or higher capacity

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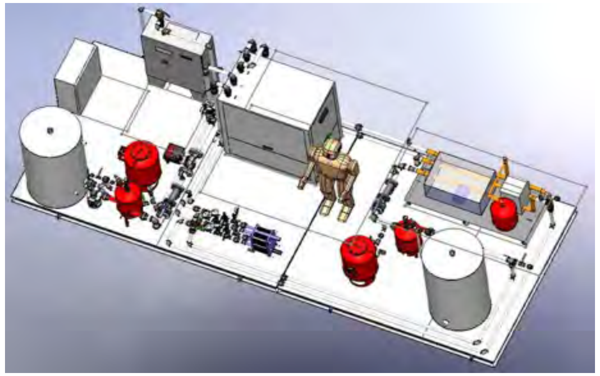
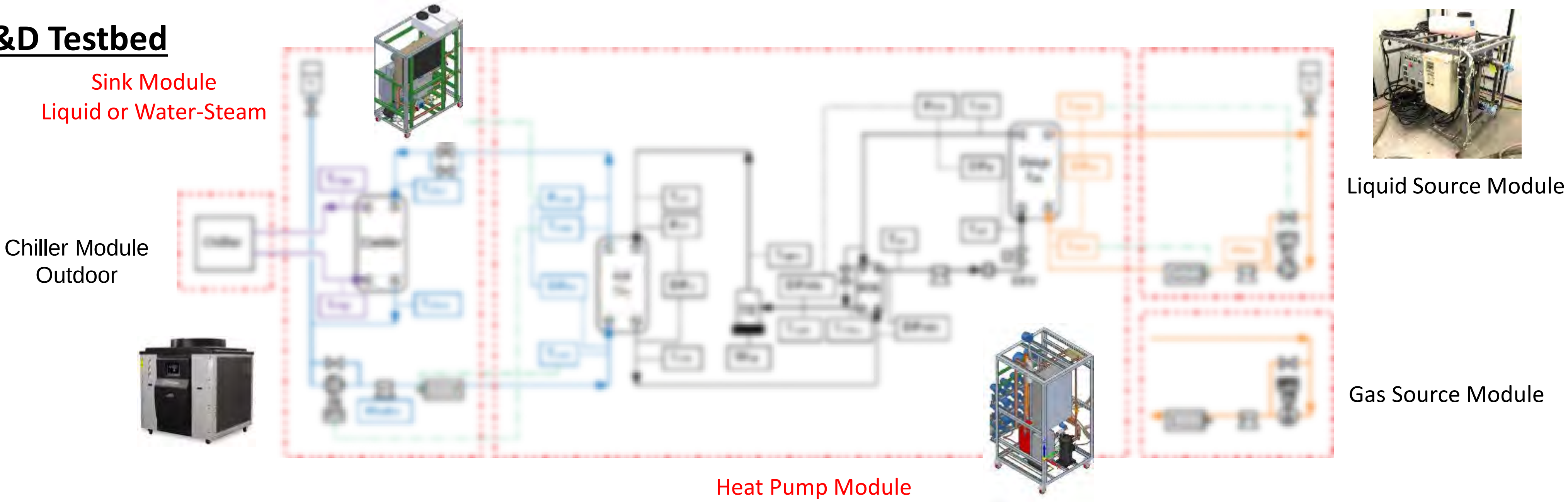
HTHP Test Capabilities

- **Plug-In Whole Unit Testbed**



- **Modular R&D Testbed**



Refrigerant selection

❖ Screening Working Fluids for HTHPS with T_{supply} = 120℃

- Thermal suitability, e.g., high T_{cr} and low p_{cr};
  Generally, $T_{supply,max} < (T_{cr}$ -10K) and $T_{source,min}$ > NBP
- Thermophysical properties, e.g., high COP at a large ΔT_{lift}, large VHC, and small ΔT_{SH};
- Environmental compatibility, e.g., low-GWP, Zero-ODP, no per or polyfluoroalkyl substances (PFAS);
- Safety, e.g., non-toxicity and low flammability;
- Commercial availability, e.g., available on the market and low price;
- Other factors, e.g., chemical compatibility with lubrication oils and material compatibility with metals.

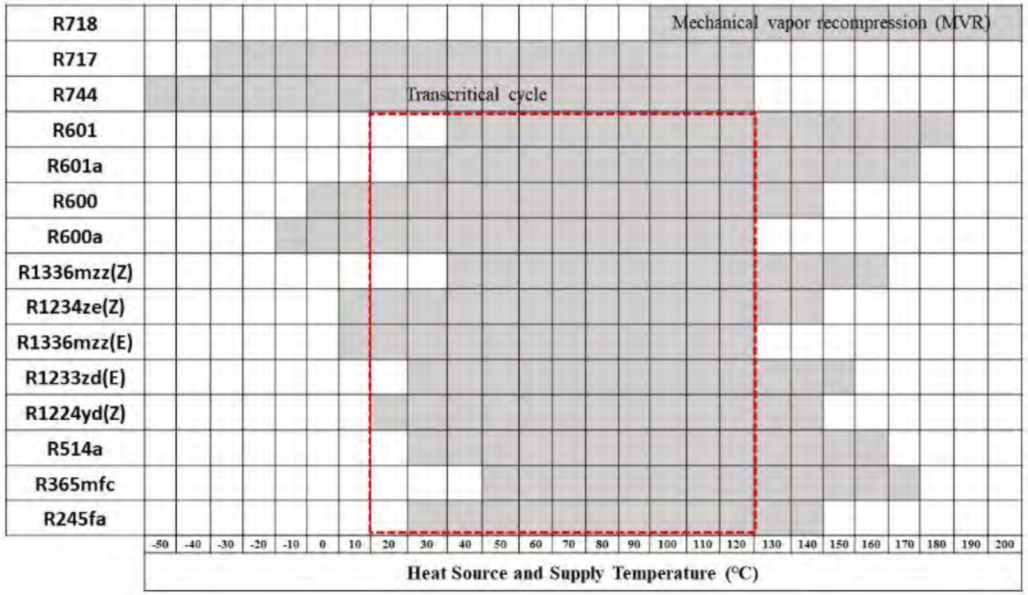


Figure 1. Temperature application ranges of WFs in HTHP (T_{supply} ≥100℃)*.

*Zühlsdorf, Benjamin, Jonas Lundsted Poulsen, Sabrina Dusek, Veronika Wilk, Johannes Krämer, René Rieberer, Manuel Verdnik et al. "IEA HPT Annex 58: High-Temperature Heat Pumps. Task 1 report: Technologies." (2023).

❖ Selected Working Fluids

For subcritical, vapor compression cycle

- Hydrocarbons (HCs): R600, R600a, R601, R601a
- Hydrofluoroolefins (HFOs): R1234ze(Z), R1336mzz(E), and R1336mzz(Z)
- Hydrochlorofluoroolefins (HCFOs): R1224yd(Z), R1233zd(E)
- Hydrofluorocarbons (HFC): R245fa (used as a reference)

❖ Evaluation of Selected Working Fluids

- Using the thermodynamic model of a single-stage vapor compression cycle with an internal heat exchanger (IHX).
- Performance metrics

$$\mathrm{COP_{HTHP}} = \frac{Q_{cond}}{W_{comp}} = \frac{Q_{evap} + W_{comp}}{W_{comp}}$$

$$\mathrm{VHC_{HTHP}} = \eta_{Comp,vol}\rho_{comp,suc}(h_{comp,disch} - h_{cond,out}) = \eta_{Comp,vol}\rho_1(h_2 - h_3)$$

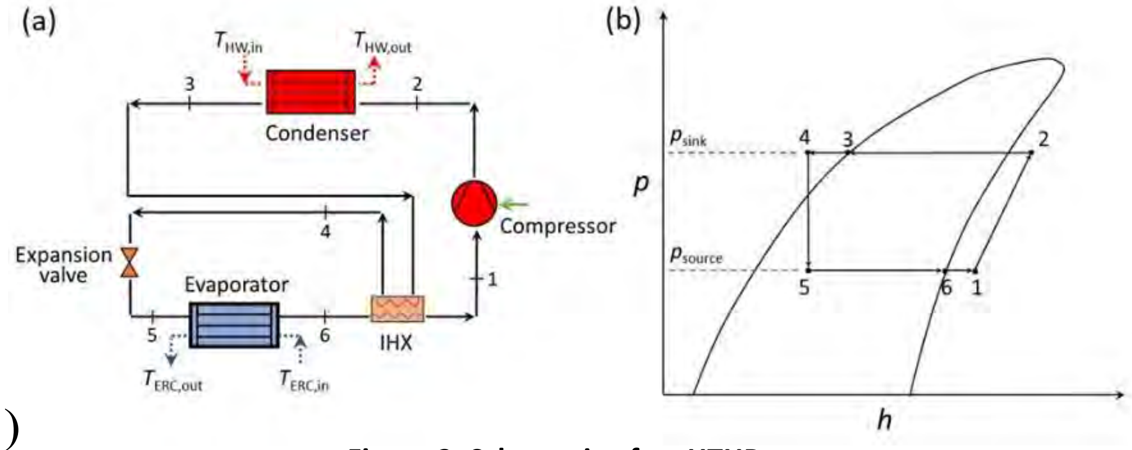


Figure 2. Schematic of an HTHP.

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Refrigerant selection

❖ **Performance of HTHPs with Selected Working Fluids**

- No perfect low-GWP WFs; a trade-off between the COP and VHC must be considered.
- R600 and R600a for the balanced COP and VHC scenarios. A3 high flammability requires specified safety measurements.
- R601, R601a, and R1336mzz(Z) for the highest COP scenario. R601 and R601a require large-size compressors;
- R1234ze(Z), R1233zd(E), and R1224yd(Z) are the best candidates for the drop-in replacement of the R245fa scenario, benefitting the state-of-art compressor technologies.

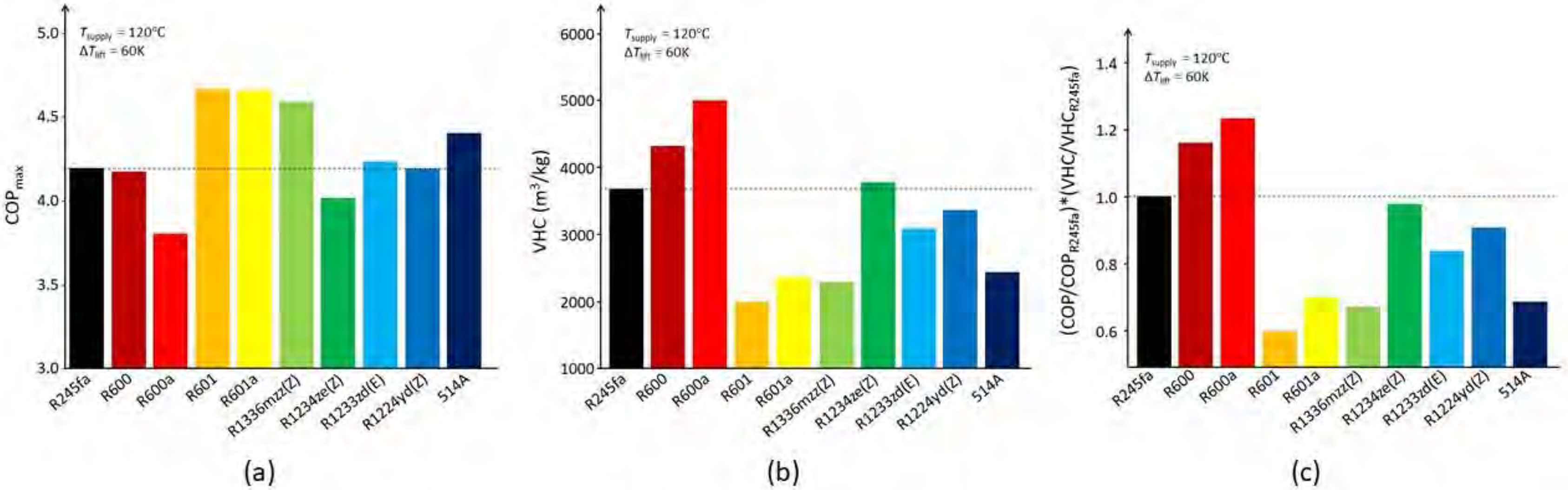


Figure 3. Performance of HTHPs using low-GWPs WFs at T_{supply} = 120℃ and ΔT_{lift} = 60K.

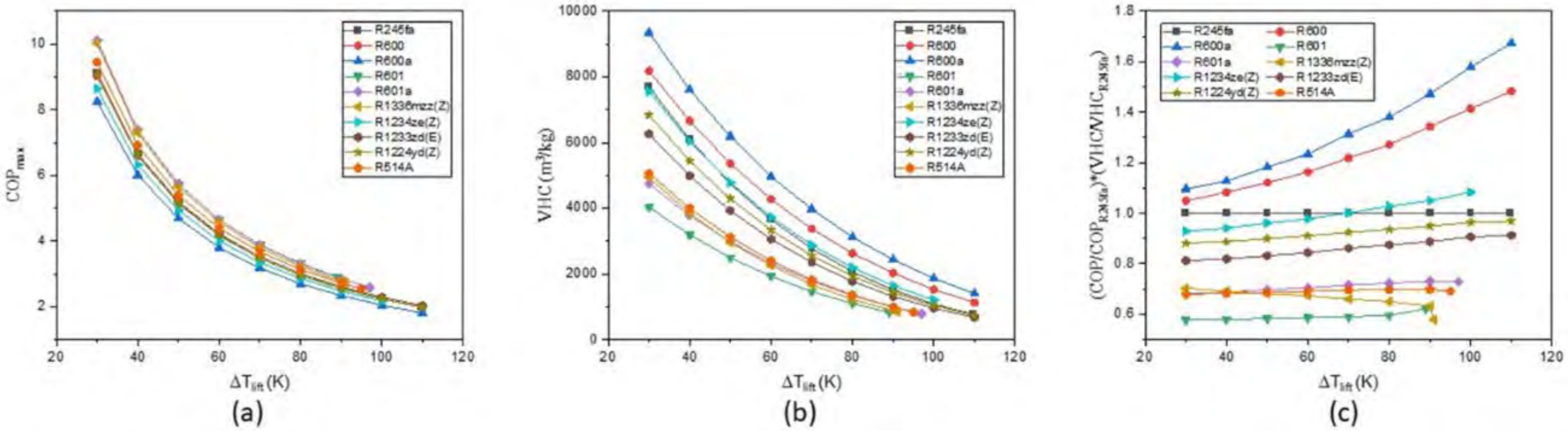


Figure 4. Performance of HTHPs using low-GWP WFs under T_{supply} = 120℃ and different ΔT_{lift}.

Overview of Low GWP Refrigerants and related R&D Efforts at ORNL

Brian Fricke

frickeba@ornl.gov

27 June 2024

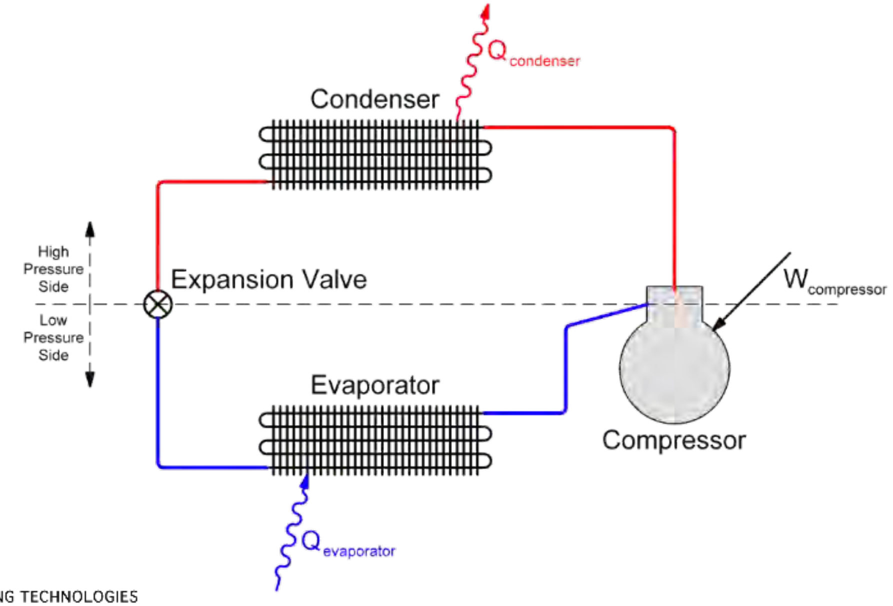
Agenda

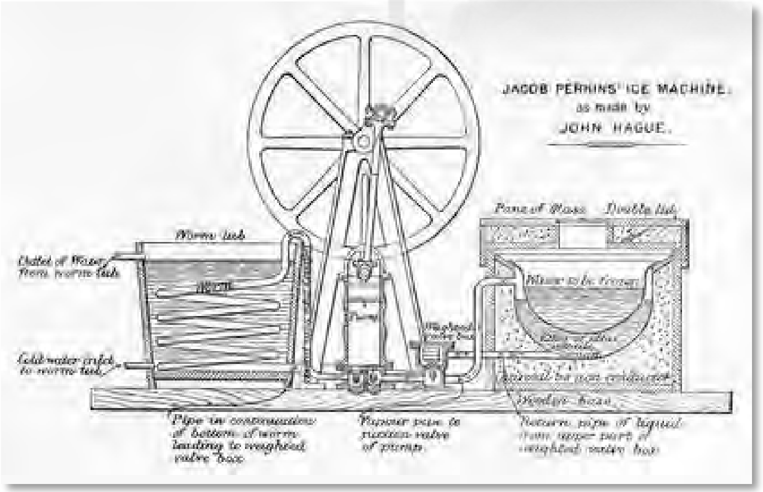
- History of refrigeration and refrigerants
- Drivers of the current transition
- Selected low-GWP refrigerant R&D efforts at ORNL

History of Refrigeration and Refrigerants

History of Refrigeration and Refrigerants

- Jacob Perkins (1766 – 1849)
  - American inventor
  - Patent filed for first vapor compression refrigeration system in 1834
    - Contains the four basic components we recognize as a vapor compression system
    - First commercially successful systems built around mid-1850s





History of Refrigeration and Refrigerants

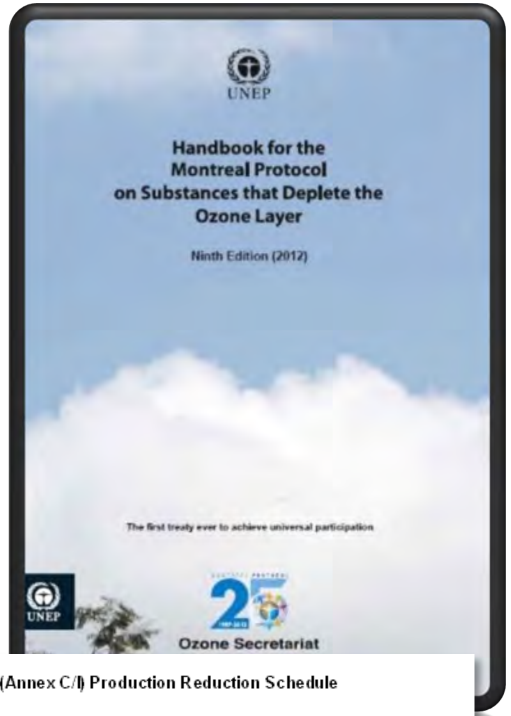
- Early applications (c 1850 – 1900)
  - Ice making, brewing, shipping, meat packing
- Common refrigerants in early refrigeration systems
  - Ether
  - Carbon dioxide (CO_2)
  - Sulfur dioxide (SO_2)
  - Methyl chloride (CH_3Cl)
  - Hydrocarbons
  - Ammonia (NH_3)
  - Chosen for their availability, not necessarily for safety

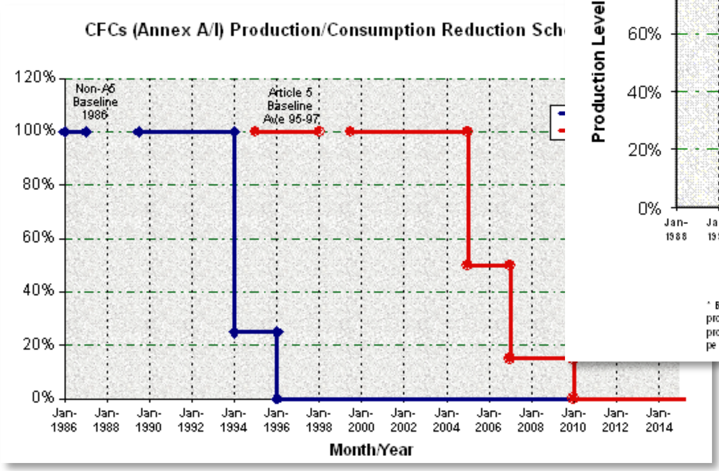
History of Refrigeration and Refrigerants

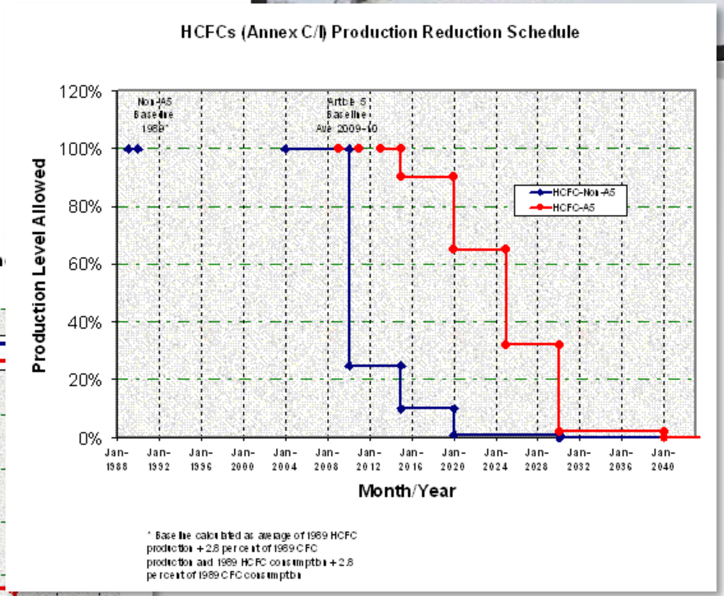
- Thomas Midgley, Jr. (1889-1944)
  - Mechanical Engineer by training
  - Employed by General Motors
    - GM owned Frigidaire
  - 1920s:
    - Beginning of refrigeration machinery operated in proximity to general public
    - Common refrigerants were toxic
    - A “safety refrigerant” was desired
    - Developed dichlorodifluoromethane (CCl_2F_2) – “Freon” or R-12
      - A whole family of chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) refrigerants

Refrigerants and the Ozone

- Chlorine in upper atmosphere can break down atmospheric ozone
  - A single chlorine atom is able to react with 100,000 ozone molecules before it is removed from the catalytic cycle
- Significant source of chlorine:
  - CFCs and HCFCs
- Montreal Protocol (1987):
  - Phase-out of CFCs and HCFCs



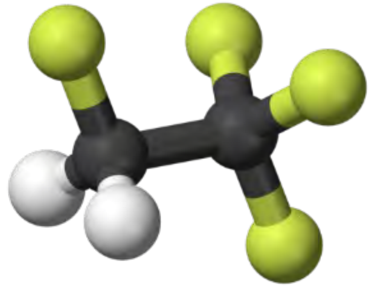




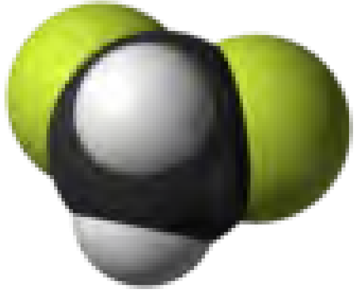
OAK RIDGE National Laboratory | BUILDING TECHNOLOGIES RESEARCH AND INTEGRATION CENTER

Current and Next Generation Refrigerants

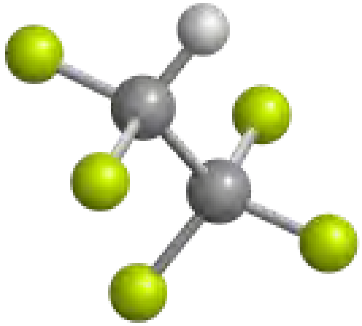
- Hydrofluorocarbons (HFCs)
  - Contains no chlorine
    - No threat to ozone
  - Potent greenhouse gasses
    - Several thousand times more potent than CO_2
- Hydrofluoro-olefins (HFOs)
  - Fluorinated propene isomers
  - Low Global Warming Potential
- “Natural” Refrigerants
  - What’s old is new again?
  - Ammonia, CO_2, hydrocarbons
  - Very low global warming potential



R-134a

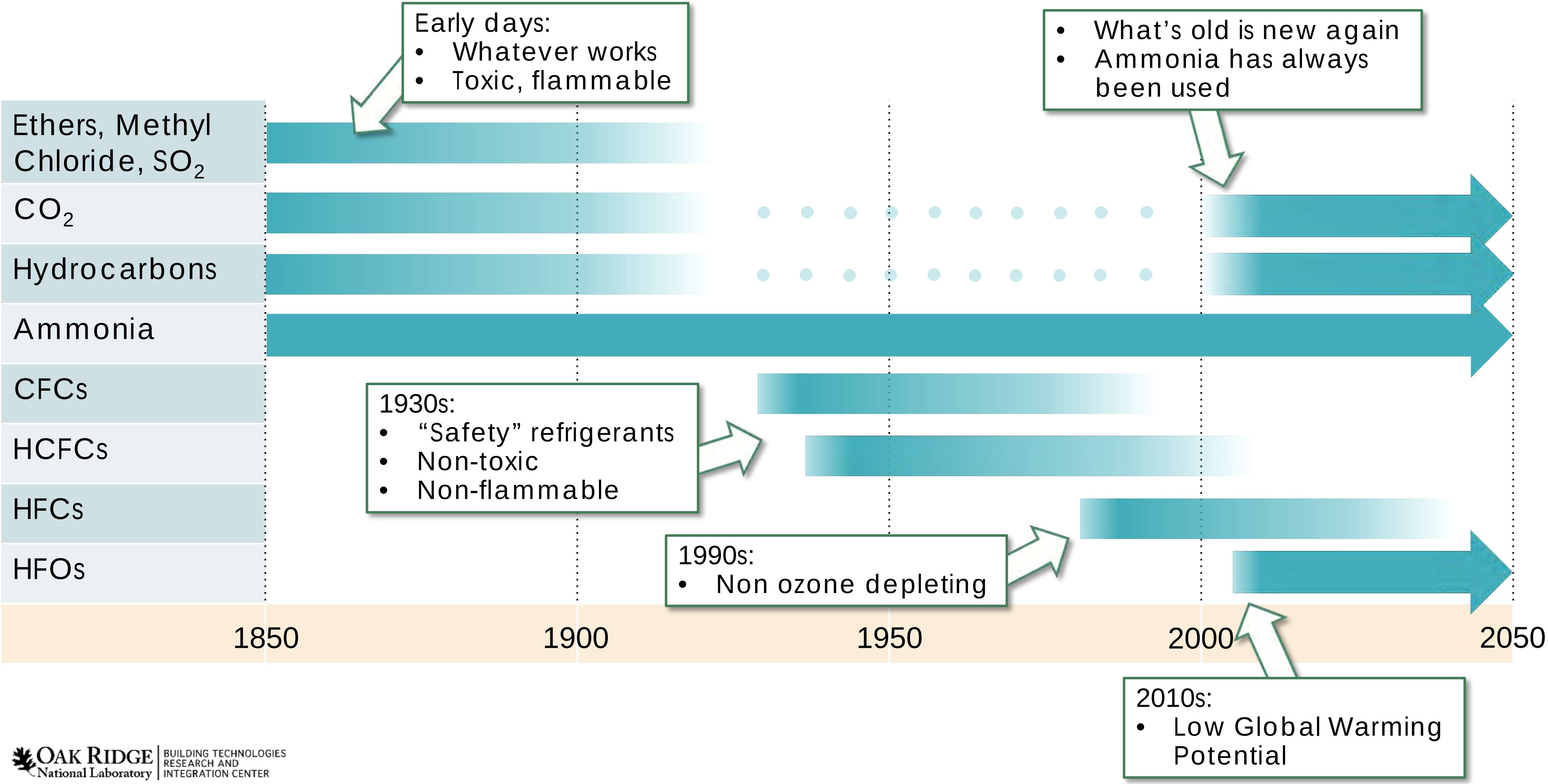


R-32



R-125

Timeline of Refrigerants



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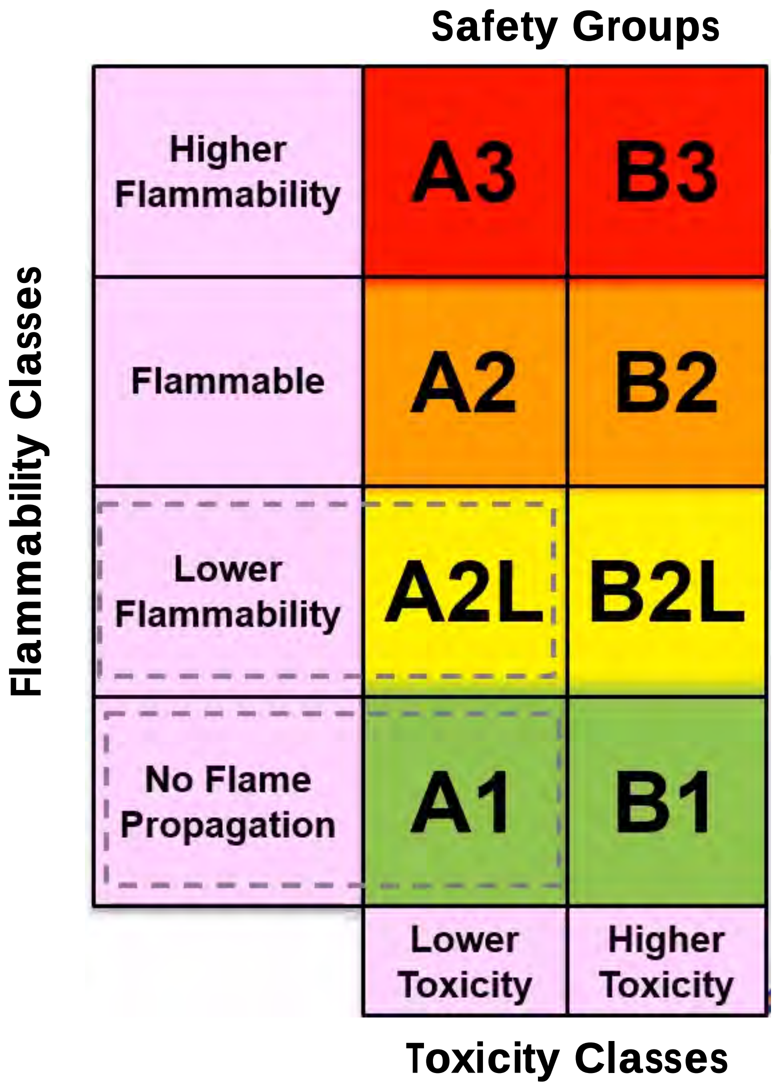
ASHRAE Refrigerant Safety Classification

- **Toxicity:**
  - Low: A (OEL ≥ 400 ppm)
  - High: B (OEL < 400 ppm)
- **Flammability:**
  - No Flame Propagation: 1
  - Lower Flammability: 2L
    - Burning velocity lower than 10 cm/s
  - Flammable: 2
  - Higher flammability: 3
- **Examples:**
  - A1: R-22, R-404A, R-410A
  - A2L: R-1234yf, R-1234ze, R-32, R-454B, R-454C, R-455A,...
  - A2: R-152a, R-142b, R-143a,
  - A3: Hydrocarbons (R-290, R-600a)
  - B1: R-123, R-245fa
  - B2L: Ammonia (R-717)



Drivers for the Current Transition

Refrigerants: Drivers, Short-Term/Long-Term Options, Roadblocks

	Current	2022-2023	2024-2028	2029-2033	2034-2035	2036+

Drivers

- **Kigali Amendment**: Baseline 2011-13; Reduction of -40% by 2024, **-70% by 2029**, -80% by 2034, -85% by 2036
- **US EPA AIM**: Baseline 2011-13; Reductions of -40% by 2024, **-70% by 2029**, -80% by 2034, -85% by 2036
- **EU F-Gas**: Baseline 2009-12; Reductions of -69% by 2024, -76% by 2027, **-79% by 2030**

Technologies

Air Conditioning R-410A
- R-32 and R-454B in A/C
- GWP<150 Options: Hydrocarbons, R-1234yf, R-1234ze, R-454C, R-455A,… →

Refrigeration R-404A
- Interim replacements: R-448A, R-449A,…
- Long term: Transcritical CO2, Hydrocarbons, R-454C, R-455A,… →

Water Heaters R-134a
- Interim replacements: R-513A, R-515B,…
- Long term: CO2, Hydrocarbons, R-1234ze, R-1234yf ,… →

Chillers, HTHPs R-123, R134a
- Low pressure chillers (R-123) and High Temperature Heat Pumps (R-245fa): R-1233zd, R-514A, R-1336 →
- Medium pressure centrifugal chillers: R-1234ze →

Roadblocks, Breakthrough?

- **Roadblock 1**: Safety Stds. & Building Codes
- **Roadblock 2**: Availability of optimized components/equipment
- Highly flammable hydrocarbons are limited to small-charge systems – Need to reduce charge or use secondary fluid systems
- **Breakthrough**: New molecules to replace R-410A, R-404A

If it happens, there is little time available for implementation

Regulations: Specific to the USA market

Kigali Amendment

Steps	Date
Baseline	2011-2013
1st step	2019 – 10%
2nd step	2024 – 40%
3rd step	**2029 – 70%**
4th step	2034 – 80%
Plateau	2036 – 85%

HFC consumption and a 15% HCFC consumption (in CO_2-equivalents) are included in the baseline

- Almost every region (Europe, Asia, America) is following the path defined by the Kigali Amendment.
- Year 2029 marks a step reduction in consumption (CO2e).
- The expectation is to go to lower GWPs by that date.

EPA AIM

Steps	Date
Baseline	2011-2013
1st step	***2022 – 10%***
2nd step	2024 – 40%
3rd step	**2029 – 70%**
4th step	2034 – 80%
Plateau	2036 – 85%

- EPA also regulates using SNAP. Example: SNAP 23 allows R-32, R-454B, R-454A, R-454C, and R-457A for residential and light A/C
- The HFC allowance program is another mechanism. It affects production and imports.
- Allowances were established for 2022 and 2023, similar to the quota process used for R-22.

CARB California

New Equipment	GWP Limit	Date
Domestic Refrigerators	150	2021
Comm Refrig. (+50lb)	150	2022
Small A/C (Window,,…)	750	2023
A/C Chillers	750	2024
Larger A/C (RAC, Comm)	750	2025
Comm. A/C (VRF)	750	2026

- California is pursuing GWP limits similar to EU F-Gas.
- The more aggressive measures use GWP<150. The expectation is for others to follow.
- They have been receiving input from the whole industry. Hence, GWP limits are being implemented progressively.

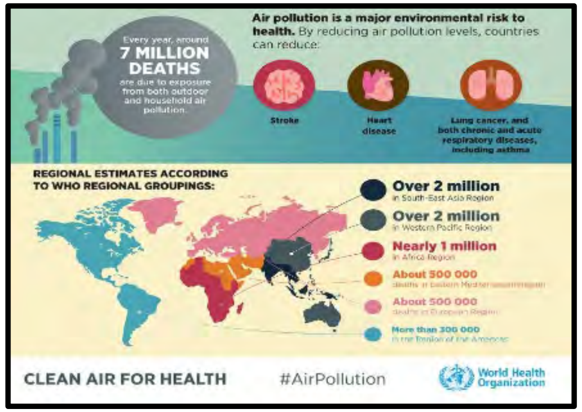
GWP<150 seems to be the long-term target

Selected Low-GWP Refrigerant R&D Efforts at ORNL

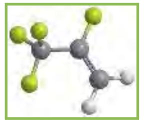
- Fundamentals
- Enabling Technologies
- Applications

Low GWP Refrigerant R&D Work at ORNL

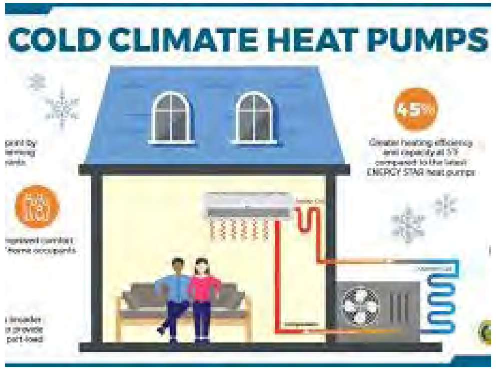
The quest to accelerate the deployment of A/C Heat Pumps and Refrigeration Systems



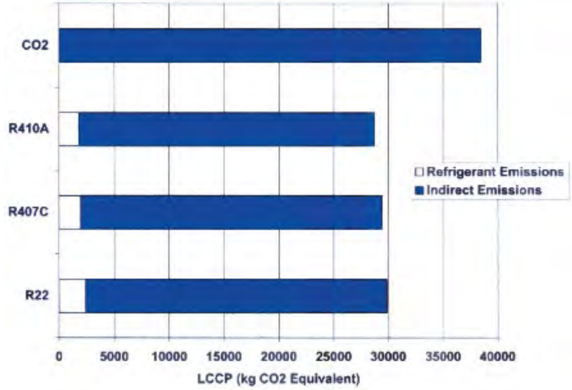
The true impact of TFA formation



Heat Exchangers & Compressors for refrigerants



Cold Climate Heat Pumps using low GWP Refrigerants



CO_2 emission over the lifetime of the equipment using low GWP refrigerants

Tackling the Environmental Challenges

- Support the chemical and HVAC industry in their evaluations of Environmental issues with the new Low GWP refrigerants (HFCs, HFOs, Hydrocarbons, CO_2)
- Perform scientific studies to evaluate the environmental impact of degradation products

Optimization of Key Components

- Development of optimized heat exchangers for the next generation of refrigerant with GWP<150
- Develop high efficiency compressors designed to perform well with new refrigerant (GWP<150).

Development of HVAC Systems

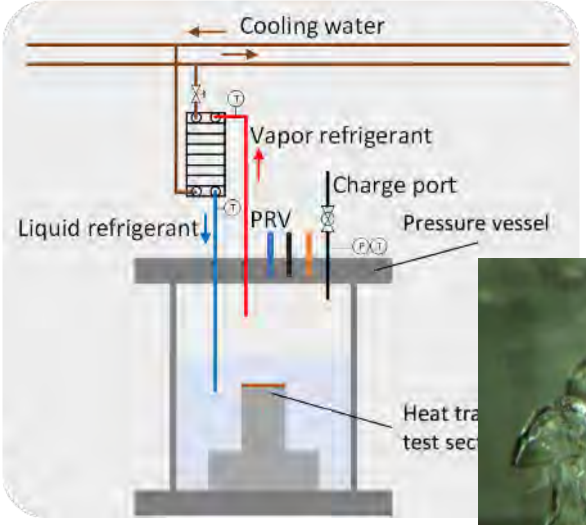
- Development and use of advanced system models (HPDM to design Heat Pumps, Refrigeration systems, Heat Pump Water heaters and refrigerators).
- Experimental evaluations of system using ultra-low GWP refrigerants

Ensure Sustainability based on Lifetime Evaluations (LCCP, LCA)

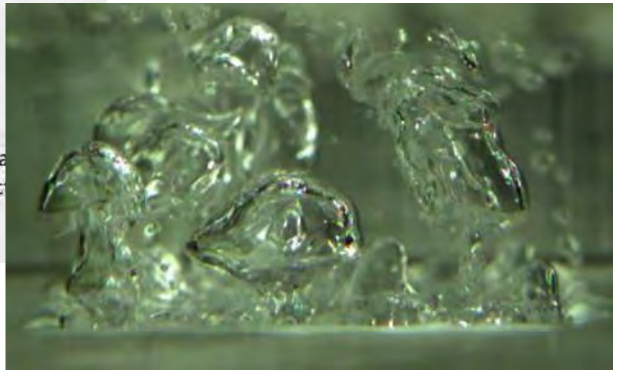
- RAC Heat Pumps LCCP model
- Refrigeration LCCP model......
- Use models of new systems to produce reliable LCCP and LCA data

Low GWP Refrigerant R&D – Fundamentals

Pool Boiling Heat Transfer



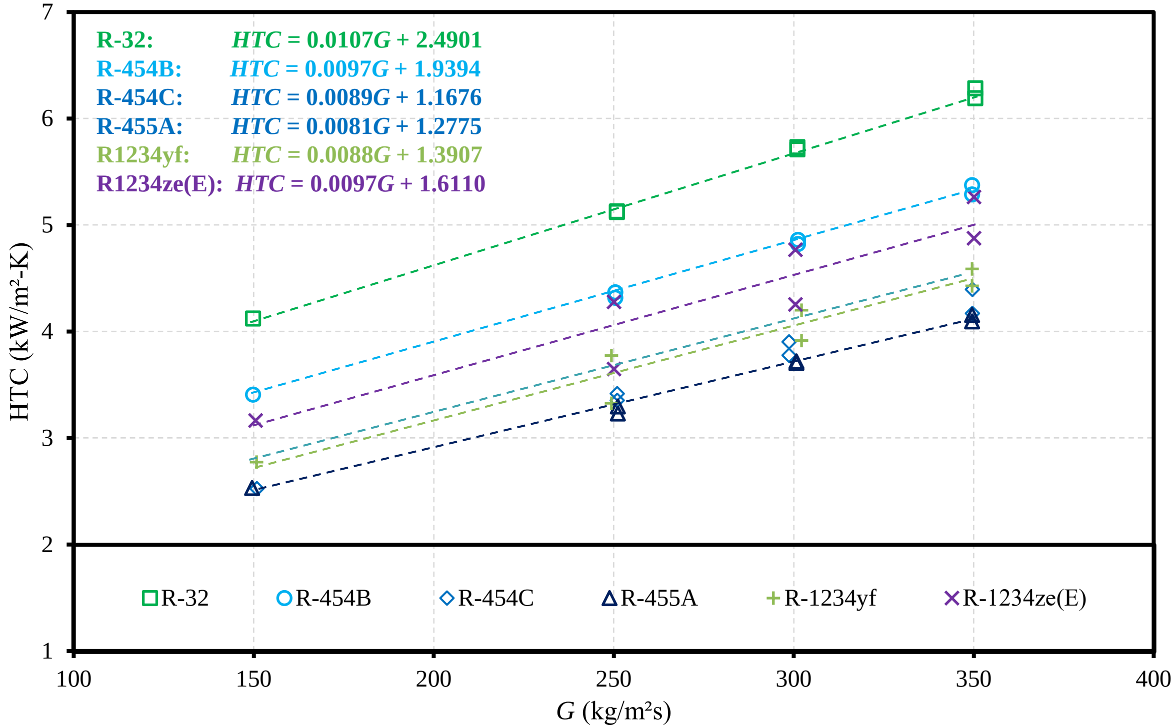
Pool boiling facility



Fundamental data to enable immersion cooling for data centers

- Data center energy consumption is increasing rapidly, and air cooling is quickly reaching its limit.
- Immersion cooling using ultra low GWP fluids can reduce GHG by 40% compared to current air-cooled technologies

Heat Transfer and Pressure Drop Characterization

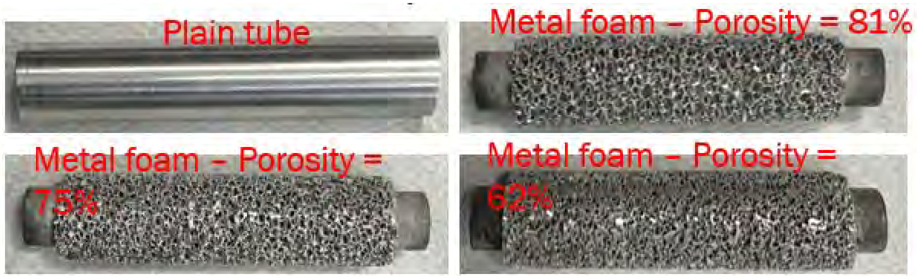


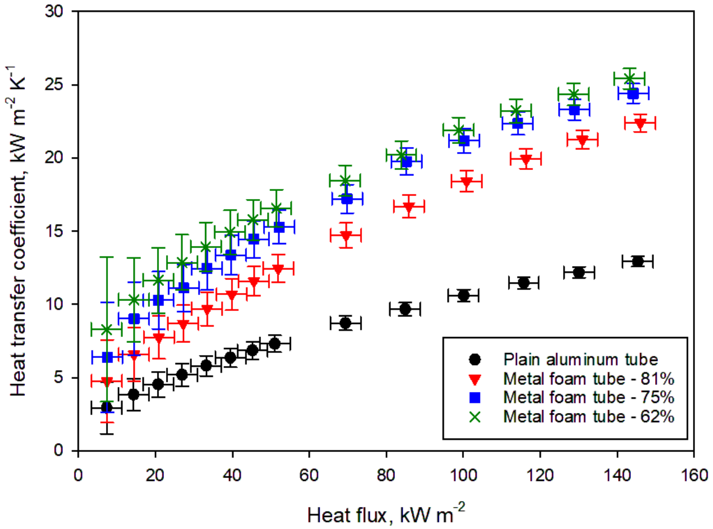
Data for condensation of high-glide mixtures

. This study is among the first to be performed for this tube material (aluminum), geometry (axial micro-fin tubes), and using low GWP refrigerant mixtures

Low GWP Refrigerant R&D – Enabling Technologies

Compact Flooded Evaporators for Commercial AC and Refrigeration

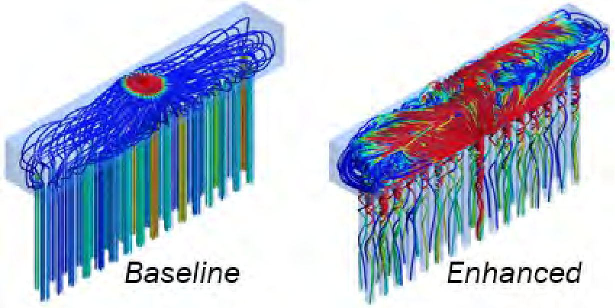




Advanced materials provide significantly enhanced heat transfer, resulting in smaller heat exchangers with reduced refrigerant charge.

Heat Exchanger Solutions for Low GWP Refrigerants

Liquid-to-refrigerant heat exchanger test facility

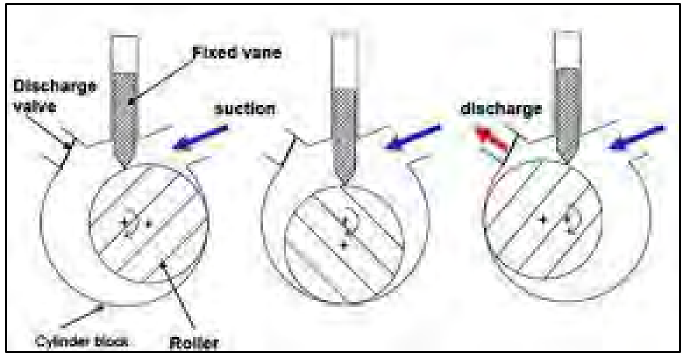


Simulation of flow in a novel heat exchanger manifold

Compressor Technology Development

Reciprocating

Scroll

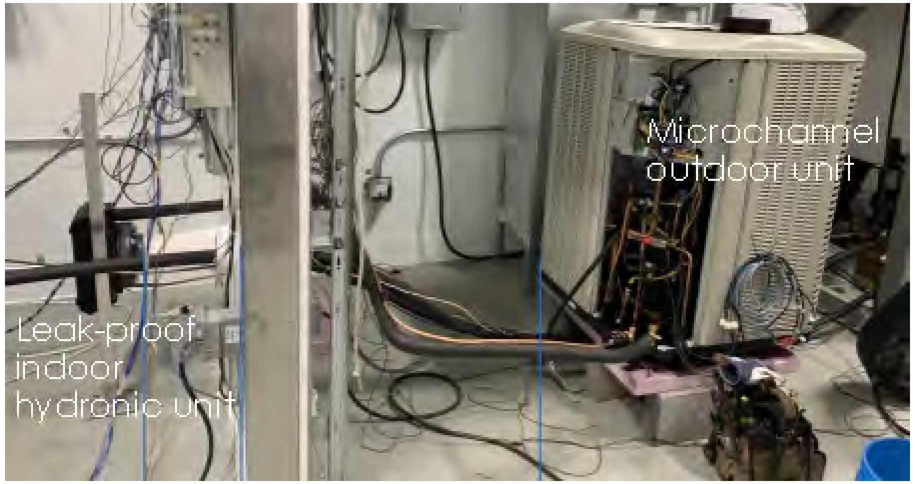


Rotary

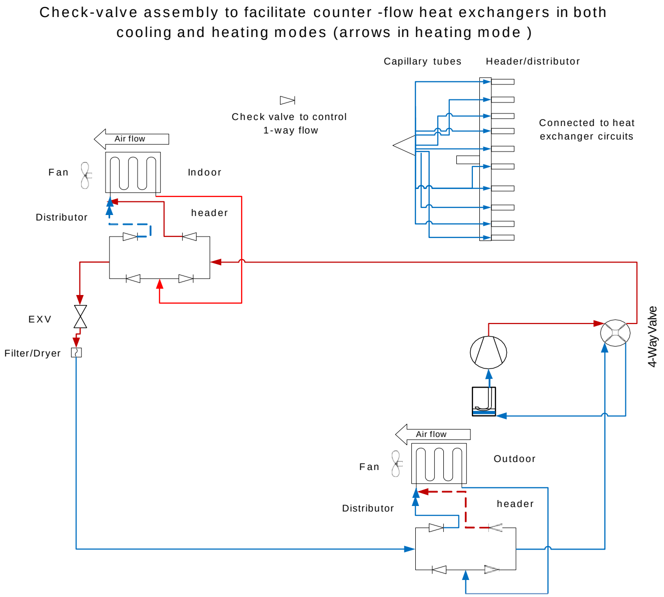
Minimizing compression heat losses and internal leakage, and proper Electric motor selection and sizing are crucial for achieving high efficiency

Low GWP Refrigerant R&D - Applications

Hydronic Heat Pump using Propane
Less than 1200 grams of propane;
Achieved 16 SEER/10 HSPF



Low-cost Heat Pump using Novel Reversible Heat Exchangers
High glide R-457A (GWP=139);
Achieved 16 SEER/10 HSPF

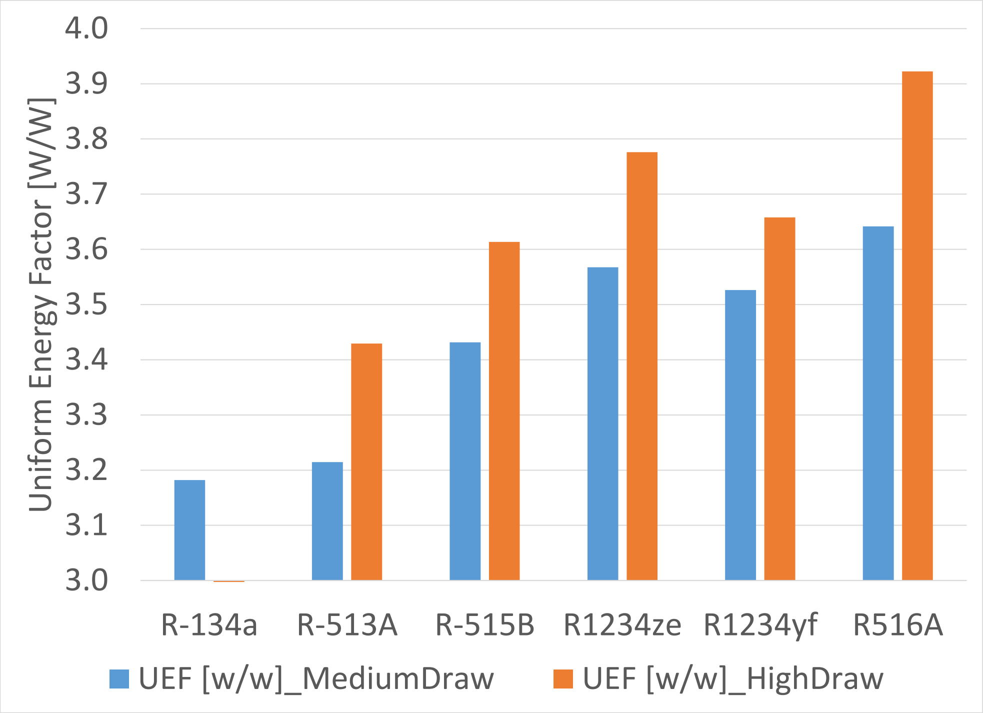


5-mm tube cross-counterflow outdoor coil

Micro-cascade supermarket refrigeration system
Trial at a local supermarket in Tennessee
Two condensing units charged with R-471A

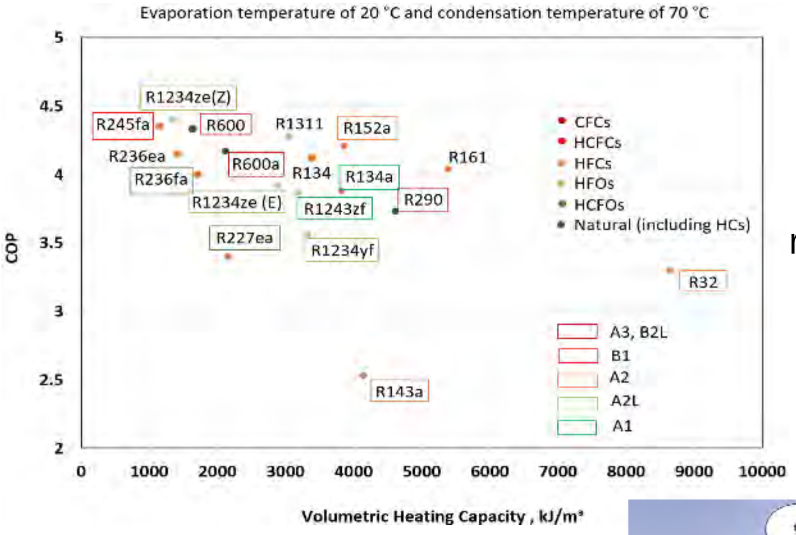
Low GWP Refrigerant R&D - Applications

Low GWP Refrigerant Evaluation in a 50-gallon, 110V Residential Heat Pump Water Heater

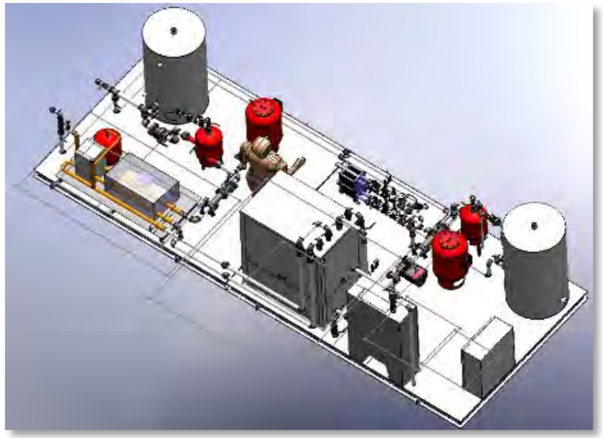


	R-134a	R-513A	R-515B	R1234ze	R1234yf	R516A
Optimized Charge [oz]	64	64	68	64	64	56
UEF [w/w]_MediumDraw	3.18	3.21	3.43	3.568	3.526	3.642
UEF [w/w]_HighDraw	N/A	3.43	3.61	3.776	3.658	3.922
FHR [gallon]	69.2	63.5	58.9	63.2	66.8	68.8

High-Temperature Heat Pumps for Commercial Building Space and Water Heating



Low GWP refrigerant selection



High-temperature heat pump test bed

Collaboration Mechanisms

Funding mechanisms and Collaboration mechanisms

Ways to fund research at ORNL

- AOP (DOE)
- Lab Call (DOE)
- FOA (DOE)
- SPP (non-DOE)
- SEED and LDRD (ORNL)

Ways other organizations can work with ORNL

- CRADA
- Subcontract
- Co-funded partner (FOA)
- Informal advisory role

Industry collaboration mechanisms

Table is non-comprehensive and for illustrative purposes only

Collaboration mechanism	Industry contribution		*Typical* treatment of generated IP	Publications and reporting requirements
	Quantity	*Type*		
FOA: funding opportunity announcement	10-20% cost share	In kind	Background: unchanged By industry: industry owns By ORNL: ORNL owns Joint: right of first refusal	Annual peer review. Journal, conference pubs. Regular reporting to DOE.
CRADA: cooperative research and development agreement	50% typical	In kind[3]	Background: unchanged[1] By industry: industry owns By ORNL: ind. has ROFR[2] Joint: ind. file; has ROFR	Journal, conference pubs. Regular reporting to DOE. Final report (optional embargo for some years).
SPP: strategic partnership project	100%	Direct funds	Industry sponsor may own or take title to generated IP	Report to DOE.

Footnotes cover some additional details:

1. Can become CRADA subject inv. if first reduced to practice under CRADA
2. Commercial license is another option
3. Can also be combination of in-kind plus funds-in

More details: https://www.ornl.gov/sites/default/files/MechanismsMatrix.pdf

Acknowledgements

- Contributors to these slides: Bo Shen, Zhenning Li, Xiaobing Liu, Jason Hirschey, Sara Sultan, Chad Malone, Kashif Nawaz, Brian Fricke, and more from ORNL team
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- This research used resources at the Building Technologies Research and Integration Center, a DOE Office of Science User Facility operated by the Oak Ridge National Laboratory.


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OAK RIDGE
National Laboratory

Tell Us What You Think…

- What did you find most helpful in this segment?
- What would you like to learn more about?

Drop your thoughts into the chat with #ORNL

Break

Return at 10:45

Agenda

8:30 am	Welcome and Announcements
9:00 am	*New!* ORNL Emerging Technology Update
10:30 am	*Break*
10:45 am	*New!* New Buildings Institute
11:45 am	*New!* Regional Room Heat Pump Field Study
12:00 pm	*Break*
12:15 pm	*New!* NW Power & Conservation Council
12:45 pm	Wrap-Up

New Buildings Institute

NBI Selected Emerging Tech Spotlights

Presented to NEEA RETAC | June 27, 2024

What is New Buildings Institute?

- 501(c)(3) nonprofit
- 25+ year history
- **Mission**: We advance best practices, codes, and policies through market leadership, research, guidance, and technical advocacy toward a built environment that equitably delivers community benefits and climate solutions.

www.newbuildings.org

NBI headquarters office at PAE Living Building, Portland, OR Photo by Portland Drone

NBI’s Building Innovation Team

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Technical Associate

NOAH GABRIEL
Senior Project Analyst

DR. VIDHISHA MOOPNAR
Project Analyst

SMITA GUPTA
On Assignment at CEQ

Today's Agenda

1. Overview of the "MOVER" electric school bus resiliency microgrid field validation project (in Hood River, OR)

2. Sneak peek at results from NBI's 120V HPWH field study phase 2: load shifting & TOU optimization (in CA)

3. Overview of NBI's just-launched "MAGIC" central HPWH field validation (nationwide, incl. Portland, OR)

4. Evaluating the distribution grid level impacts of building electrification (by utility, starting with SCE, CA)

JOE WACHUNAS
Senior Project Manager

NOAH GABRIEL
Senior Project Analyst

ALEXI MILLER
Director of Building Innovation

Photo: Lion Electric

nbi new buildings institute

MOVER Demonstration Project

Microgrid Opportunities: Vehicles Enhancing Resiliency

MOVER Project Technologies + Funding

1) Electric school bus, Solar, EVSE, Batteries

2) It takes a village to fund a microgrid

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

PACIFIC POWER
A DIVISION OF PACIFICORP

bef BONNEVILLE ENVIRONMENTAL FOUNDATION

HOOD RIVER ELECTRIC & INTERNET CO-OP

OREGON DEPARTMENT OF ENERGY

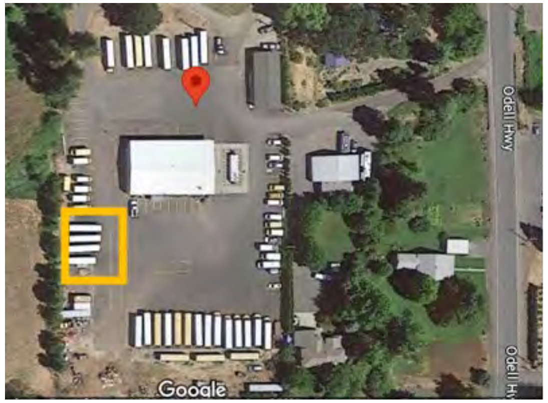
MOVER Goal - #1

Begin to electrify Hood River County School District’s (HRCSD) bus fleet

- Purchase an electric school bus
- Train staff
- Install Level Two EV chargers & extras for future EV purchases

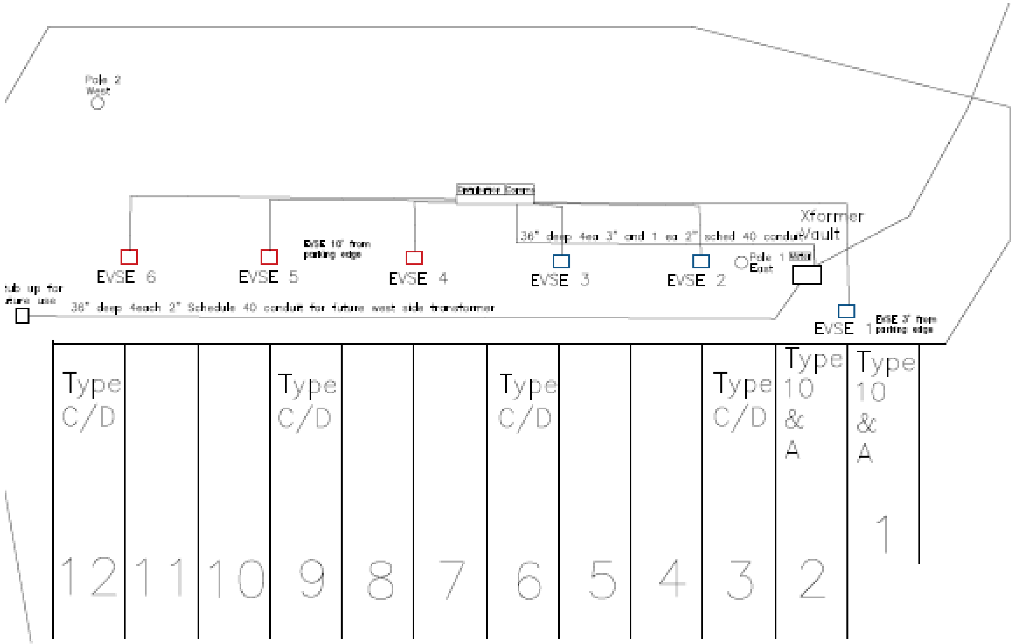
Wy’East Middle School

Administrative Offices



Bus Barn

Challenges, Progress, Learnings



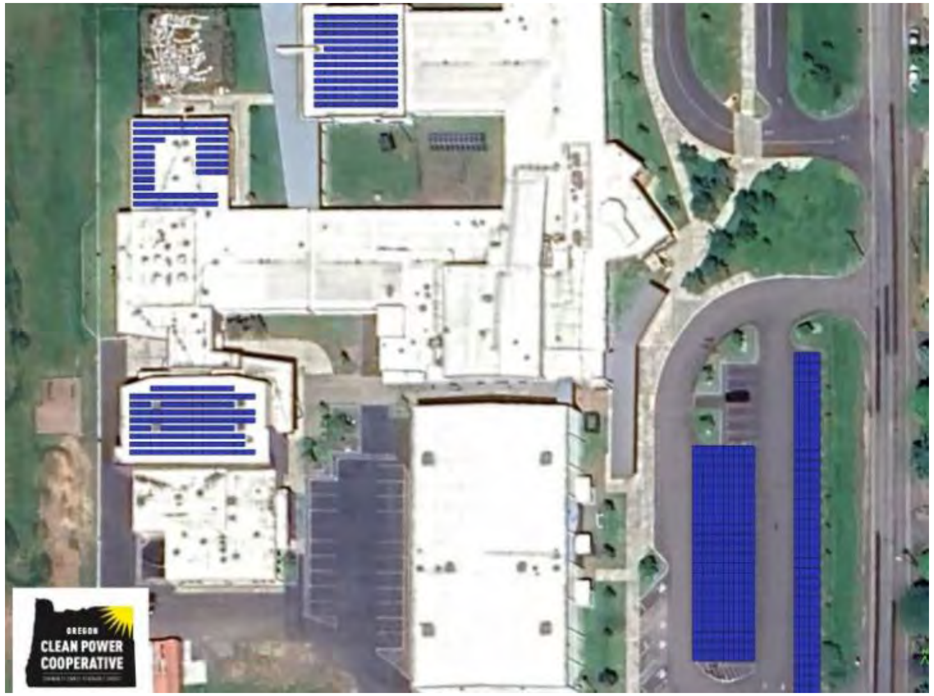
- Bus Barn charger design
  - Significant assistance required
- Vehicle standards and interoperability within microgrid
  - Still working out standards
  - Need for vehicles to have drop down snow chains
- EVSE and software interoperability within the microgrid
  - V2B is a good starting point for bi-directional charging
  - Ensuring open standards to guard against companies going out of business
- MOVER Funding has led to more ESB Funding

MOVER Goal #2

Install Solar Panels at Wy’East Middle School

- Lower utility bills & provide renewable energy day-to-day
- Provide power for resiliency oriented microgrid

Challenges, Progress, Learnings



- Needed utility permission for large PV array
  - HR Co-op board approved in February, 2024
- Snow loads and structural issues disqualify many buildings
- Solar canopies are emerging as a low-cost solar option

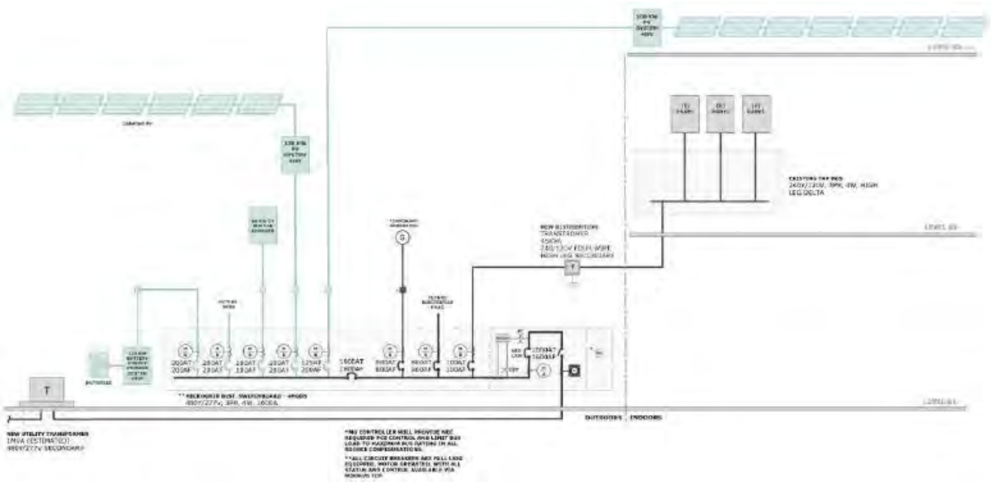
MOVER Goal - #3

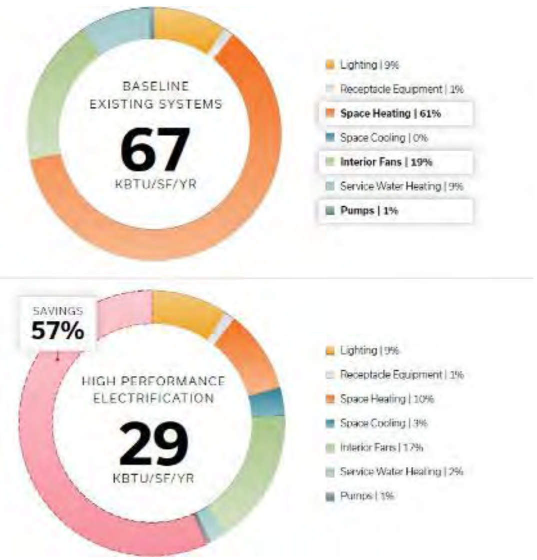
Create Microgrid at Wy'East Middle School

- Create a safe place for the community during grid outages

- Test the concept to teach other schools how to install their own microgrids

Challenges, Progress, Learnings





- Existing electrical systems present challenges
  - System upgrades necessary - long lead times
- Existing mechanical systems challenge resiliency
  - Gas heating + no cooling have led the team to look to electrify HVAC systems… added cost & time to project
- Commissioning microgrid will be an adventure!
  - There will be learning galore
  - No workforce to service the microgrid

Project Timeline

2024	2025	2026-2027
• Feedback and design • Purchase bus	• Installation and testing • Student education • Staff training	• Operation and study • Student education • Publish results

Contact: joe@newbuildings.org

Questions?

ADVANCED WATER HEATING INITIATIVE

Advanced Water Heating Initiative

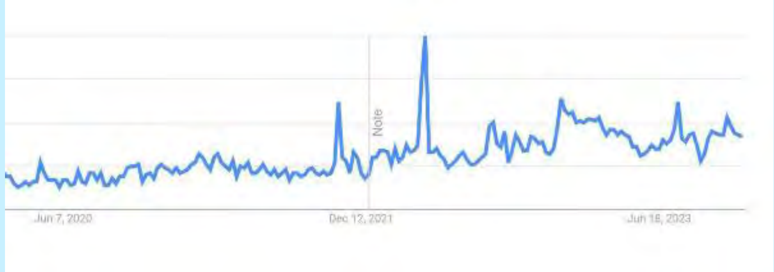
2024 Update

new buildings institute

AWHI Impact

New products

Increased sales and interest



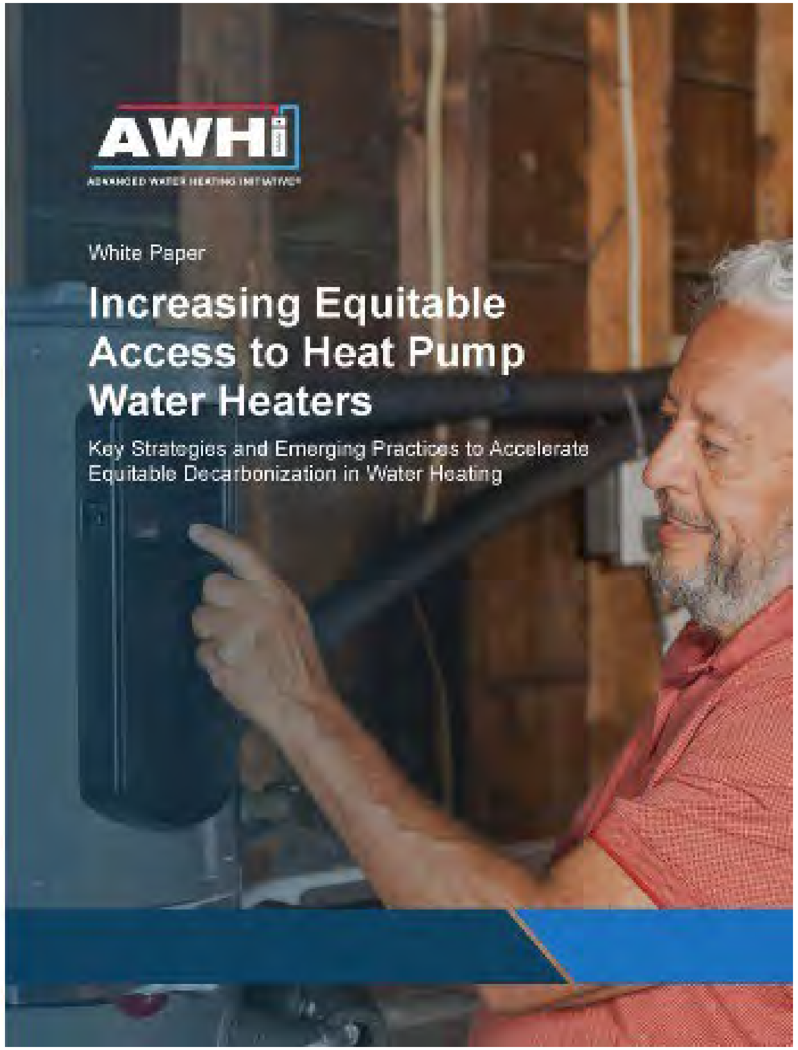
Policies to drive Market Transformation

AWHI & Related 2024 Projects

Advanced Water Heating Initiative

National Initiative	Technology Focused Projects	Outreach
DOE Convener	National Field Validation Partnership Pacific Northwest NATIONAL LABORATORY	San Diego LEARN Webinars SAN DIEGO LEARN
	120V Pilot Project – Phase 2 Pacific Gas and Electric Company SOUTHERN CALIFORNIA EDISON Energy for What's Ahead SMUD TECH	CEDA Webinars CEDA
AWHI Sponsors SMUD NEW YORK STATE OF OPPORTUNITY. NYSERDA neea THE McKNIGHT FOUNDATION comed AN EXELON COMPANY SOUTHERN CALIFORNIA EDISON An EDISON INTERNATIONAL Company	MAGIC	HPWH Day 
	Buildings Up NREL NATIONAL RENEWABLE ENERGY LABORATORY	

See Our Two Most Recent Reports



Contact: joe@newbuildings.org

Questions?

Load Shifting with 120V HPWHs

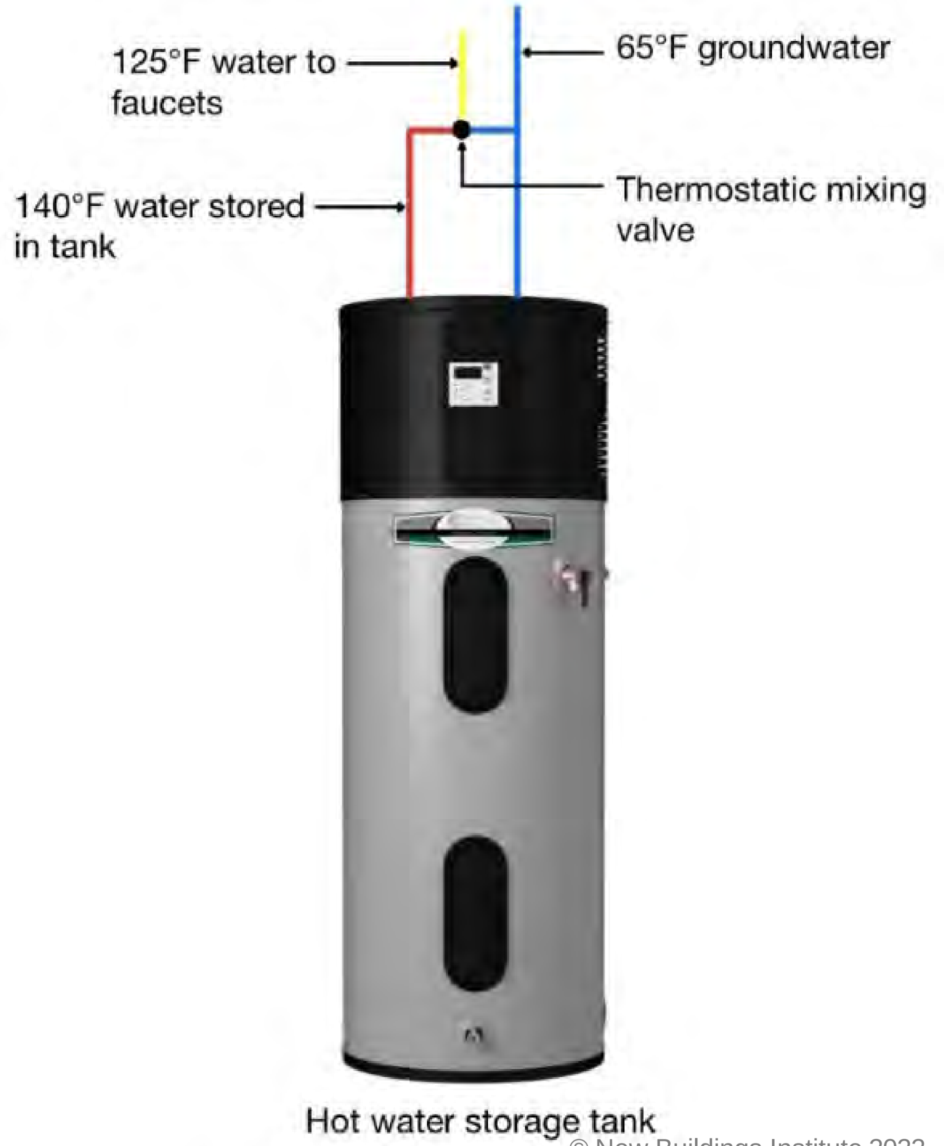
Noah Gabriel, New Buildings Institute
Thursday, June 27th

What is a 120-volt HPWH?

Operates on a **120-volt, 15-amp circuit**

Usually has a **thermostatic mixing valve** (TMV)

Trades power for **increased thermal storage**



The report

nbi new buildings institute

Plug-In Heat Pump Water Heater Field Study Findings & Market Commercialization Recommendations

Lessons learned on the performance of 120-volt HPWHs from California-wide installations

Prepared By:

New Buildings Institute

Authors:

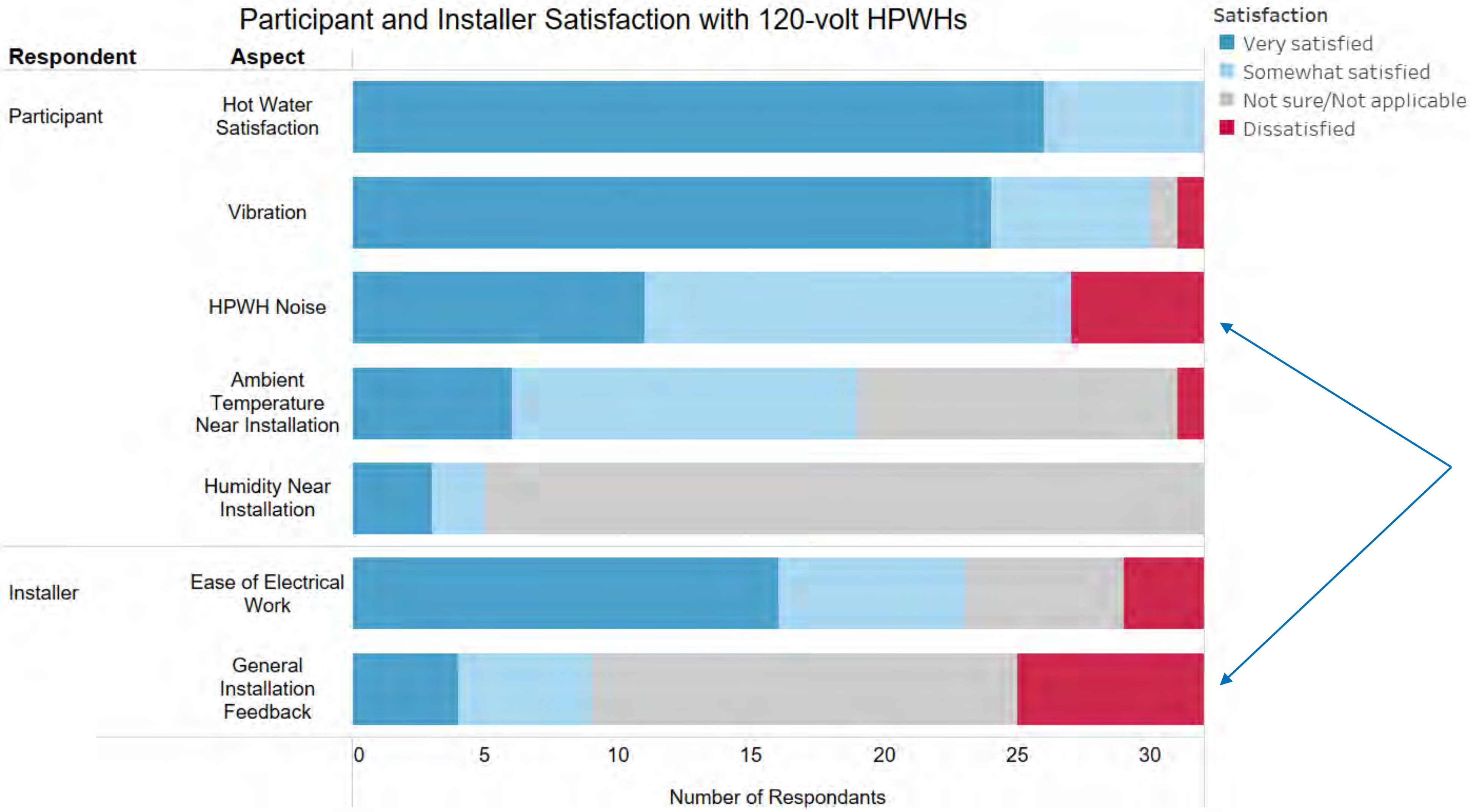
Amruta Khanolkar, Associate Director and Principal Investigator
Mischa Egolf, Technical Associate
Noah Gabriel, Senior Project Analyst

July 2023

In Partnership with Richard Heath & Associates and kW Engineering

Prepared for Pacific Gas and Electric, Southern California Edison, Sacramento Municipal Utility District, TECH Clean California Program, and Department of Energy

Participants were happy with HPWH performance



Key barriers to address

Recruiting participants

Scope:

32 install sites throughout CA for Phase I

12 sites recruited for Phase II

CTA-2045

A standardized set of signals for load shifting:

Load Up

Advanced Load Up

Shed

Research Question 1

How much can load shifting control schedules reduce energy use and utility bills?

Research Question 2

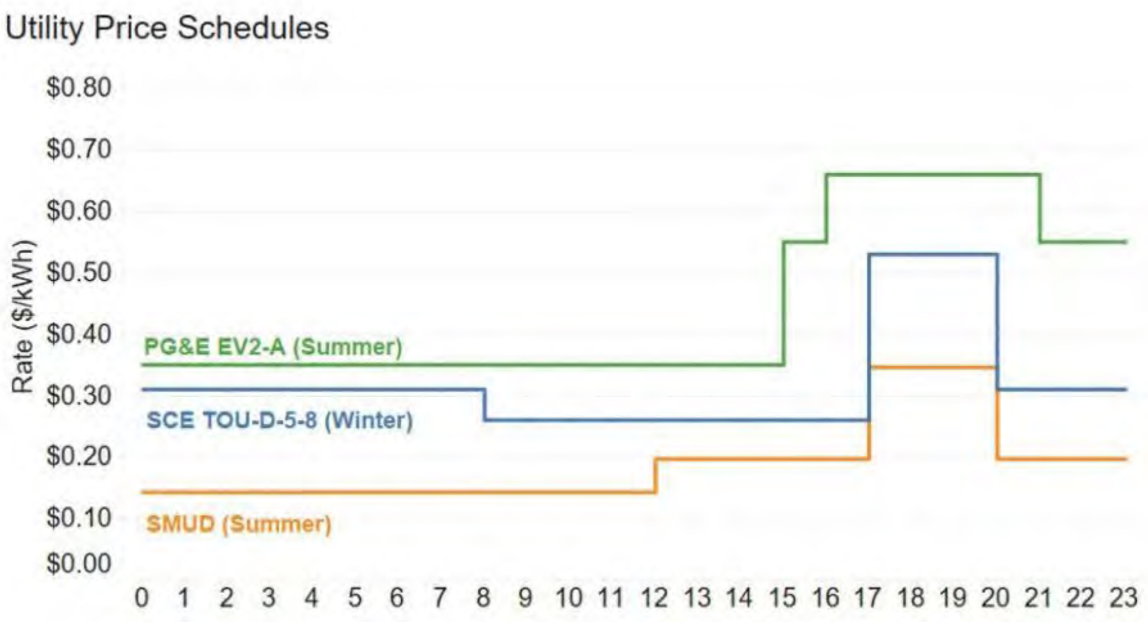
How important is the Advanced Load Up CTA-2045 signal, and do 120V HPWHs conform?

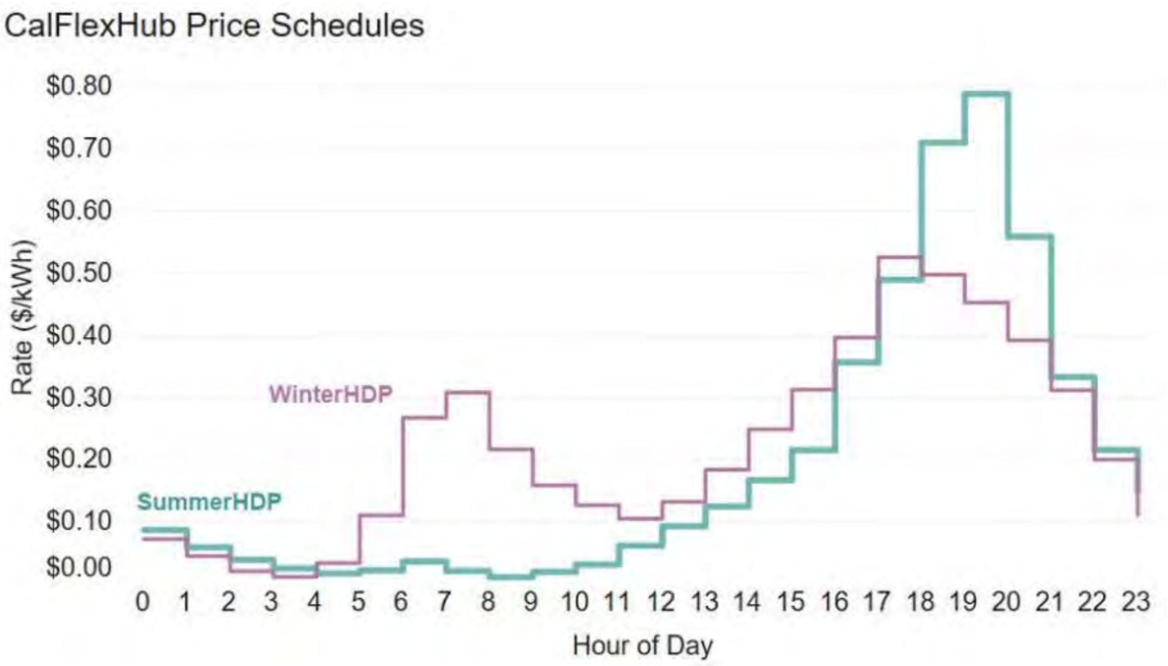
Research Question 3

How can we modify the load shifting controls to accommodate for day-to-day variation in HW consumption?

What's the goal?

To minimize costs for the following price schedules:



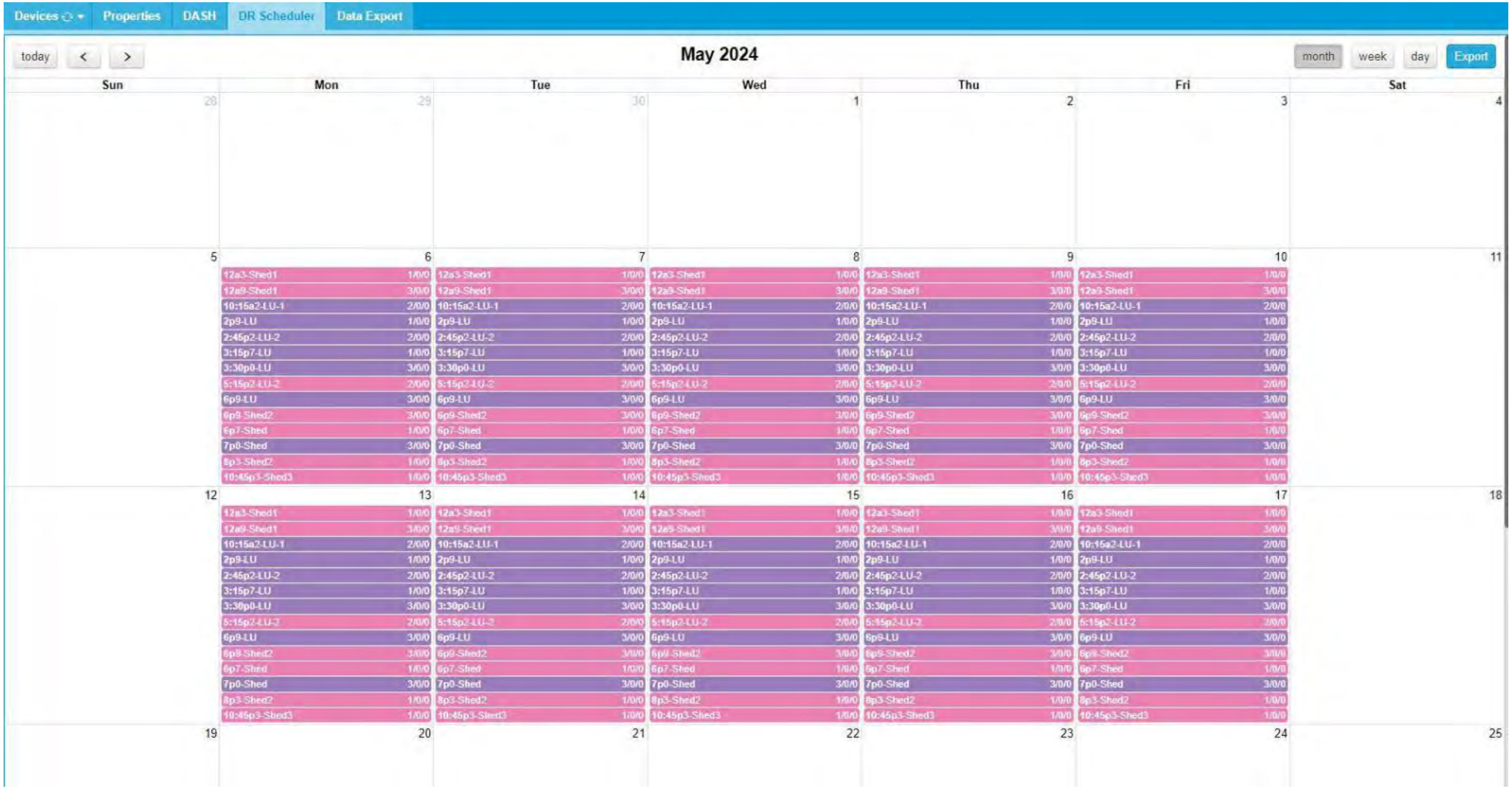


Installing the EcoPort

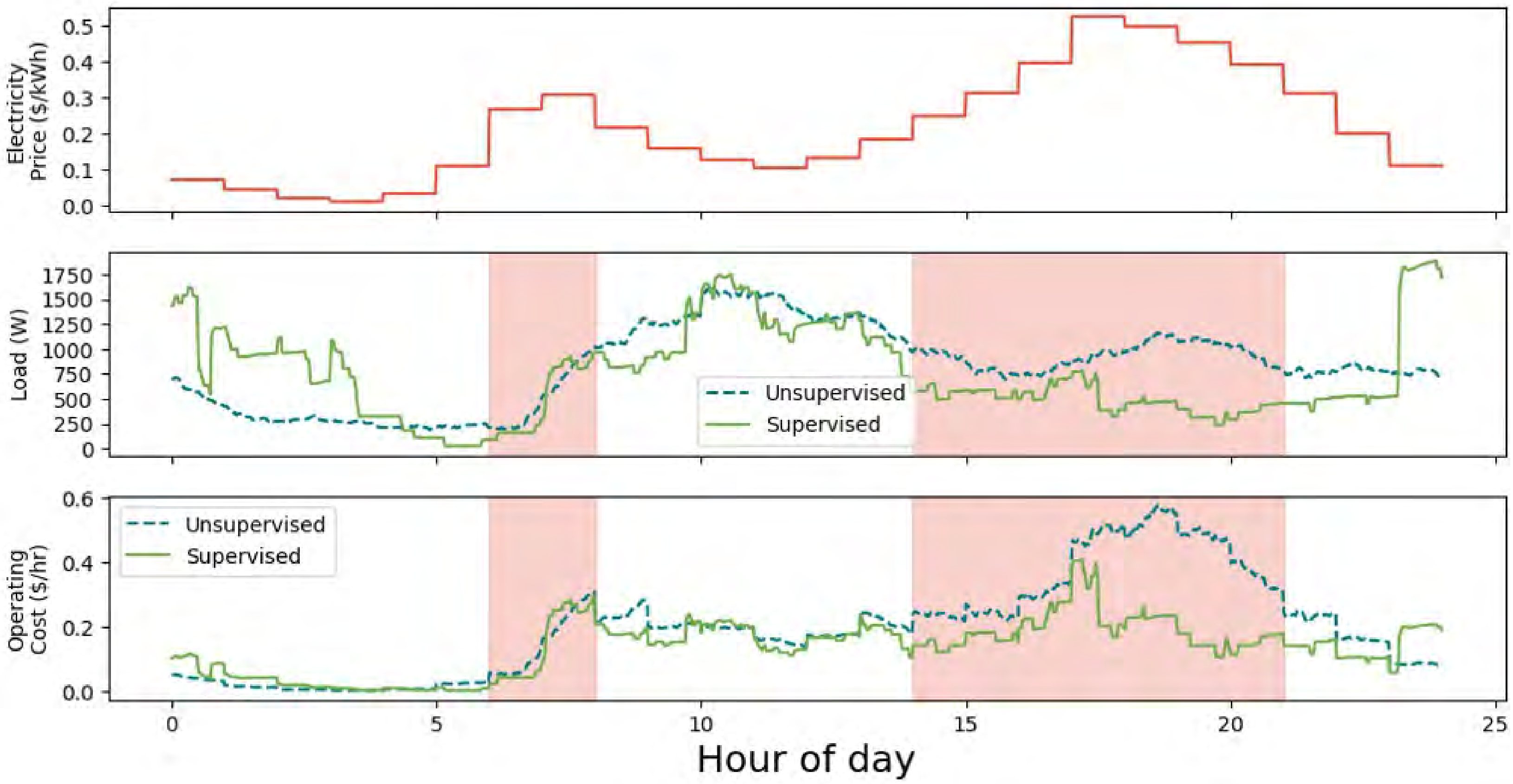
NBI created installation guide for participants

10/12 installed successfully

Scheduling the CTA-2045 signals



CalFlexHub: Winter Price Schedule

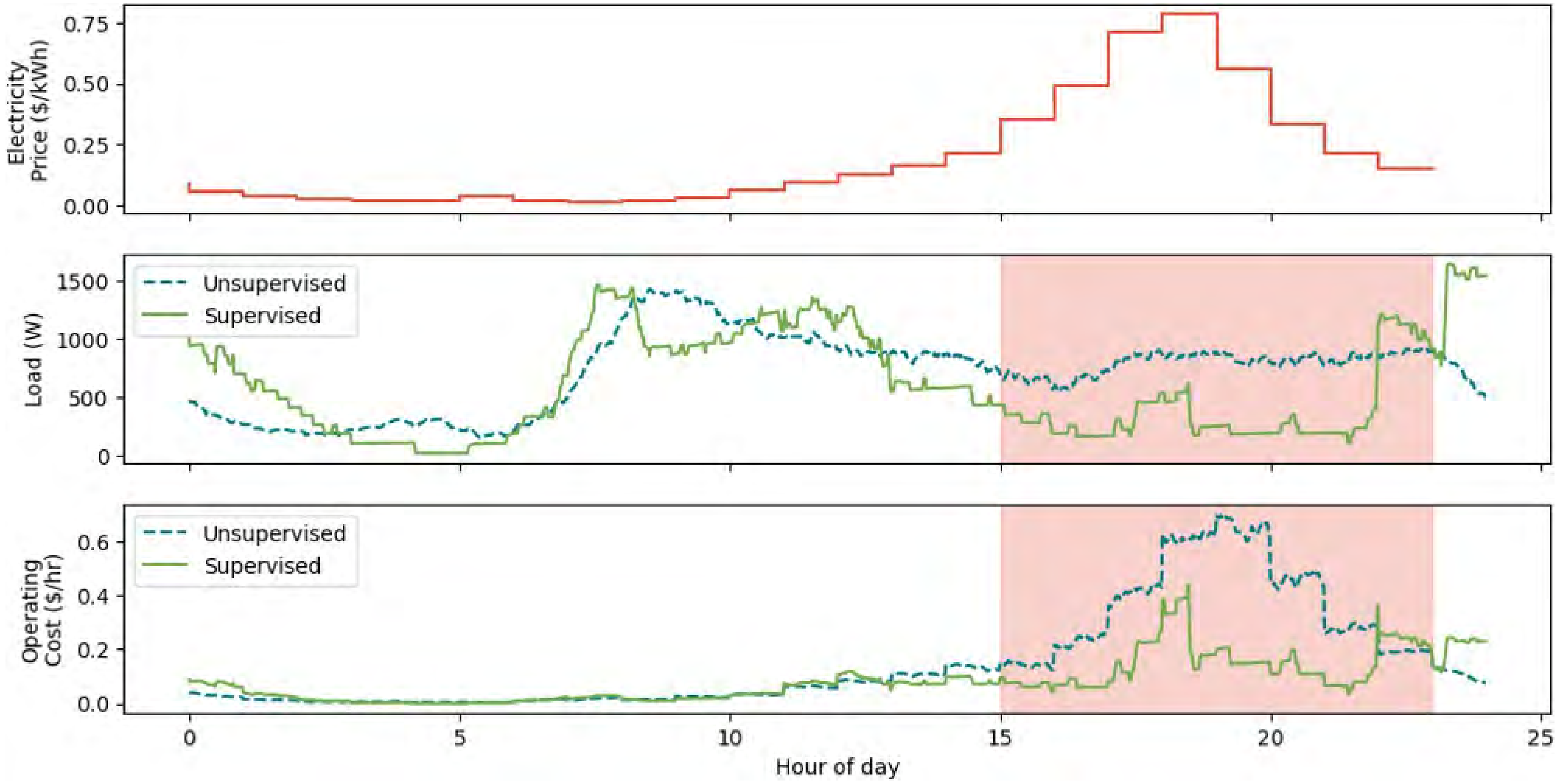


Peak kWh Reduction: 42%

Operating Cost Decrease: 30%

Fleet: 10 HPWHs

CalFlexHub: Summer Price Schedule

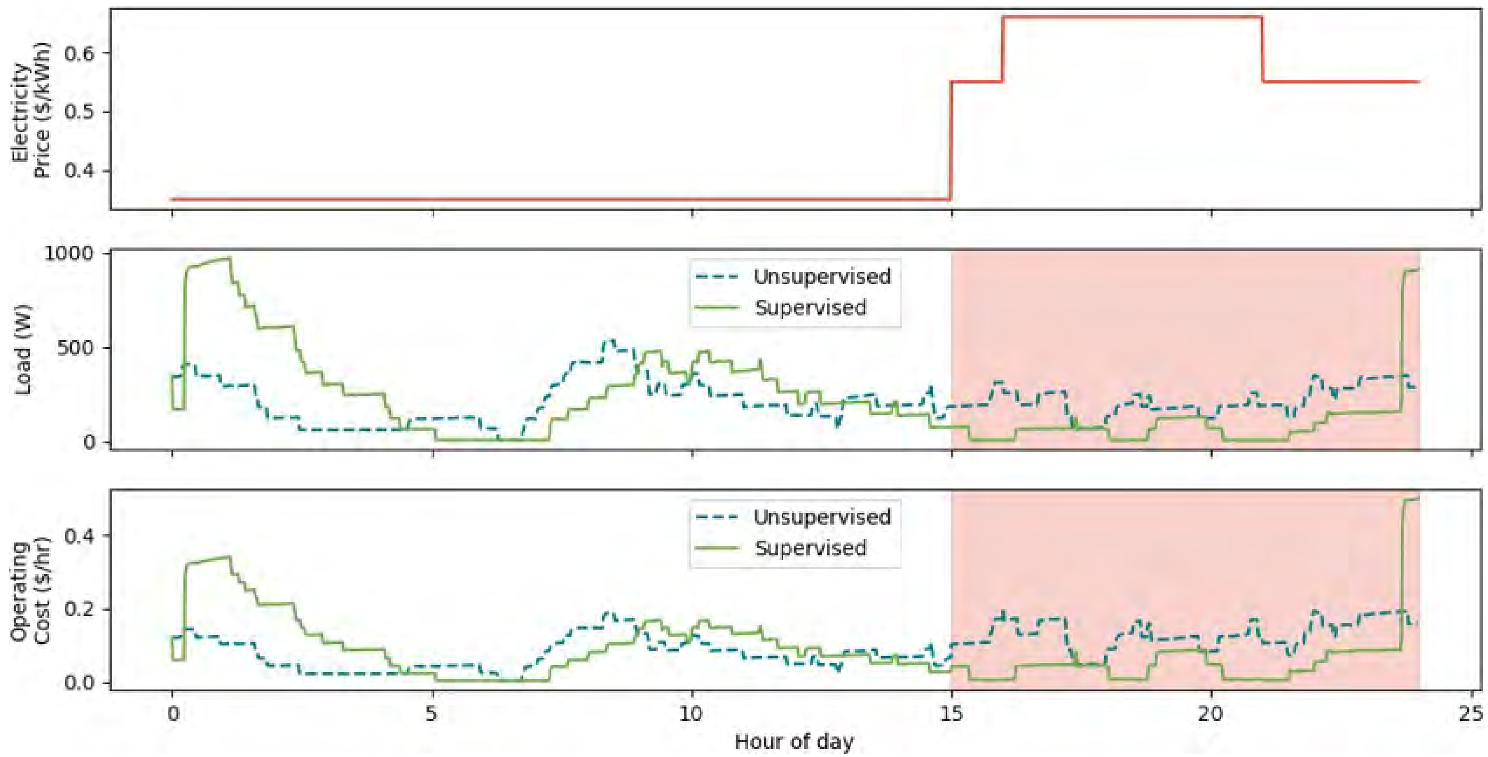


Peak kWh Reduction: 52%

Operating Cost Decrease: 46%

Fleet: 10 HPWHs

PG&E: EV2-A Price Schedule

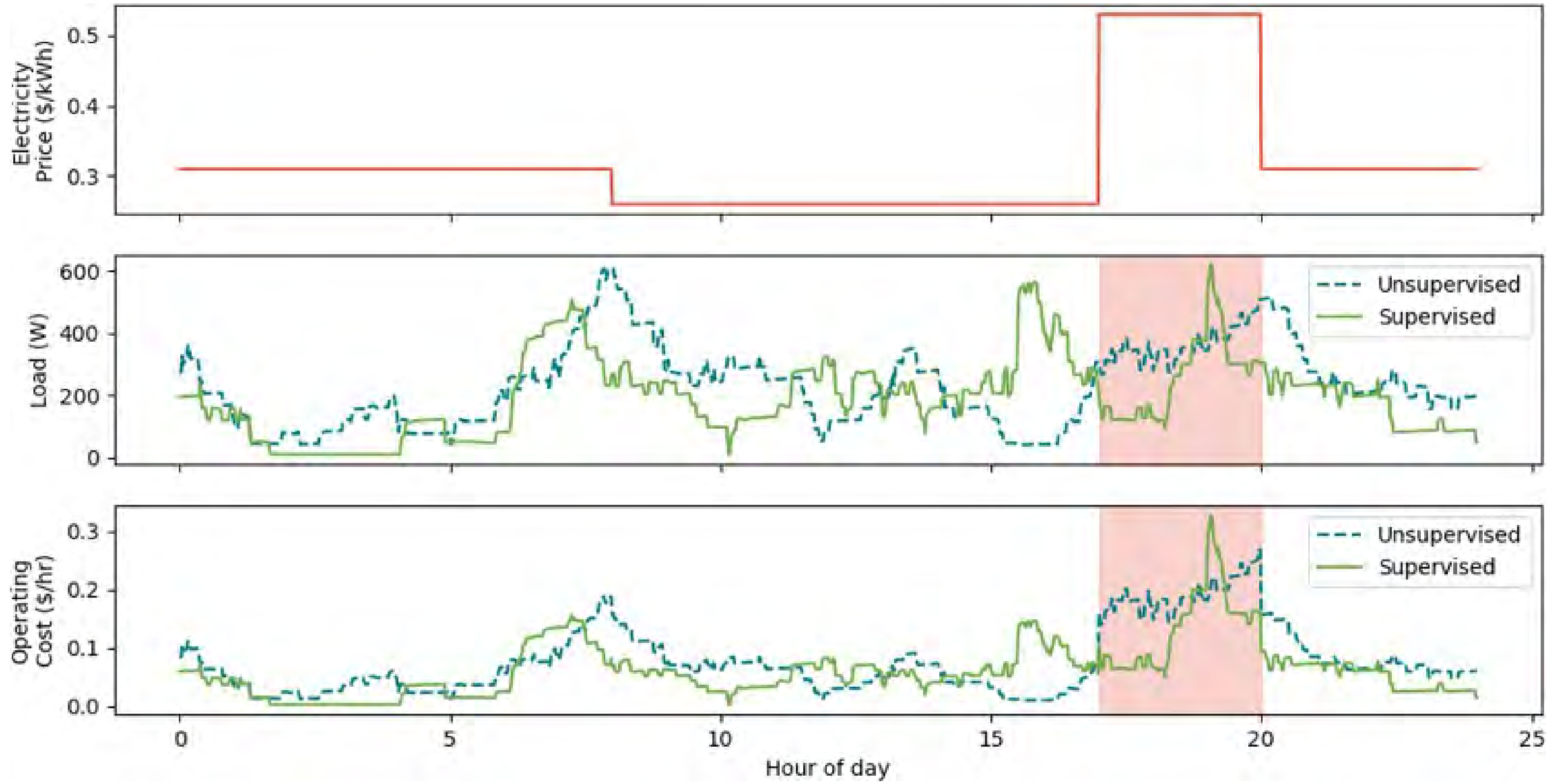


Peak kWh Reduction: 54%

Operating Cost Decrease: 8%

Fleet: 4 HPWHs

SCE: TOU-D-5-8PM Price Schedule

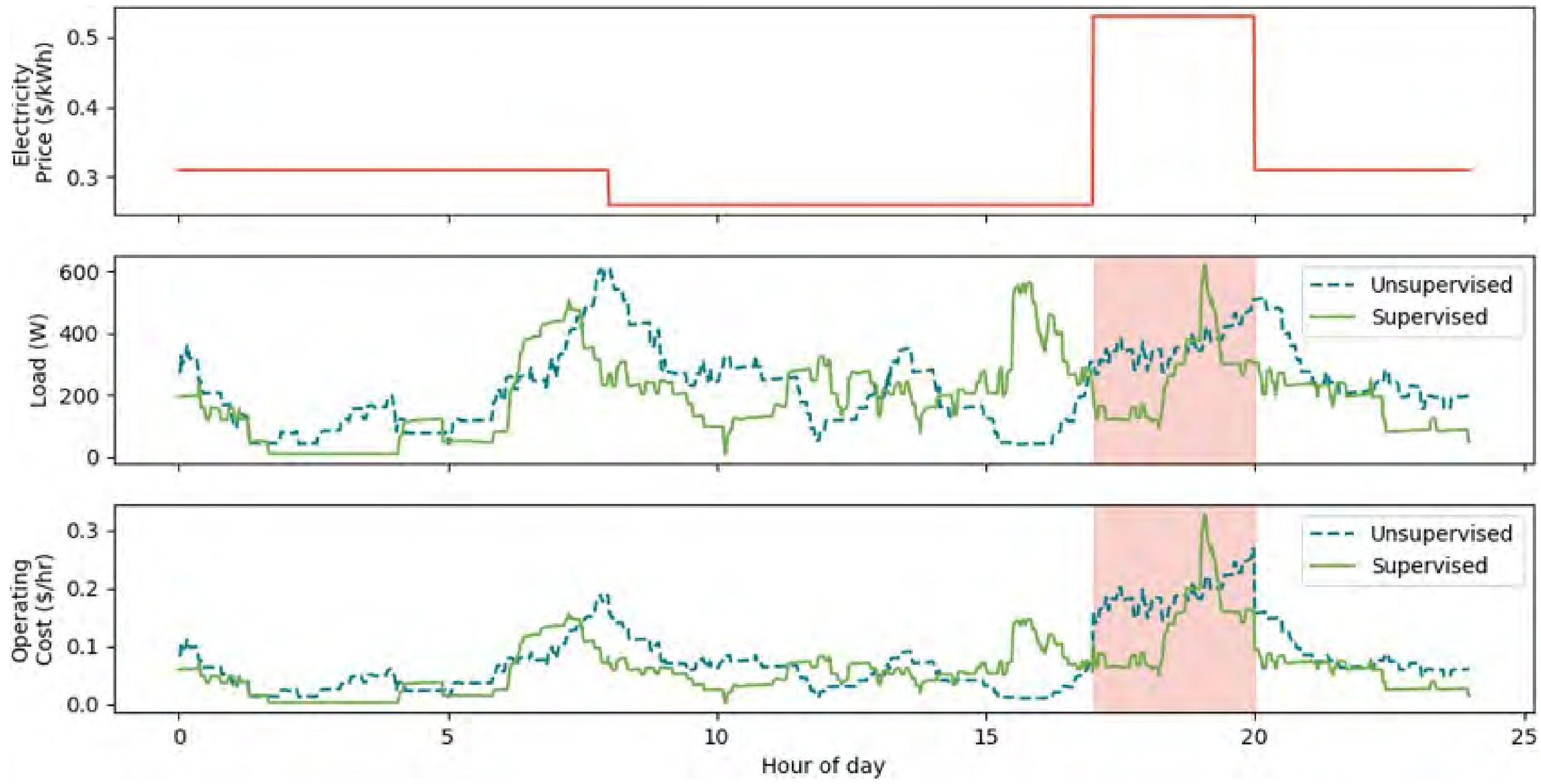


Peak kWh Reduction: 29%

Operating Cost Decrease: 19%

Fleet: 3 HPWHs

SMUD: Summer Price Schedule



Peak kWh Reduction: -5%

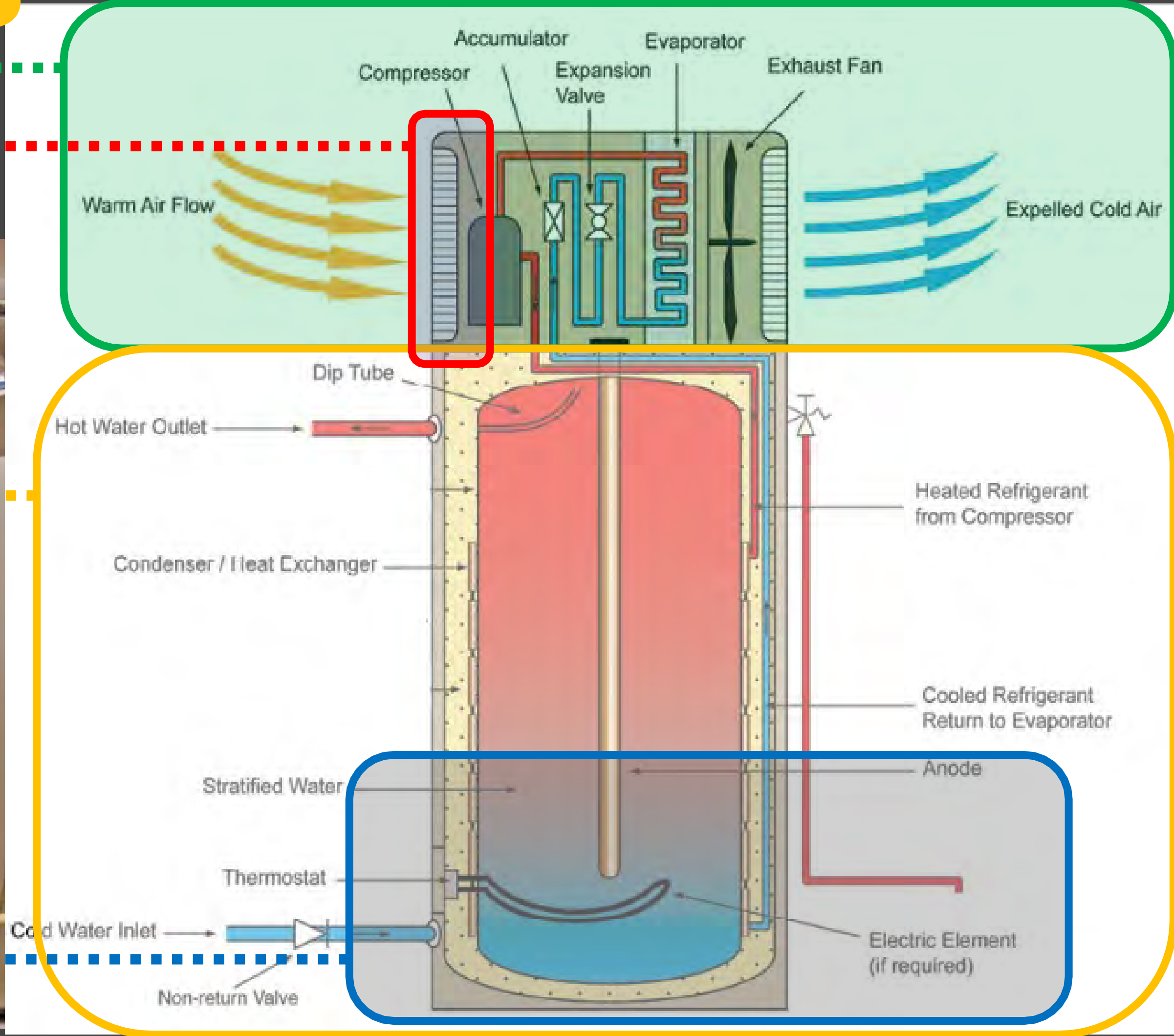
Operating Cost Decrease: -9%

Fleet: 3 HPWHs

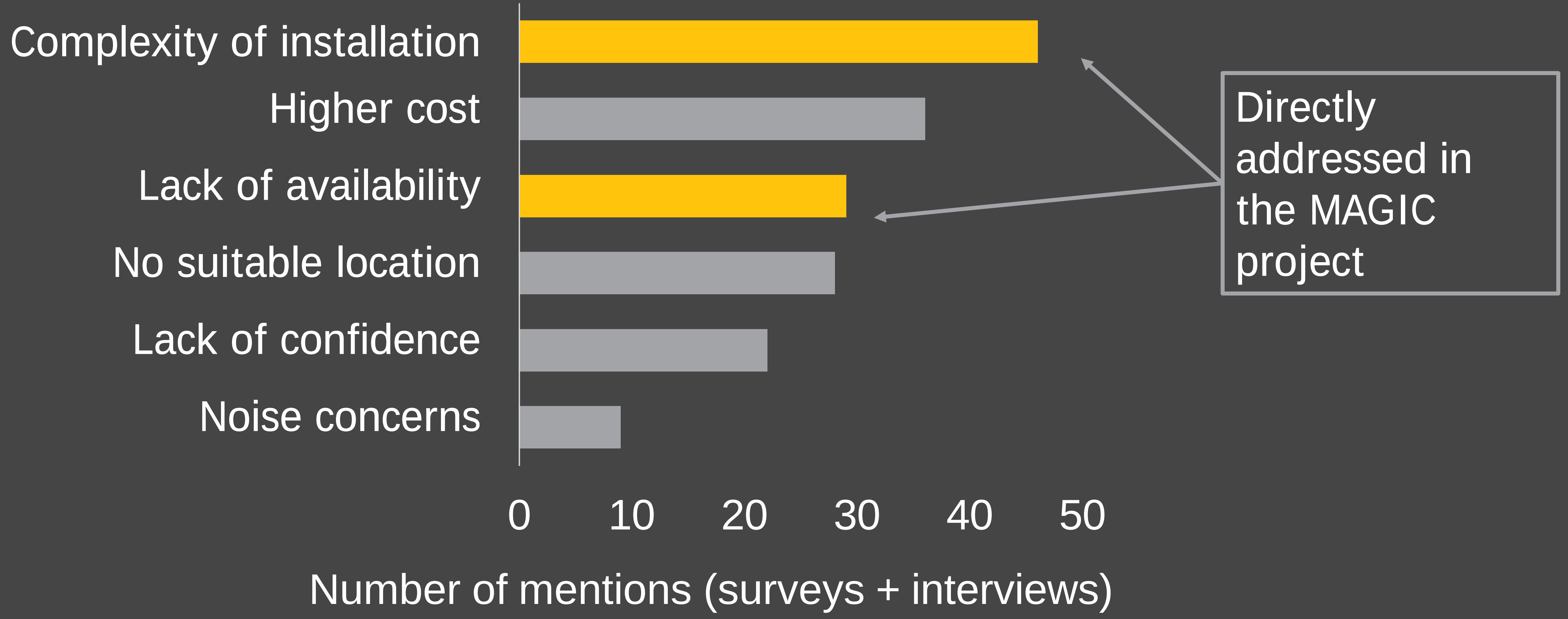
Contact: noah@newbuildings.org

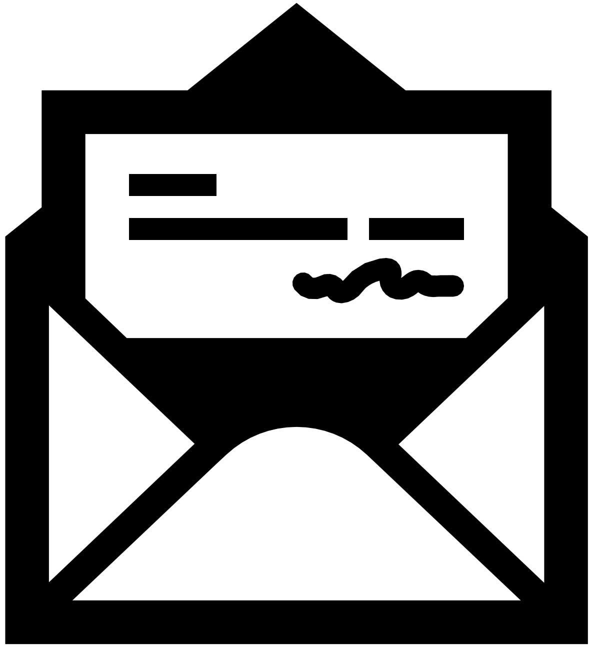
Questions?

Commercial heat pump water heater systems



Barriers to CHWPH Adoption





Upfront cost is a major barrier to adoption, but incentives can provide an effective solution

- **Incentives** most frequently cited driver of CHPWH adoption
- **TECH Clean California**: $1,800 per apartment served for central HPWH systems
- **Pilot demonstration grants** pivotal in advancing this technology

Market Analysis Recommendations

Share best practices

Increase WF education + training

Boost access to building performance data

Promote packaged ("skid") systems

Made in America Grid Integrated Commercial HPWH Systems (MAGIC) Project

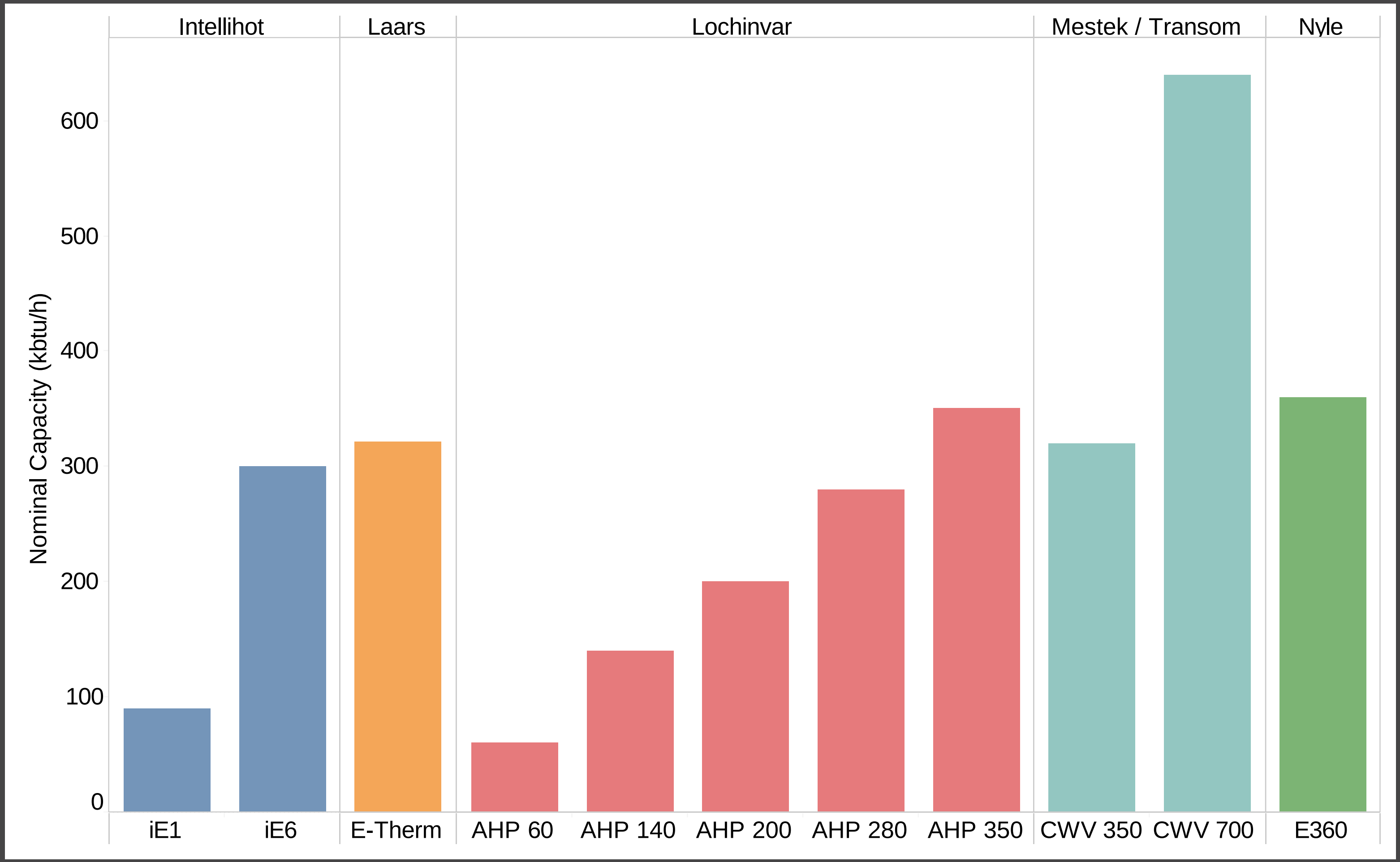
Goal: Enable rapid decarbonization of multifamily water heating by bringing more American-made Commercial HPWHs to market

- Low GWP refrigerants
- Load shifting capability

November 2023 → December 2026

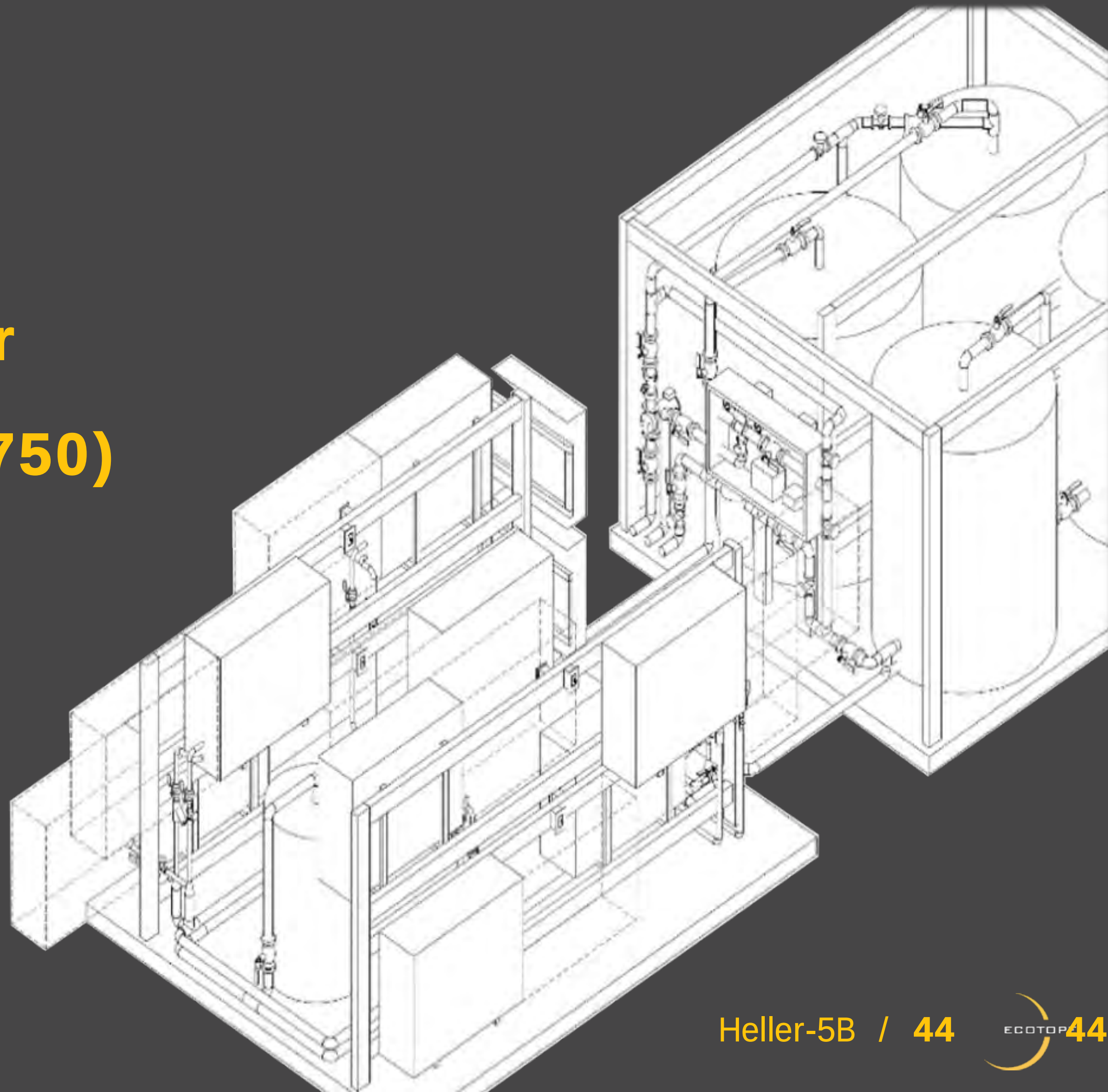
Funded by the U.S. Department of Energy

New MAGIC models



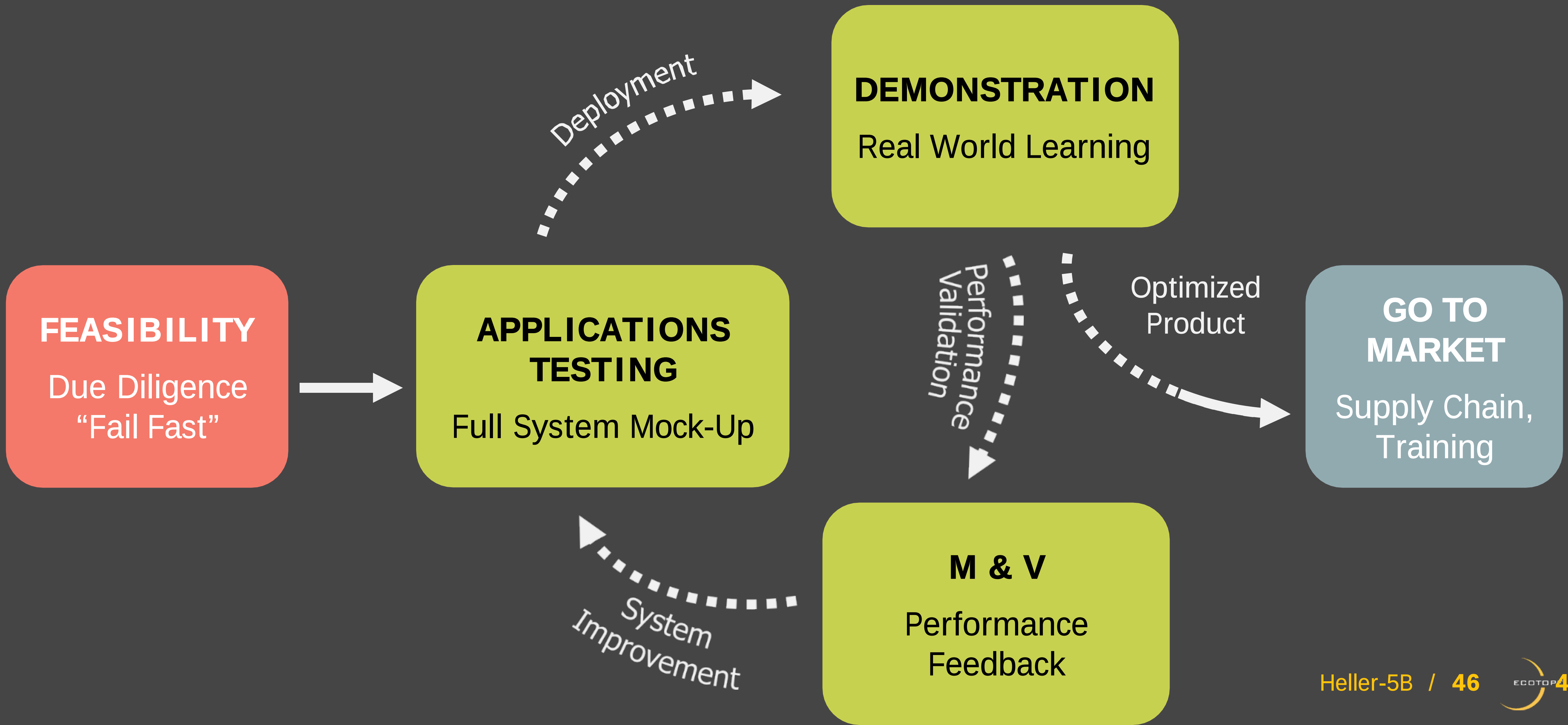
CHPWH Product Vision

+ Plug-and-play Systems
+ Single point of sale / warranty
+ Average system COP of 3.0 or better
+ Use low-GWP refrigerants (GWP < 750)
+ Affordable
+ Reliable and redundant systems
+ Standardized load shifting / DR



Bayview Tower

Technology Innovation Model



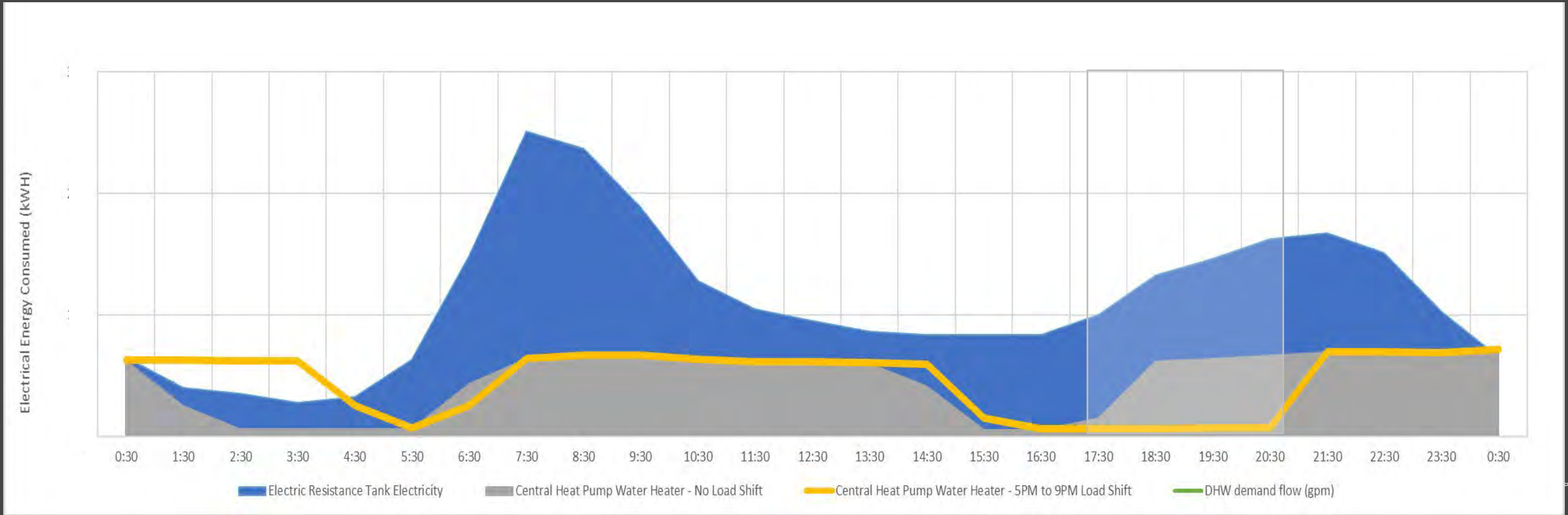
Design is key to performance

55 tons / 1,000 gallons

5 tons / 520 gallons

DHW Load Shape w/CHPWH and TOU

+ Baseline ER load shape directly aligned with DHW demand, while CHPWH has typical daily cycle that leverages storage to meet demand
+ Load shift strategy modifies typical cycle, achieving ~40% peak demand reduction
+ Technology deployment achieves ~$20,000 annual energy savings, TOU rates with load shift adds ~$1000 annual utility bill savings.



How will these projects aid the CHPWH market?

- ✓ Add new products to the **Qualified Product List**
- ✓ Measure and validate **field performance data**
- ✓ Galvanize transition to **low GWP refrigerants**
- ✓ Slash installation time & complexity w/ **skid-mounted systems**
- ✓ Standardize **load shifting controls**

Heat2o installation in CA

ECOTOPE

Project Timeline

Accomplished to Date:

- ✓ Recruited demonstration sites in Sacramento and Seattle
- ✓ In talks with demonstration site #3
- ✓ Met with 7 participating manufacturers

2025

- ❑ Install CHPWH systems at 6+ sites
- ❑ Install M&V equipment at each site

2026

- ❑ Analyze 1 year of performance data
- ❑ Publish case studies for each site

ECOTOPE

Contact: noah@newbuildings.org

Questions?

Distribution Grid Analysis Dashboards

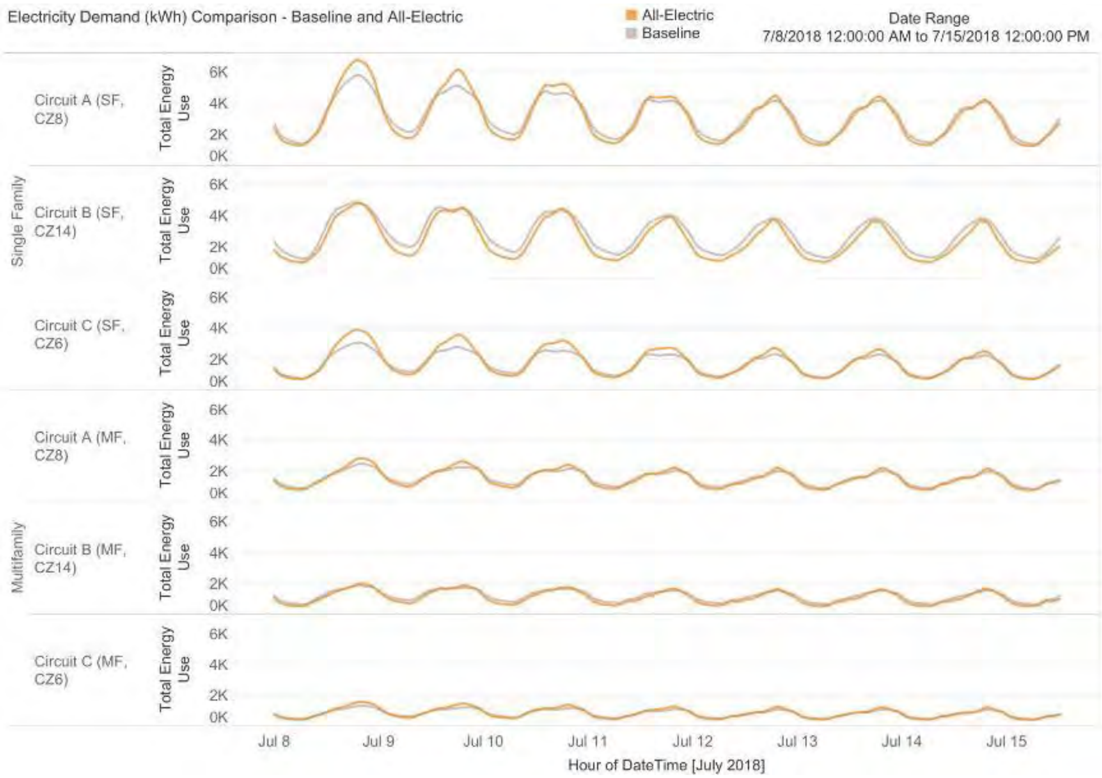
- **Goals:**
  - Study the impact of building electrification and DERs on circuits, to help with grid management and planning
  - Enable more/faster/better-optimized building decarbonization without stressing grids & triggering equipment upgrades

Evaluating the Distribution Grid Implications of Building Electrification and Demand Flexibility

- Building interactive dashboards to stochastically predict circuit-level impacts of various electrification + other scenarios
- Started with 3 specific overloaded/stressed circuits, calibrated
- So far: single family dominated circuits
- Next: commercial circuits & DER load shape integration
  - EV charging
  - Stationary batteries
  - Distributed PV

To the Dashboard We Go!

- https://public.tableau.com/app/profile/newbuildingsinstitute2/viz/GridElectrificationDashboardSample/Intro



Contact: alexi@newbuildings.org

Questions?

Tell Us What You Think…

- What did you find most helpful in this segment?
- What would you like to learn more about?

Drop your thoughts into the chat with #NBI

Regional Room Heat Pump Field Study

Cold Climate Room Heat Pumps

- Key innovation is use of an atomizer to get rid of condensate and melt water without need of melt water system or risk of freezing water dribbling down the side of the building.
- Two new products are entering the market that can operate below 5F
- These systems are available in limited production runs at a cost of $3000-$4000

Midea PWHP

Specs subject to change

Image courtesy Midea

	Outdoor Condition	Capacity (BTU/hr)	Efficiency
Cooling Mode	95 °F (35 °C)	9010	11.81 EER
Heating Mode	47 °F (8.3 °C)	9050	4.05 COP
	17 °F (-8.3 °C)	9060	2.42 COP
	5 °F (-15 °C)	9000	2.0 COP
Min Temp	-13 °F (-25 °C)	5050	1.41 COP
CEER	16		
SEER2	18.76		
HSPF2	10.12		
Indoor Sound Pressure Level	High	Low	Silent
	51 dB(A)	43 dB(A)	26 dB(A)
Unit Weight	130 lbs		

Gradient All Weather Unit

Specs subject to change

Image courtesy Gradient

Electrical Requirement	**Voltage**	**Phase**	**Circuit Amps**
	120 VAC	60 Hz	15 A
Thermal Performance	**Outdoor Temp**	**Capacity**	**Efficiency**
	95 °F (35 °C)	9000 BTU/h	10.0 (EER)
	47 °F (8.3 °C)	9000 BTU/h	4.00 (COP)
	17 °F (-8.3 °C)	9000 BTU/h	2.60 (COP)
	5 °F (-15 °C)	7200 BTU/h	2.35 (COP)
	-7 °F (-21.7 °C)	4900 BTU/h	1.71 (COP)
Weight	125 lbs		
Refrigerant	R32		
Indoor Sound Level	**High**	**Medium**	**Low**
	47 dB(A)	44 dB(A)	38 dB(A)

*Specifications are subject to change.

EPA's HP Test Procedure and Rating

ENERGY STAR® Program Requirements
Product Specification for Room Air Conditioners

Draft Final Test Method to Determine
Room Air Conditioner Heating Mode Performance
April 2024

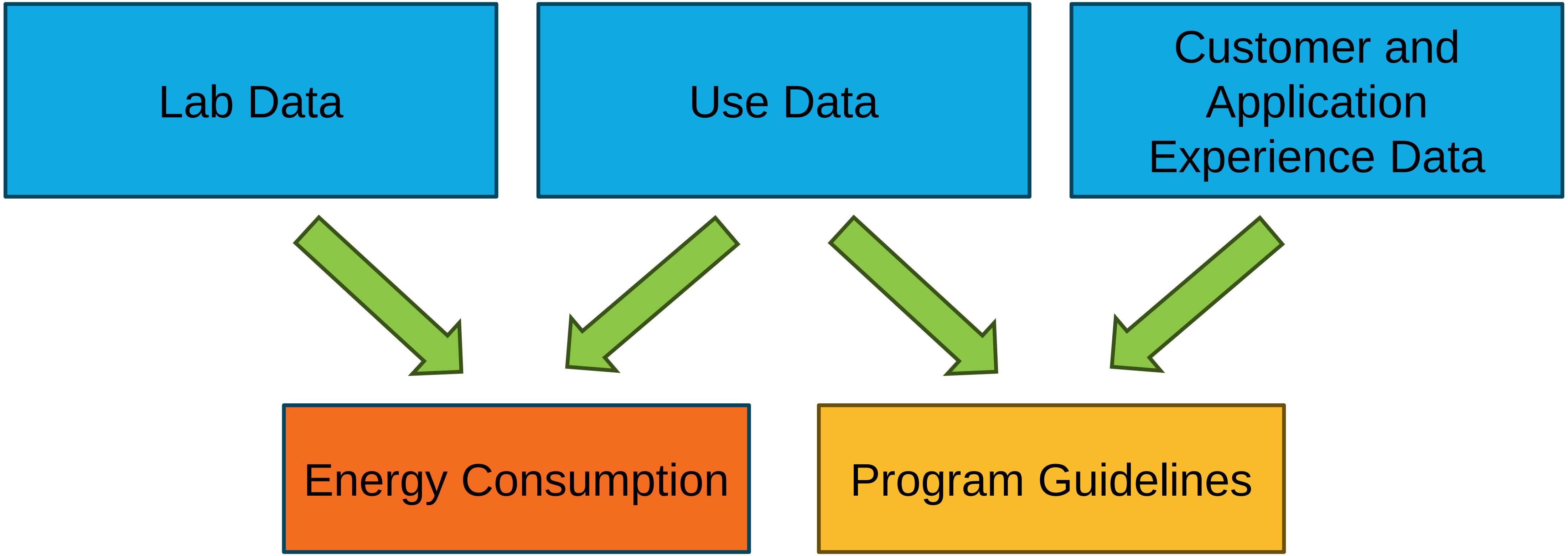
Final version out soon

Seasonal Rating = "HEER"

Room heat pump: A room air conditioner as defined at 10 CFR 430.2 that utilizes reverse cycle refrigeration as its prime source for heating the indoor space.

	Category	Heating Range (outdoor Temp)	Active Defrost	Notes
	AC with Electric Heater	5 - 75°F	-	Inefficient during heating
	AC with Heat Pump	40 - 75°F	NO	Very limited heating range
"Type 3"	Mild Climate Heat Pump	17 - 75°F	YES	Not yet available
"Type 4"	Cold Climate Heat Pump	5 - 75°F	YES	Available Q4 2024+

Field and Lab Data



Research Objectives

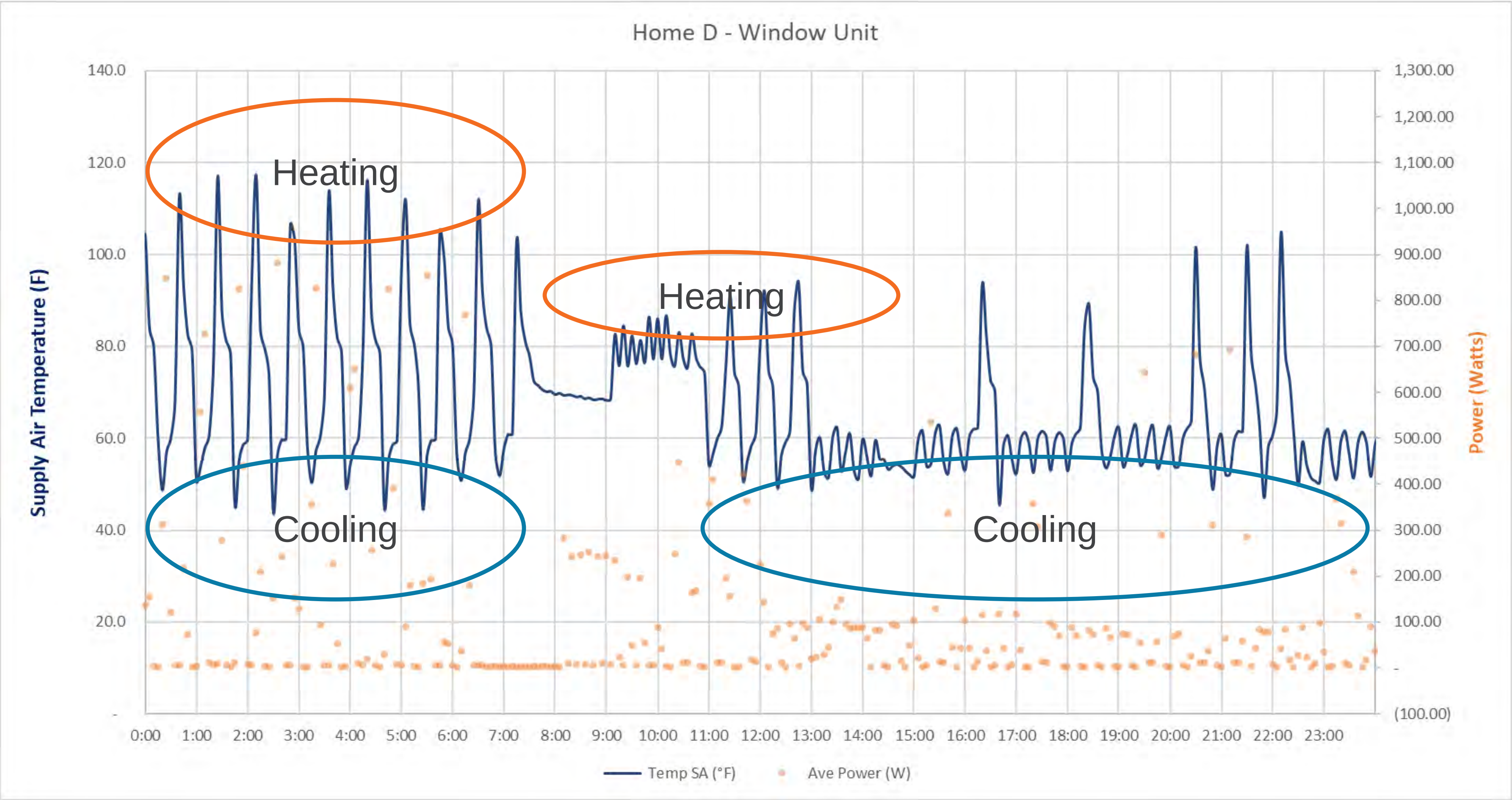
- Collect consistent set of heat pump use data that can be used to calculate energy savings from window heat pumps compared to other heating and cooling systems.
- Collect consistent set of customer experience data that can be used to develop program recommendations that increase customer value propositions and remove adoption barriers.
- Help build market interest and confidence in window heat pumps through development of case studies and earned media coverage.

Research Questions

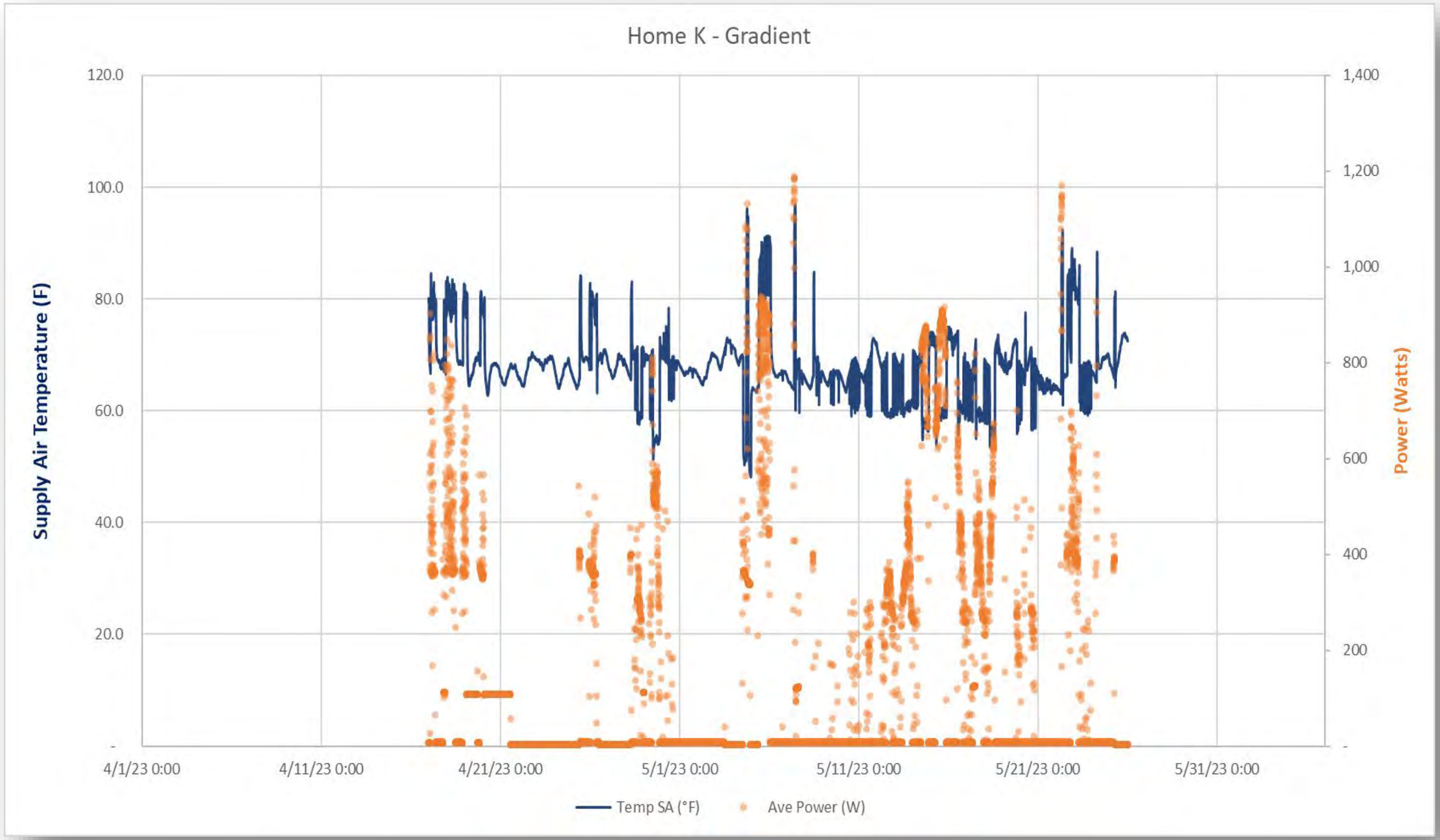
- How are window heat pumps used?
  (operating hours, time of use, settings, use behaviors)

- What information do customers need to know about advanced window heat pumps to accelerate adoption and enhance savings potential?

Temperature Provides A Lot of Information



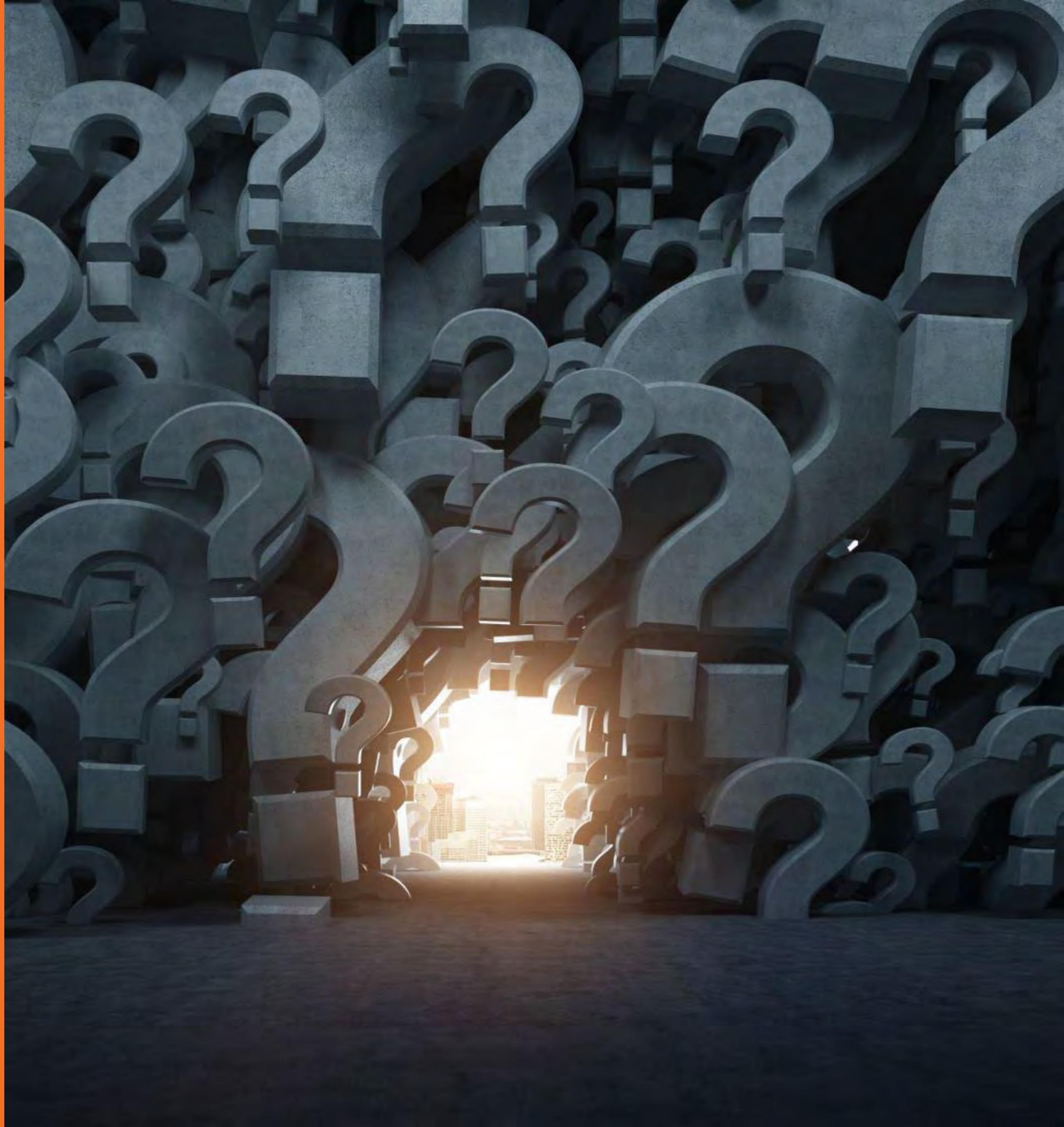
Data Loggers



WSU Workplan

- Feasibility Analysis – codes, sound, market conditions
- Lab Testing (done by OEMs)
- Field Testing (20-30 units in HZ1 and HZ2)
- Savings and Measure Development
- Program Guidelines

Questions and Discussion



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Tell Us What You Think…

- What did you find most helpful in this segment?
- What would you like to learn more about?

Drop your thoughts into the chat with #HP

Break

Return at 12:15

Agenda

8:30 am	Welcome and Announcements
9:00 am	*New!* ORNL Emerging Technology Update
10:30 am	*Break*
10:45 am	*New!* New Buildings Institute
11:45 am	*New!* Regional Room Heat Pump Field Study
12:00 pm	*Break*
12:15 pm	*New!* NW Power & Conservation Council
12:45 pm	Wrap-Up

Northwest Power & Conservation Council

The Ninth Regional Power Plan – Timeline and New EE Measures

Regional Emerging Technology Advisory Committee (RETAC)

Kevin Smit

Manager of Power Planning Resources

June 27, 2024

Northwest **Power** and **Conservation** Council

Agenda

- The Council, the Power Plan, and the Definition of EE
- Brief Summary of 2021 Plan
- Ninth Power plan timeline
- Power Plan Models and Process
- **Measure list – what new measures can we include?**

Northwest Power and Conservation Council

The 1980 Northwest Power Act authorized Idaho, Montana, Oregon, and Washington to develop a regional power plan and fish and wildlife program to balance the Northwest's environment and energy needs.

Three main tenets:

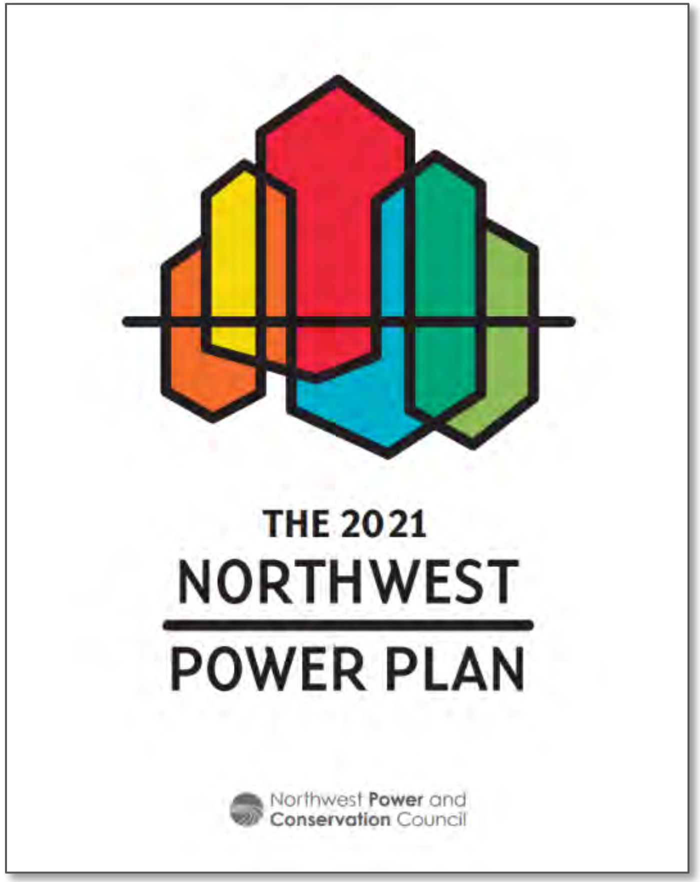
- Adequate, efficient, economical, reliable power system
- Protect, mitigate, & enhance fish and wildlife
- Open public process

Who is the Council?

- Two members from each state, appointed by the Governor
- Central staff
- Advisory Committees, Including the Regional Technical Forum (RTF)

The Council's Power Plan

- Goal: Ensure an adequate, efficient, economical, reliable power supply
  - Focused on the electric system
  - Provides a long-term (20 year) perspective
  - Aims for a resource strategy meeting regional needs while managing cost and risk
  - Includes recommendations for Bonneville and the region around implementation
- How is the Plan Used?
  - Guides Bonneville Power Administration's resource decisions
  - Independent reference for the region's utilities, regulatory commissions, and policy-makers



Definition of Conservation in the Power Act

"Conservation" means any reduction in electric power consumption as a result of increases in the efficiency of energy use, production, or distribution.

1. Does the opportunity reduce electric power consumption?

and

2. Is the reduction in electric power consumption the result of an increase in efficiency of energy use, production, or distribution?

**Also, must be Reliable and Available when needed

2021 Power Plan Resource Strategy Reminder

Existing System: Increase Reserves

To reduce regional needs and support integration of renewables, the region needs to double the assumed reserves. This can most cost-effectively be done through more conservative operation of the existing system (both thermal and hydro units).

Renewables: At least 3,500 MW by 2027

Renewables are recommended due to their low costs, interruptibility, and carbon reduction benefits. Long-term build out will impact the transmission system and should be done mindful of the cumulative impacts of the new resources.

Energy Efficiency: 750-1,000 aMW by 2027

Significantly less acquisition than prior plan - less cost-competitive, a slower build resource, not inherently dispatchable, and sensitive to market prices. Efficiency that supports system flexibility is most valuable.

Demand Response: Low-Cost Capacity

Highest value products are those that can be regularly deployed at a low-cost and with minimal to no impact on customer. The Council identified demand voltage regulation and time of use rates as two products, estimating 720 MW of potential.

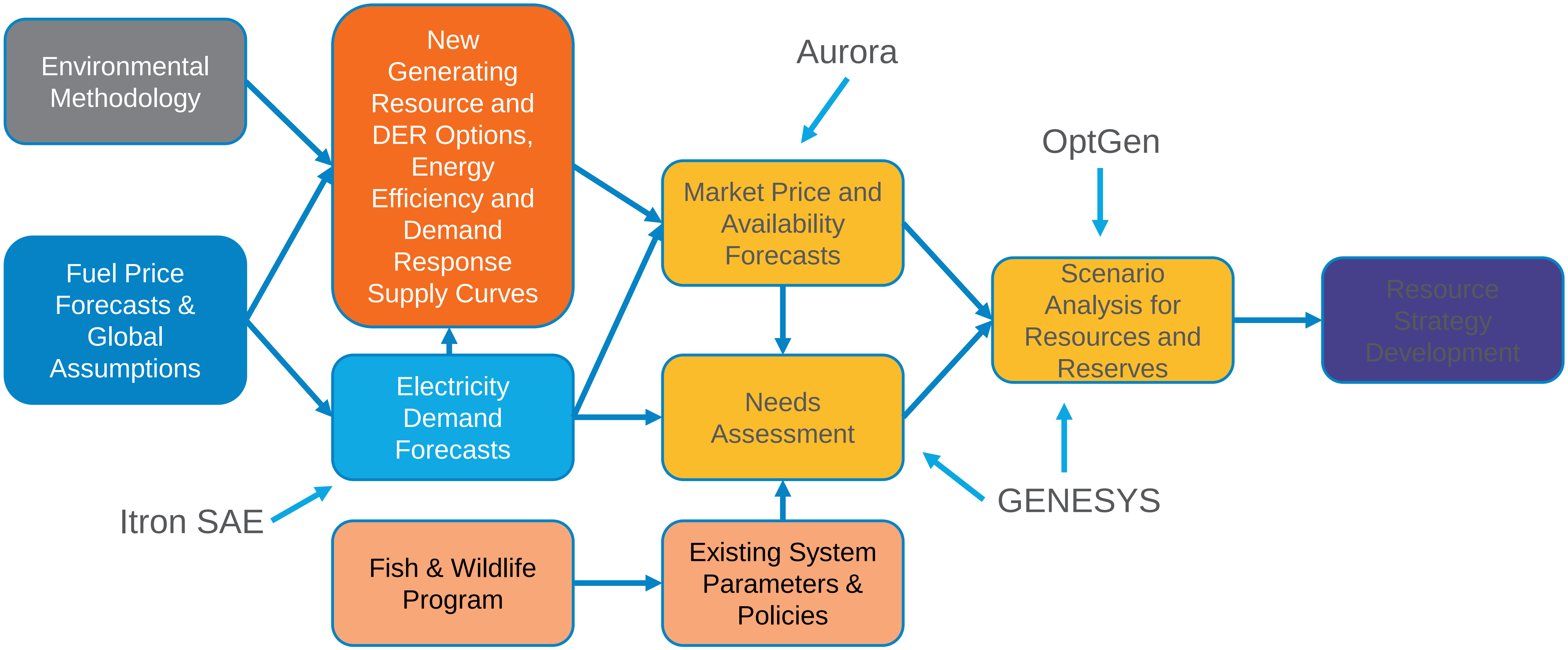
2021 Plan Resource Strategy: Impact on EE

- The 2021 Plan resource strategy included a relatively low EE target (750-1000 aMW in 6 years)
  - This resulted in a much lower EE avoided cost (~$30-$40/MWh range)
  - This means fewer measures are cost-effective
  - Low cost generating resources (Solar, Wind)
  - Our region's ability to integrate intermittent resources
    - Big hydro battery
    - Utilize other reserves
  - Relatively flat load forecast
- However,…
  - Our recent mid-term assessment and current adequacy assessment *may* be signaling:
    - Greater load growth (i.e., primarily data centers)
    - More that the minimum EE needed (upper end of the range rather than the lower)
    - Costs are going up; both EE and the alternate resources

We are Working on the Ninth Power Plan

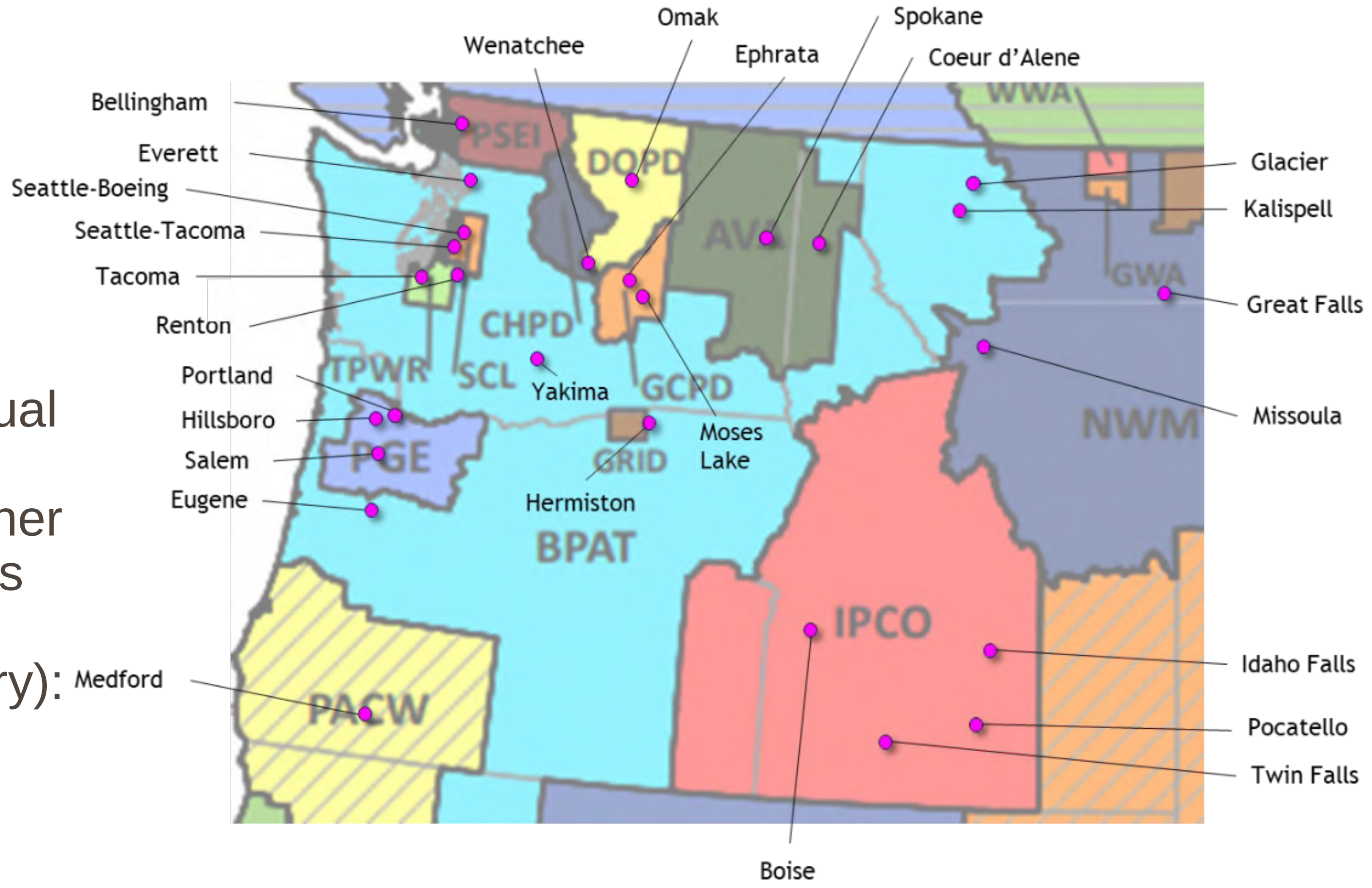
- Timing of power plan development is informed by the power act and connected to the Fish and Wildlife Program Amendment process
  - Plan needs to be "reviewed" by the Council at least every five years [Section 4(d)(1)]
  - Act also requires that the Council call for recommendations to amend the fish and wildlife program (and triggering the amendment process) prior to review of the plan [Section 4(h)(2)]
- Requirements relate to our current timing: we are in a … tarting official review in the 5 year window

Ninth Plan Models and Process Overview



What's New in the Ninth Plan?

- New models – hourly rather than quarterly
- Analysis by 17 "zones", roughly equal to the Balancing Authorities
- More attention to climate and weather
- Many new EE measures and values
- Updated DR analysis
- Distributed solar (and solar + battery):
  - Residential
  - Commercial
  - Industrial
  - Community



The Ninth Power Plan

- Preliminary work is beginning on the Ninth Plan (official kickoff is next spring)
- Digging into RBSA, CBSA, EULR data
- EE and DR research and measure development needs to happen now

- **Currently, we are in the process of identifying new EE measures – can you help?**

- Following slides are from NEEA’s monitoring list

Envelope and Consumer Products

	Measure	In Last Plan?	Include in 9th Plan?	Notes
BUILDING ENVELOPE	**Window Attachments**	Y	Y	
	Non-glass Secondary Windows			?
	Retrofit Wall System Improvements			?
	Dynamic Glazing		?	Not ready
	High Efficiency Windows*	Y	Y	Thin triple
	Integrated Design / Performance Path Code*			
CONSUMER PRODUCTS	Clothes Dryer Innovations (UV, Ultrasonic, others)			Available products?
	Thermo-electric HP Dishwasher			Not available
	Commercial Laundry Innovation			Ozone, HP Dryer
	Commercial Cooking	Y	Y	
	Induction Cooktops	Y	Y	
	Displays/Monitors*		Y	
	Combination Washer-Dryers*		Y	

*Existing NEEA Program

HVAC

	Measure	In Last Plan?	Include in 9th Plan?	Notes
HVAC	**Variable Speed Heat Pumps***	Y	Y	
	Alternative Refrigerants		NA	
	Micro Heat Pumps*		Y	
	Heat Pump Commissioning Products*		?	
	Hybrid Heating Systems (Gas / Electric)			
	High Efficiency Dedicated Outdoor Air Systems*	y	Y	
	Efficient Roof Top Units*	y	Y	
	Air Quality Monitoring and HVAC Control*			EE measure?
	Cold Temperature Heat Pumps*		Y	
	Thermostats	y	Y	
	Radiant Heating/Cooling*		?	
	Energy and Heat Recovery Ventilation*	y	Y	
	Inverter Driven Packaged Terminal Heat Pumps		Y	
	Gas Heat Pump		no	
	Heat Pumps for Manufactured Homes*		Y	
	Duct Sealing		?	
	Combination Space and Water Heating (Combi)		?	

Lighting, Motors, Water Heating

	Measure	In Last Plan?	Include in 9th Plan?	Notes
LIGHTING	Zonal Lamp Control & HVAC			Measure?
	Intelligent Buildings (AI)			Measure?
	Network Lighting Controls			Data available?
	Residential Lighting Controls		?	
	Outdoor Luminaire Level Lighting Controls*		?	Data available?
MOTOR-DRIVEN PRODUCTS	**XMP – Pumps***	Y	Y	
	Power Drive Systems		?	What is this?
	Advanced motors	Y	Y	
	Fans*	y	Y	
WATER HEATING	HPWHs for Challenging Installs*		?	
	Demand Response Enabled Water Heaters*			DR Potential
	Mid/Large Scale Multi-Family		Y	
	Low-rise Multi-Family Water Heating		Y	
	Commercial Water Heaters	y	Y	
	Hybrid (dual fuel) Water Heaters		N	Gas
	Drain Waste Heat Recovery	y	Y	
	Gas Heat Pump Water Heating (GHPWH)*		N	Gas
	Industrial Heat Pumps		Y	

Any other new or emerging measures to consider?

Measure	Description	Notes
Data Centers and Server-related measures	Researching what we can include for Data Centers	RTF Study underway
Ag sector measures		Research underway
Ozone Laundry		
Grocery refrigeration measures	Suite of refrigeration-related measures, mostly found in grocery stores	RTF measures, plus 2021 Plan
Distribution Efficiency	CVR, Reconductoring, DLR	

Let me know if you have ideas and/or data for other new measures
Thanks
Kevin Smit
ksmit@nwcouncil.org

Tell Us What You Think…

- What did you find most helpful in this segment?
- What would you like to learn more about?

Drop your thoughts into the chat with #26Power

CLOSING

- ❑ ***Public Comments/Q&A***
- ❑ ***Poll Questions***

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Poll Question…

How would you rate the overall value of today’s session?

If the poll didn’t work for you, please let us know in the chat box what the problem was: if you used the app or browser, and the error message you got, if any.

Thank You!!