



Manufacturer's Roundtable

VHE-DOAS Manufacturers Roundtable

September 23, 2026



© New Buildings Institute 2024

WHAT IS CEDA?



The California Energy Design Assistance (CEDA) program is the only statewide utility incentive program for new construction and major renovations.

- Promotes **electrification** and **decarbonization**
- CEDA works in collaboration with project teams to reduce energy demand, consumption, and carbon emissions.
- Serves commercial, public, high-rise multifamily, industrial, and agricultural projects in Pacific Gas & Electric (PG&E), Southern California Edison (SCE), SoCalGas (SCG), and San Diego Gas & Electric (SDG&E) service areas.



WHY PARTICIPATE IN CEDA?



- Receive complimentary **decarbonization** analysis tailored to project goals to identify most effective measures to implement



- Gain analysis of **energy costs and paybacks**
- Receive **financial incentives** to help offset the costs of decarbonization measures



- Demonstrate commitment to high performance building practices and design

INCENTIVES



- **\$4000 Design team incentive** per project as a thank you for participation
- Based on the project measure package the design team chooses for implementation



HIGH PERFORMANCE MEASURES



CEDA aims to exceed California's decarbonization standards by identifying high performance measures and providing educational opportunities to explore use cases and best practices.

This not only advances the market, but also qualifies participants for enhanced incentives through our program.

A current list of eligible high-performance measures can be found on our website [here](#).



HAVE A PROJECT TO DISCUSS?



For more information, please contact our program outreach specialists, visit our website, or fill out an interest form

Scan me to enroll a project



CaliforniaEDA.com

Tina Hendrix | Program Outreach Specialist
thendrix@willdan.com
760.585.7577

VHE DOAS

In today's webinar, we'll discuss:

The components of Very High Efficiency (VHE) HVAC systems with Dedicated Outside Air Systems (DOAS)

The benefits and applications of VHE DOAS systems

The challenges and opportunities related to the adoption of these systems as it relates to design, engineering, procurement and installation

© New Buildings Institute 2024

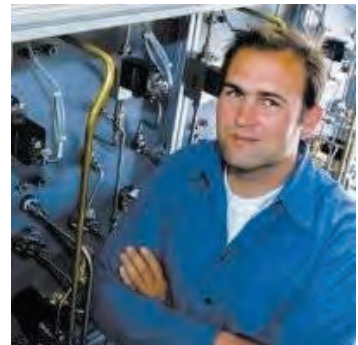
Today's Panelists



Eric Kozubal
National Laboratory
of the Rockies



Earl Allen
Trane



James Dean
Oxygen8

© New Buildings Institute 2024



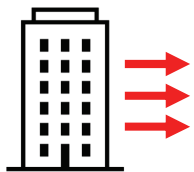
Why DOAS?

Earl Allen
Product Manager, Sourced Products

TRANE
TECHNOLOGIES



→ Why DOAS?



VENTILATE

Provide required outdoor-air ventilation



DECOUPLE

Separate ventilation/latent loads from zone sensible loads

| Ventilation is the requirement. Decoupling loads is the opportunity.

TRANE
TECHNOLOGIES

→ Where does DOAS fit?



VRF SYSTEMS



Ventilation + latent control



WATER-SOURCE HEAT PUMPS (WSHP)



Ventilation + latent control

ROOFTOP UNITS (RTUs)



Opportunity to decouple

→ A DOAS is Not Just Another RTU



TYPICAL RTU APPLICATIONS

- Mostly return-air with some outdoor air



DOAS

- Up to 100% outdoor air
- Wider entering conditions
- Greater latent challenges
- Greater need for capacity modulation



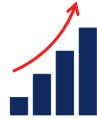
DOAS and RTUs both deliver outdoor air. DOAS is engineered to handle 100% outside air and the challenges that come with it.

→ Design for the Wide Operating Envelop



DESIGN COOLING & HEATING CONDITIONS

Handle the full range of outdoor air conditions.



CAPACITY MODULATION

Match capacity to changing loads.



ENERGY RECOVERY

Reduce the load before conditioning it.



SYSTEM INTEGRATION

Coordinate DOAS operation with zone HVAC equipment.



→ Cooling isn't the whole story



SENSIBLE

Change the air temperature

- Raise temperature in cold conditions
- Lower temperature in hot conditions

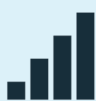


LATENT

Remove moisture

- Manage humidity in all seasons
- Prevent condensation and moisture issues

TWO DIFFERENT WAYS TO THINK ABOUT EFFICIENCY



IEER (AHR 340/360)

Cooling efficiency

Cooling output / power input (Btu/Wh)



ISMRE2 (AHR 920)

Moisture-removal efficiency

Moisture removed / power input (lb/kWh)



→ Electrification Doesn't Have to Be All or Nothing



HEAT PUMPS CAN LEAD

Heat pumps can meet the full heating load where conditions allow.



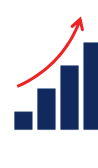
SUPPLEMENTAL HEAT PROVIDE FLEXIBILITY

Supplemental heat can cover conditions beyond heat-pump capacity.



HYBRID SYSTEMS REDUCE EMISSIONS

Hybrid systems can still reduce annual fossil-fuel use.



TECHNOLOGY KEEPS EXPANDING

Technology continues to expand the heat-pump operating envelope.



→ Valent VX

High-performance DOAS for demanding environments



Inverter Scroll Compressor
Capacity modulation for precise control



R-16, 2" foam-injected cabinet
High thermal performance and durability



Heat-pump and modulating gas-heat options
Flexible decarbonization and performance



Energy-recovery options
Improved efficiency and reduced outdoor-air conditioning load



ENHANCED INDOOR ENVIRONMENT



ENERGY EFFICIENT



FLEXIBLE DESIGN OPTIONS



BUILT FOR DEMANDING APPLICATIONS



→ Valent VR

Flexible unit to cover high outdoor air applications



Partial-recirculation applications
Bridge between RTU and 100% applications



Variable-speed compressors
Improved load matching and humidity control



Modulating hot-gas reheat
Simultaneous temperature and humidity control



Air-sourced heat pump
All-electric heating and cooling



Injected-foam, double-wall cabinet
Robust thermal envelope



→ Mojave Arcticdry



Liquid-desiccant dehumidification
Dedicated latent removal



35-55°F supply-air dew-point control
Delivers low, stable dew points



Tight humidity control
Maintains comfort across changing conditions



Avoids conventional overcool-and-reheat
More efficient dehumidification



DX and chilled-water configurations available
Flexibility for a range of applications



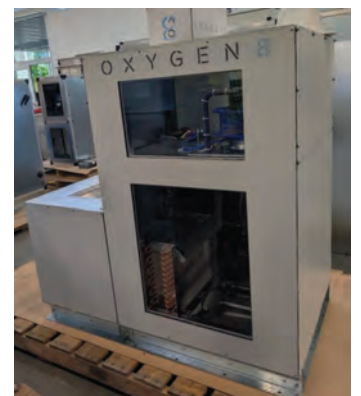
Strong fit for high-latent and tight-humidity control applications
Supermarkets, process spaces, and other high-latent applications



High-Performance DOAS for Healthy and Sustainable Buildings

Introduction to James Dean

- Passionate about entrepreneurship, sustainability & healthy buildings
 - Founder & CEO of Oxygen8 (High-Performance Ventilation Systems)
 - Founder & CEO of CORE (Membranes, ERV Cores, FC Humidifiers)
 - Co-CEO of Greenlight Power (Hydrogen Fuel Cells)
- Past Board Member Home Ventilating Institute and AHRI ERV Committee
- Built West Vancouver's 1st Net Zero Energy Home: Passive House Certified



Agenda

- Introduction to Oxygen8 and Split DX-DOAS
- Comparison of Energy Recovery Ventilation Technologies
- Split DOAS vs Packaged DOAS
- Case Study: Split DOAS in a Passive House Building
- NEEA Very High Efficiency DOAS Program

Introduction to Oxygen8



About

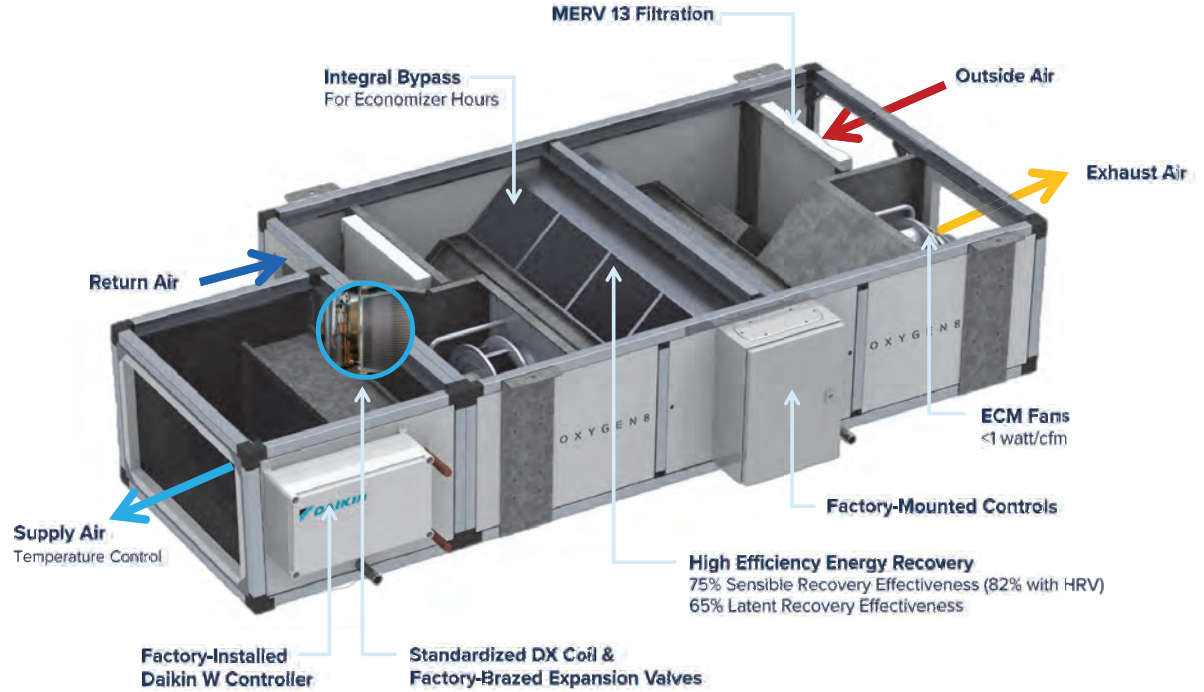
- **Our Business:** Improving Indoor Air Quality with Low Energy Consumption and Low GHG Emissions
- **Products:** High-Performance Ventilation Systems
 - **Low Profile:** Decentralized Ventilation
 - **High Efficiency:** Meet Advanced Building Codes
 - **All Electric:** VRV Heat-Pump Integration
 - **Integrated Controls:** Remote Access, IAQ Dashboard
- **Key Vertical Markets:**
 - **Education:** K-12, Universities
 - **Multi-Unit Residential:** Affordable Housing, Sr. Care, Condos
 - **Offices:** Retrofit and New Construction
 - **Retail:** Apple Stores (12), JP Morgan Chase & US Bank (150+)
- **Locations:** 3 Mfg Facilities in Van, R&D in Toronto
- **# Projects:** 3000+
- **Team:** 230

Technology **Fast 500**
2025 NORTH AMERICA
Deloitte.

100% Fresh Air with Temperature Control



VRV Heat-Pump
COP-3-4



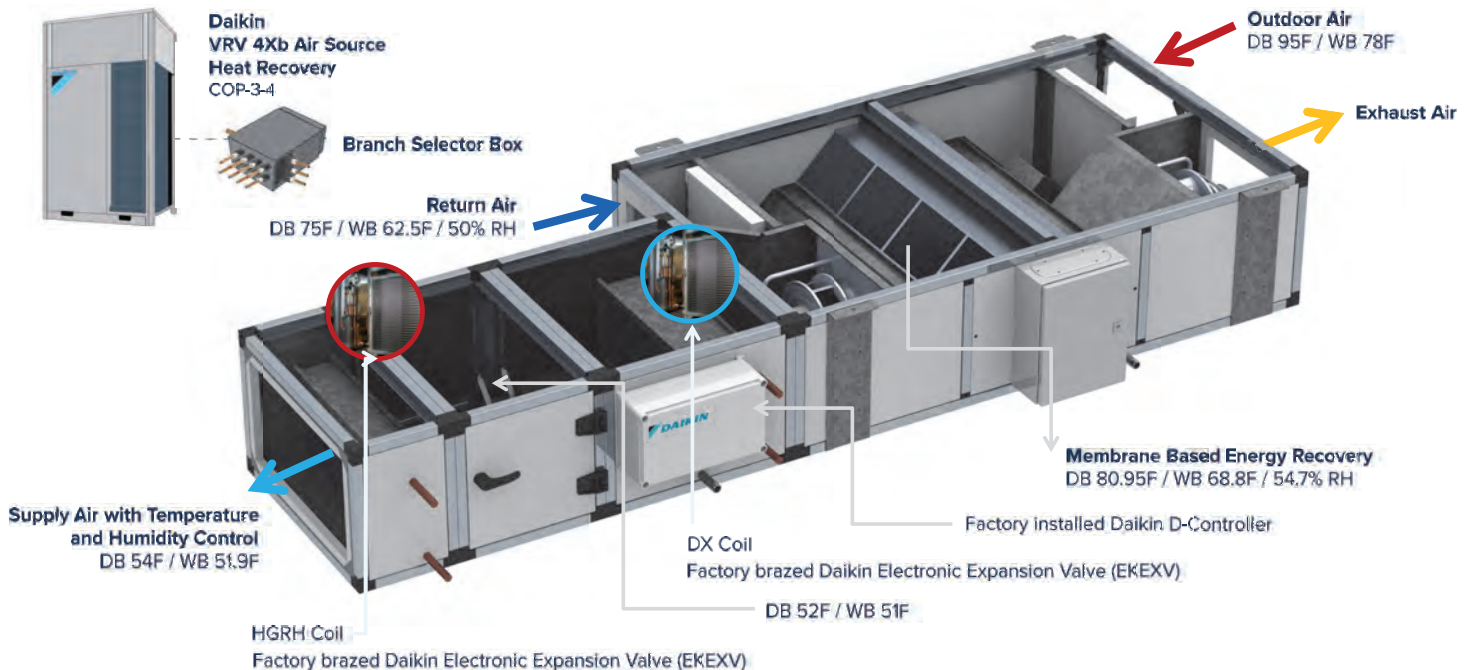
100% Fresh Air with Temperature & Humidity Control



Daikin
VRV 4Xb Air Source
Heat Recovery
COP-3-4



Branch Selector Box



Integrated DDC Controls

Standard Control Algorithms

1. Airflow Control

Constant Flow | Constant Pressure | Demand Control
Ventilation based on CO₂/VOC

2. Temperature and Humidity Control

Discharge Air Temperature Control
Dehumidification

3. Remote Access

Internet Connection | BACnet IP

4. Independent VRV Control

No BMS needed to operate VRV Coils
UL 60335 Certified for A2L Refrigerants



Advantages of Packaged DOAS vs Split DOAS



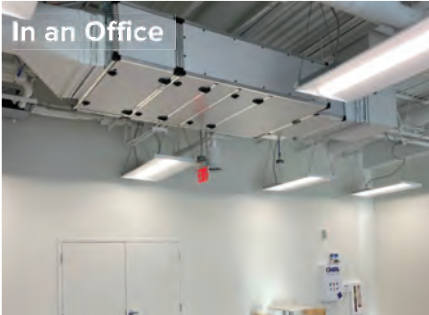
- + Simple consolidated design
- + Common ductwork
- + Less expensive
- + Many manufacturers



- + Ventilation is Decoupled from Heating/Cooling
- + More compact (compressor is in ODU)
- + Quieter/Lighter (compressor is outside)
- + No vertical duct chase
- + Easy Zone Control

Fresh Air That Fits

In an Office



In a Mechanical Room



In a Classroom



Through a Door



In a Closet

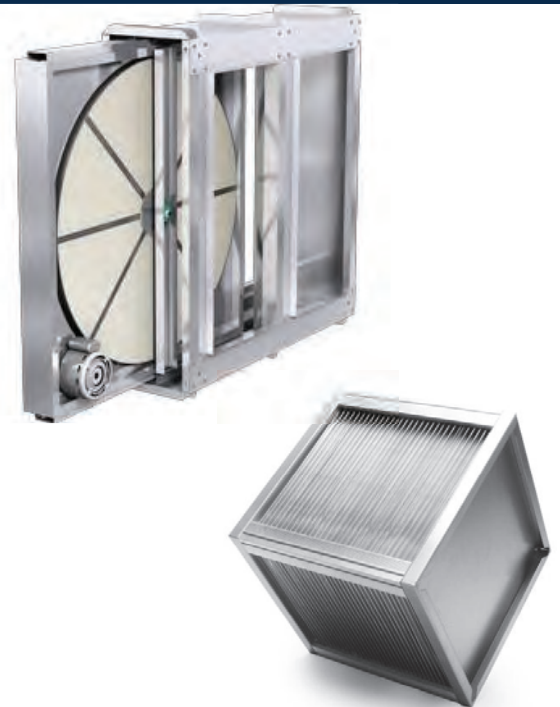


On a Wall

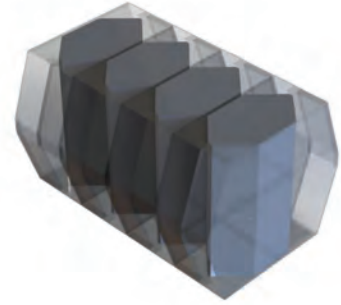
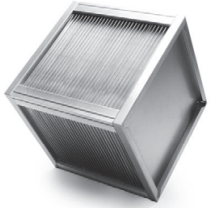


Comparing Energy Recovery Wheels vs ERV Cores

Metric	Energy Recovery Wheels	ERV Core
Performance (SRE)	70 – 90%	60 – 85%
EATR	1 – 10%	0 – 1%
Moving Parts	Motor/Belt/Bearing	None
Application	High flow rate Compact size	Low cross contamination Low maintenance



Cross-flow Cores vs Counter-flow, ERV vs HRV



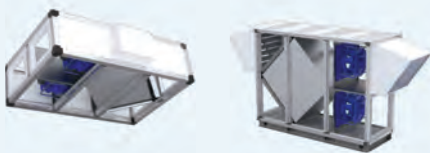
Efficiency	Sensible Recovery	Latent Recovery	Total Recovery
Cross-Flow ERV	~63%	~47%	~53%
Counter-Flow ERV	~75%	~65%	~70%
Counter-Flow HRV	~82%	--	--

**ERV Core for Climates
Hot/Humid or Cold/Dry**

**HRV Core for Climates
Moderate Temperature
and Humidity**

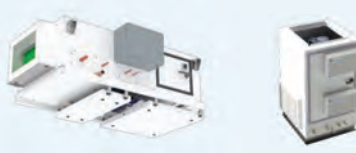
Oxygen8 Ventilation Solutions Overview

Crossflow Energy Recovery Core



Nova Indoor/Outdoor
325 – 8,100 cfm

No Energy Recovery Core



Terra H
450 – 4,800 cfm

Terra V
450 – 10,000 cfm

Modular ERV/DOAS



Omnia with Wheel
2,000 – 15,000 cfm

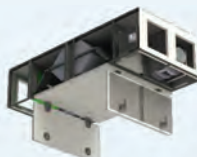
Counterflow Energy Recovery Core



Ventum H
325 – 3,500 cfm

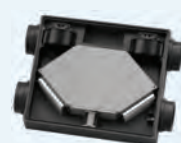


Ventum + Indoor/Outdoor
1,200 – 15,000 cfm



Ventum Lite
200 – 1,200 cfm

Multi-Unit Residential



Vela (Coming 2027)
30 – 120 cfm

Case Study: Vienna House

Architectural Details:

- Passive House certified
- 6-story of affordable housing
- 123 residential suites
- Well insulated / Air-Tight Envelop
- Balconies for Shading

Ventilation System:

- Centralized 2 x 10,000 cfm DOAS

Integrated Heating & Cooling System

- Heating: Ventilation airflow @ 85F
- Cooling: Ventilation airflow @ 55F
- 48T of Cooling for 123 apartments
- 1/3T per 2 bedroom suite
- HVAC @ \$23/ft² vs \$37/ft² for Decentral



Vienna House– Ventum+ ERV with Daikin VRV

Vancouver, BC

125 Apartments

2 ERV units

250 Dampers

Normal Airflow (Winter + Shoulder)

2970 - 4240 CFM

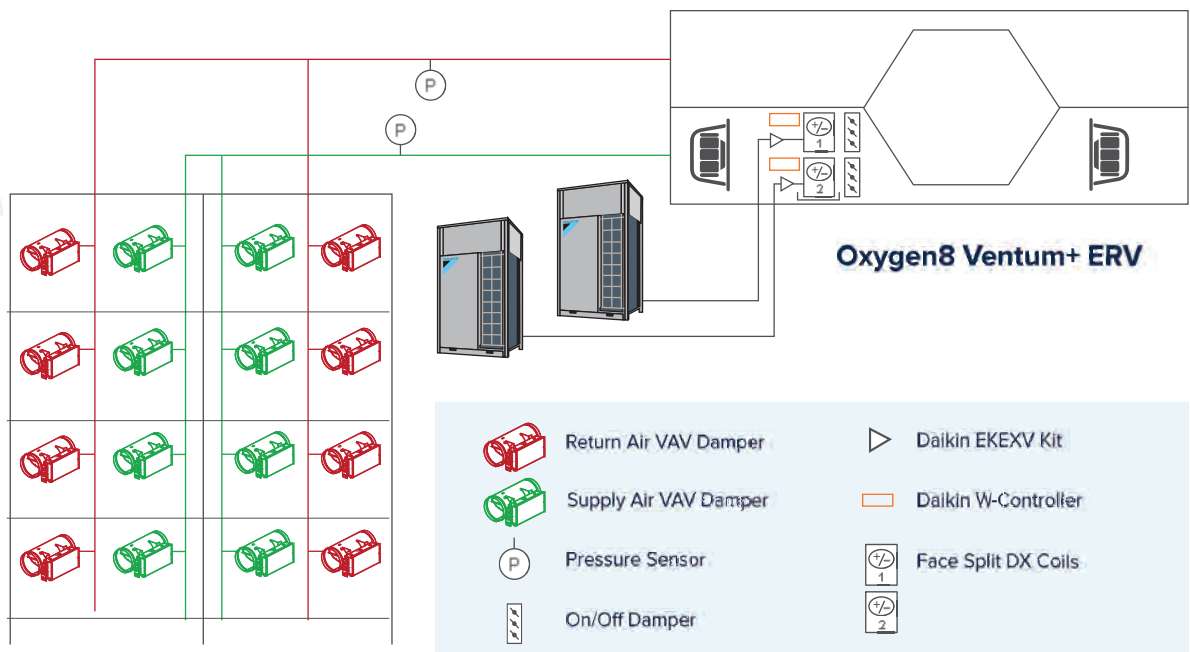
Only Coil 2 active: 75°F LAT

Boost Airflow (Summer)

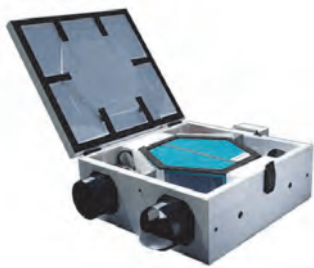
5195 - 7420 CFM

DX Coil cooling mode:

Coil 1 and Coil 2 active: 55°F LAT

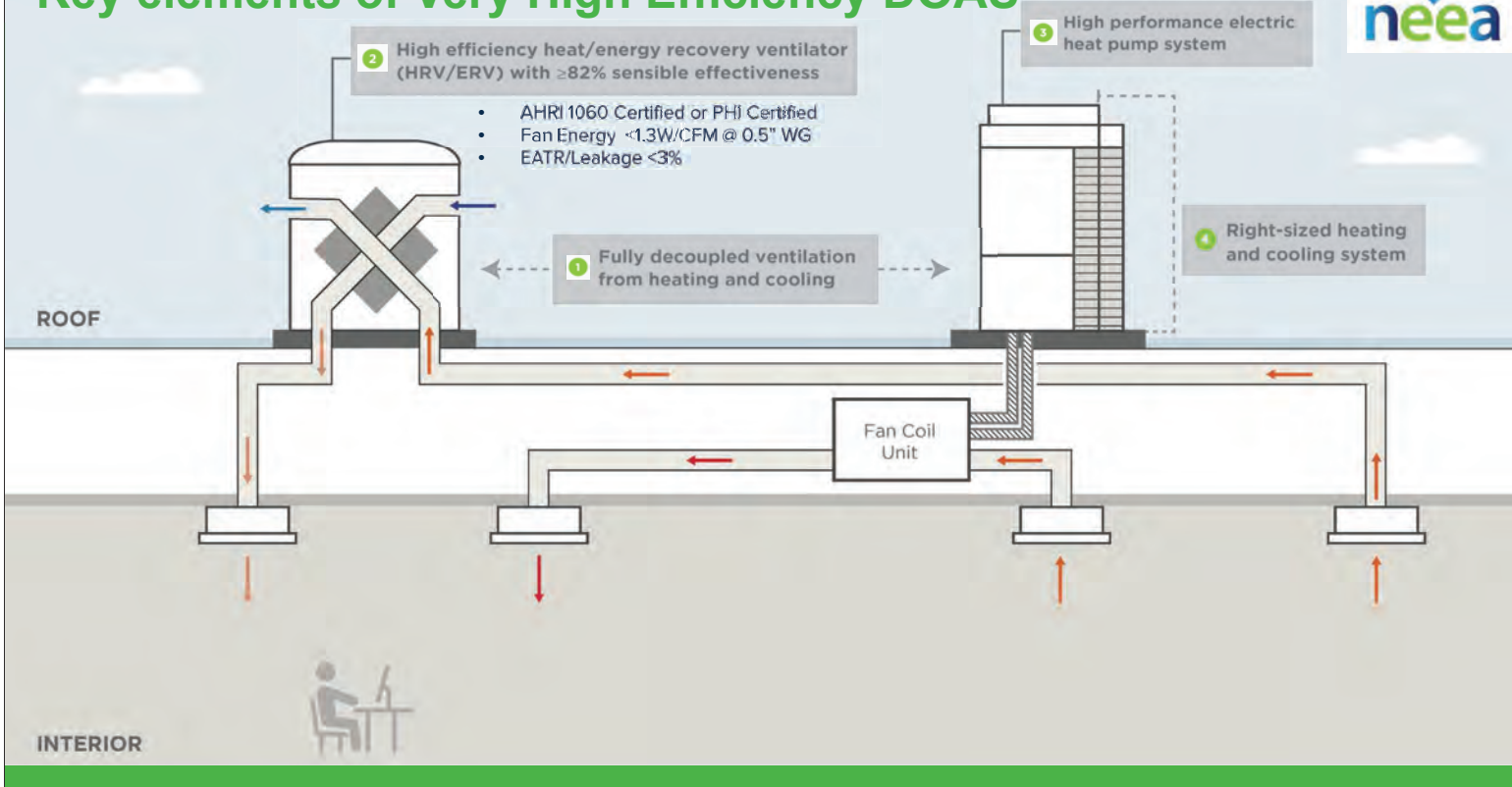


Multi-Unit Residential Ventilation Solutions



	Vita	Salda 2,3,4 XP	Salda 2,3,4 XV	ERV with Daikin FXTO
Airflow Range	30 – 120 cfm	40 – 300 cfm	30 – 300 cfm	45 – 120 cfm
Power Supply	120V/1ph	208V/1ph	208V/1ph	120V/1ph
Efficiencies	HRV Core ~82% SRE ERV Core ~72% SRE	HRV Core ~84% SRE ERV Core ~75% SRE	HRV Core ~88% SRE ERV Core ~77% SRE	ERV Core ~65% SRE
Fan Type	ECM Fans	ECM Fans	ECM Fans	ECM Fans
Other Features	Basic Wall Timer Control	Integrated Bypass & Passive House Certified	Integrated Bypass & Passive House Certified	Basic Wall Timer Control

Key elements of Very High Efficiency DOAS



NEEA VHE DOAS Directory of Compliant H/ERV Products

- Contains list of 9 Manufacturers and their products that meet NEEA requirements
- Offer financial incentives to projects using NEEA Listed Products
- Excellent resources for

betterbricks/

Very High Efficiency Dedicated Outside Air System:

Heat/Energy Recovery Ventilator Compliant Products

The following heat/energy recovery ventilator (HRV/ERV) equipment is compliant with the prescriptive requirements path of the [Very High Efficiency Dedicated Outside Air System \(very high efficiency DOAS\) Requirements](#) (see table A1: Minimum Requirements). Compliant HRV/ERV equipment is only one of four key system components needed to be a qualifying very high efficiency DOAS. Please refer to System Requirements table on page 2 of the [Very High Efficiency DOAS Requirements Summary](#) resource for additional details on the key components for a qualifying very high efficiency DOAS.

For more information on very high efficiency DOAS, including research findings and case studies, visit: betterbricks.com/vhetoos/.

Table A2: HRV/ERV Compliant Products⁵

Manufacturer	Model #	HRV/ERV	Nominal CFM
Greenheck	ERV-10-20H-VG	ERV	667
Greenheck	ERV-20-15L	ERV	1434
Greenheck	ERV-20-15L	ERV	1434
Greenheck	ERV-20-30L ¹	ERV	1734
Greenheck	ERV-20-30L ¹	ERV	1734
Greenheck	ERV-35-30L ¹	ERV	2600
Greenheck	ERV-45-15H	ERV	2600
Greenheck	ERV-45-15L	ERV	3034
Greenheck	ERV-45-30L ¹	ERV	3700
Greenheck	ERV-45-30L ¹	ERV	3700
Greenheck	ERV-90-15L	ERV	6000
Greenheck	ERV-10-HE ²	ERV	1226
Greenheck	ERV-20-HE ²	ERV	1745
Greenheck	IVE-10-HE ¹	ERV	1226
Greenheck	IVE-20-HE ²	ERV	1745
Oxygen8	Ventum H05	HRV	600
Oxygen8	Ventum H10	HRV	1000
Oxygen8	Ventum H15	HRV	1150
Oxygen8	Ventum H20	HRV	1530
Oxygen8	Ventum H25	HRV	2250
Oxygen8	Ventum H30	HRV	3000
Oxygen8	Ventum H10	ERV	1000
Oxygen8	Ventum H15	ERV	1350
Oxygen8	Ventum H20	ERV	1800
Oxygen8	Ventum H30	ERV	3000
Oxygen8	Ventum Lite H04 ⁴	HRV	450
Oxygen8	Ventum+ V20	HRV	1800

Table A2: HRV/ERV Compliant Products⁵

Manufacturer	Model #	HRV/ERV	Nominal CFM
Oxygen8	Ventum+ V60	HRV	5600
Oxygen8	Ventum+ V80	HRV	6933
Oxygen8	Ventum+ V100	HRV	8667
Oxygen8	Ventum+ V20	ERV	1800
Oxygen8	Ventum+ V25	ERV	2400
Oxygen8	Ventum+ V30	ERV	3200
Oxygen8	Ventum+ V40	ERV	4000
Oxygen8	Ventum+ V50	ERV	4800
Oxygen8	Ventum+ V60	ERV	6400
Oxygen8	Ventum+ V80	ERV	8000
Oxygen8	Ventum+ V100	ERV	10000
RenewAire	HE07	ERV	233
RenewAire	HE10 ⁶	ERV	350
RenewAire	HE15	ERV	520
SEMCO	EP-03 ³	ERV	1700
SEMCO	EP-05 ³	ERV	3000
SEMCO	EP-09 ³	ERV	5100
SEMCO	EP-13 ³	ERV	7900
SEMCO	EP-18 ³	ERV	10900
SEMCO	EP-24 ³	ERV	14300
SEMCO	EP-28 ³	ERV	17000
SEMCO	EP-35 ³	ERV	21100
SEMCO	EP-43 ³	ERV	25700
SEMCO	EP-46 ³	ERV	28000
SEMCO	EP-56 ³	ERV	33600
SEMCO	EP-70 ³	ERV	42200
Swegon	Gold RX 05	HRV	840

Thank You

Questions?



low @Oxygen8
din.com/company/oxygen8canada



Subscribe @
youtube.com/@ox

Next Generation DOAS Technology

Eric Kozubal

VHE DOAS Manufacturers Roundtable

September 23, 2026

24 Years at NLR (Formally NREL)



Eric Kozubal

SR. MECHANICAL ENGINEER

Eric.Kozubal@nrel.gov

- PRINCIPAL INVESTIGATOR
- HVAC LABORATORY LEAD

- DOAS Applications:

- Liquid and Solid Desiccants
- Dual Fuel (Heat Pump + Gas)
- Thermal Energy Storage



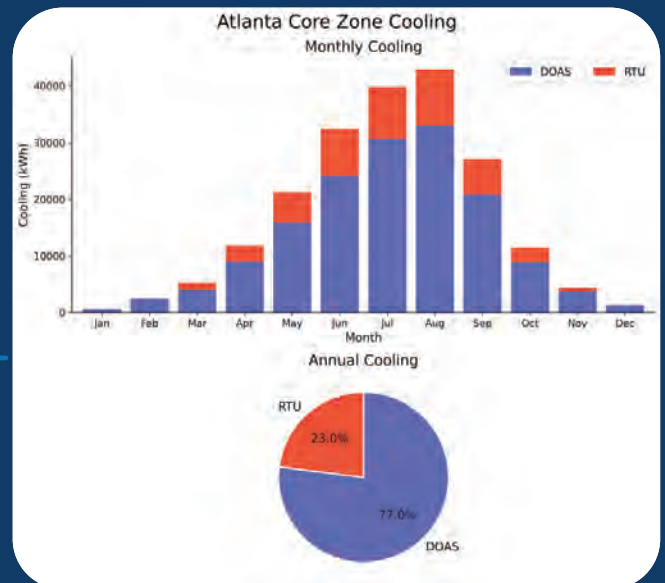
Technology Topics

- 1 Why Liquid Desiccants
- 2 Blue Frontier
- 3 Mohave
- 4 Copeland
- 5 Dual Fuel Heat Pump Research

Ventilation Cooling / Dehumidification

Building Energy Simulations Show:

DOAS Can provide ~75% of total cooling load for commercial buildings and do 100% of the dehumidification load.



Why Liquid Desiccants?

- High affinity to absorb water:
 - Equilibrates at 20% - 30% RH
 - Enable high latent ratio machines

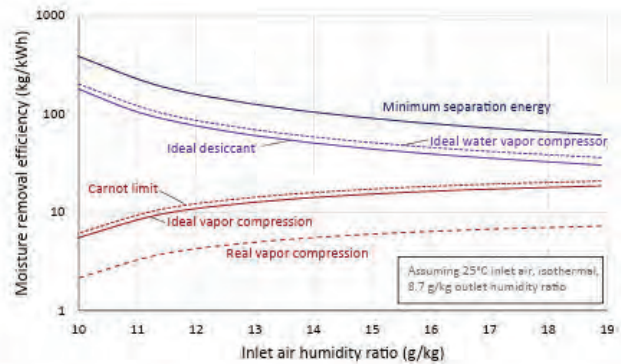
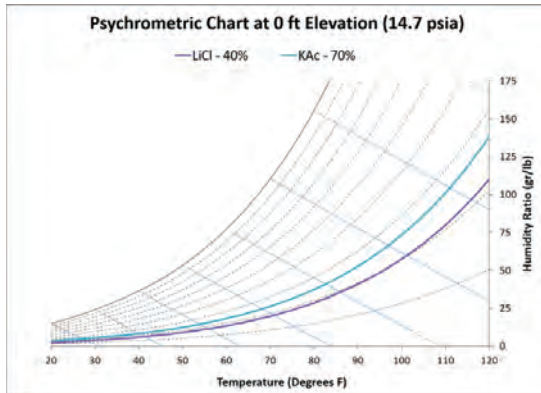


Figure 4. Moisture removal efficiency for existing technologies compared with the minimum separation energy

National Laboratory of the Rockies | 5

Blue Frontier Technology

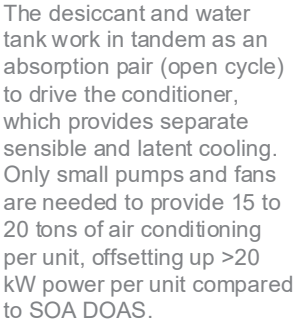


AHR Product of the Year and Sustainable Solutions Winner



National Laboratory of the Rockies | 6

with cooling storage (500 J/g)

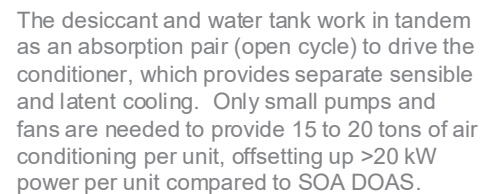


Credit: Joshua Bauer, Eric Kozubal (NLR)

National Laboratory of the Rockies | 7

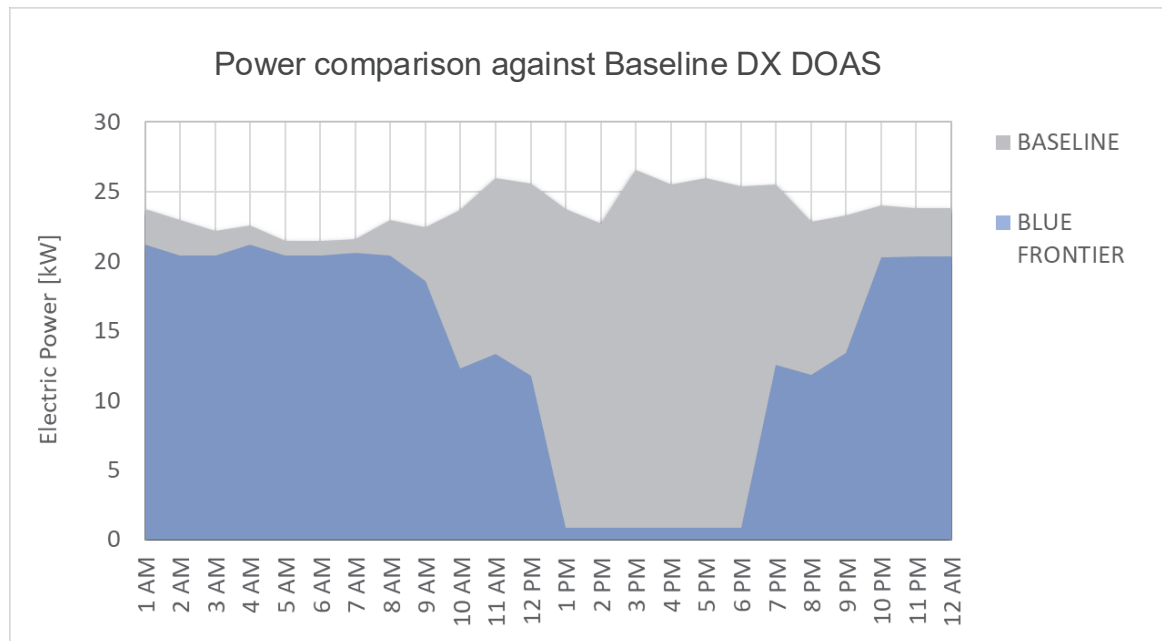
Blue Frontier DOAS

- 4 hours of storage on roof, 8+ hours ground mount
- 50% energy cost savings (ISMRE > 9.0 lb/kWh)
- Same electrical capacity required as standard DOAS
 - 24/7 operation: Simultaneous ventilation / storage charging (C/8 charge rate)
 - No efficiency penalty during charge



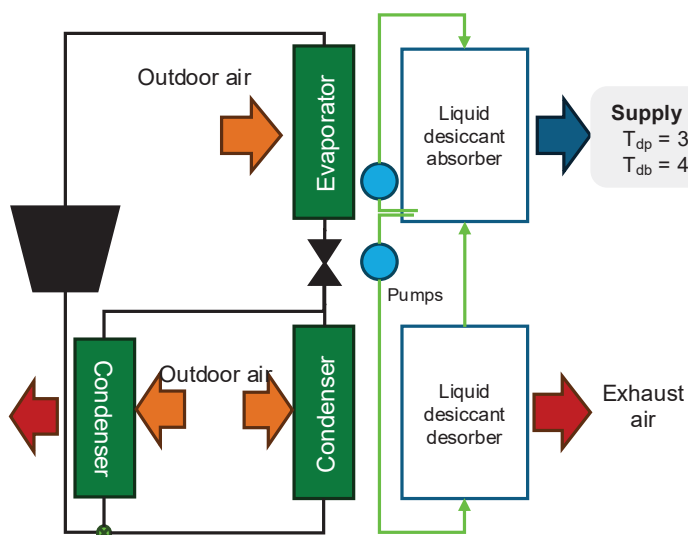
Credit: Joshua Bauer, Eric Kozubal (NLR)

Load analysis using 500 J/g and 6 hours storage



National Laboratory of the Rockies | 9

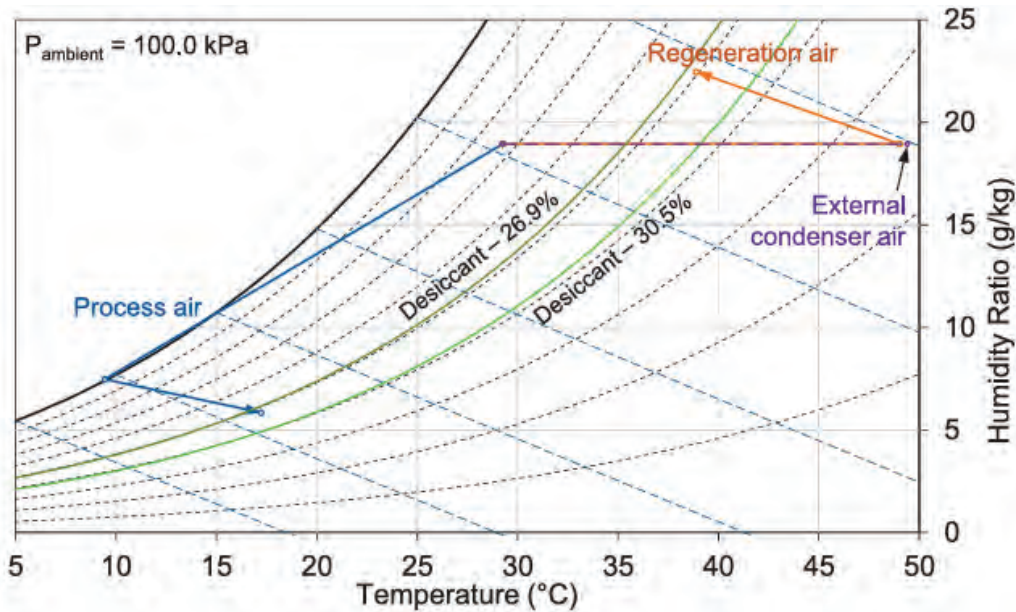
Mojave dedicated outdoor air system



- >50% Energy Savings
- ISMRE = 9.5 lb/kWh
- Supply air dewpoint down to 35°F



Mohave Dehumidification Process

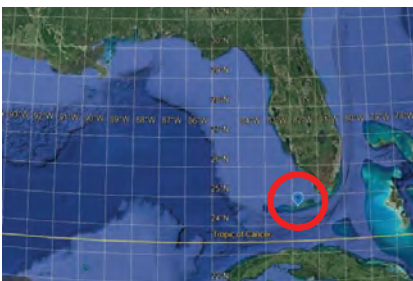


National Laboratory of the Rockies | 11

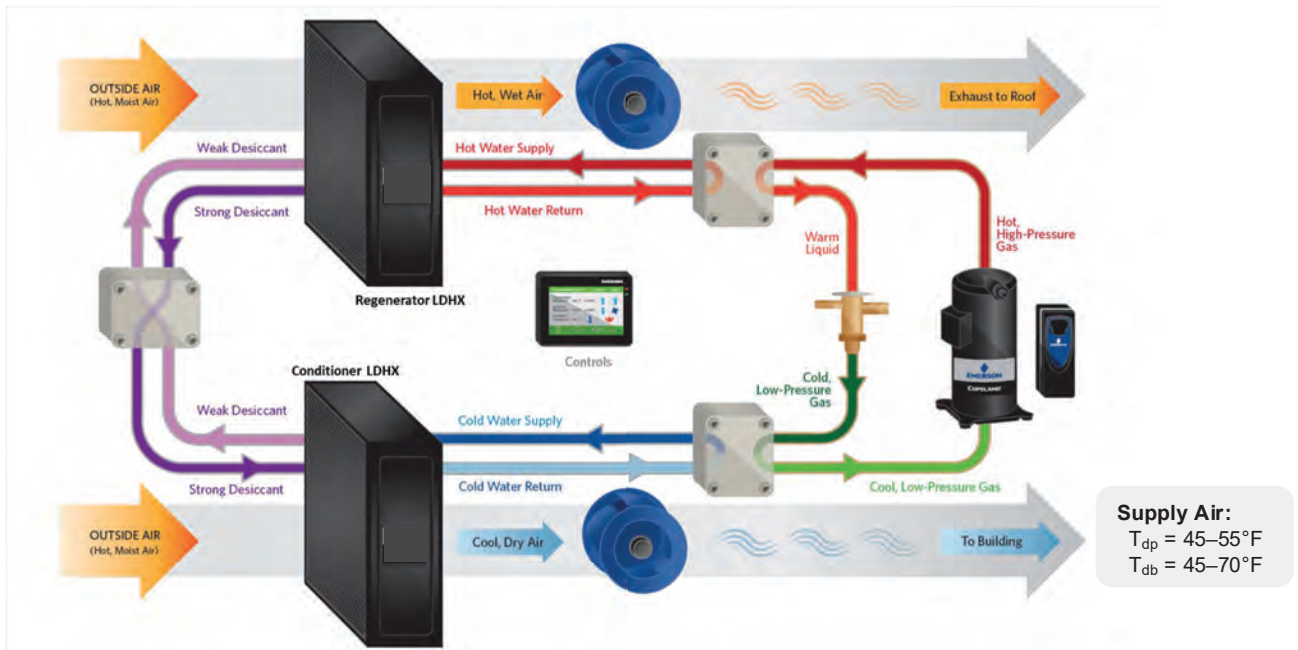
Copeland DOAS Demonstration and Copeland HMX™ at 2025 AHR show

Demonstration on Key West, FL

- MRE = 9.0 lbs / kWh in early data
- Direct to space ventilation
- 25% Total HVAC savings expected

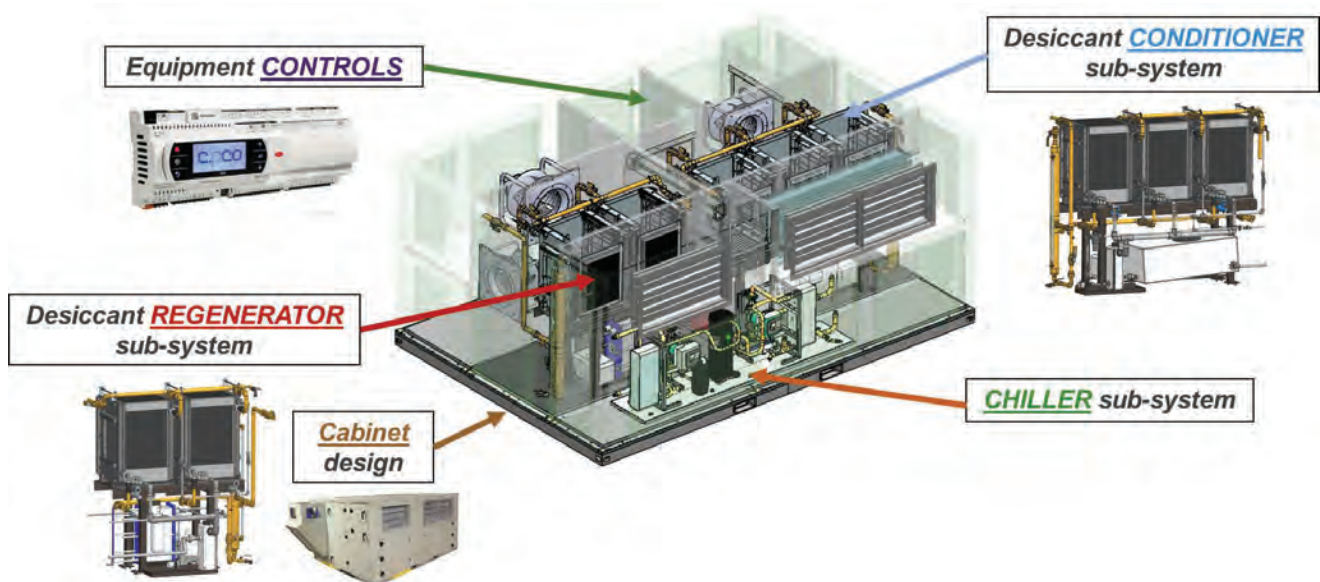


Copeland HMXs in Process Diagram



National Laboratory of the Rockies | 13

Copeland Designed DOAS and Sub-systems

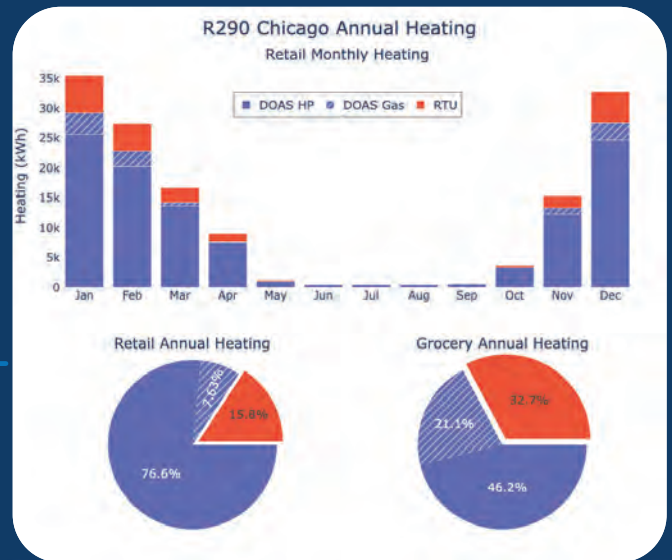


National Laboratory of the Rockies | 14

Ventilation Heating

Building Energy Simulations Show:

DOAS can provide 60%-90% of total heating load for buildings



NLR Dual Fuel Concept: A2L / A3 Compatible Dual Fuel DOAS with TES that Saves 50% on Energy Cost

- 30%-50% site HVAC energy savings: Blends **heat pump**, **TES** and **gas** to achieve minimum cost
- Expected to achieve a climate specific annualized COP = 4.5 to 5.5 (2X that of today's DOAS)



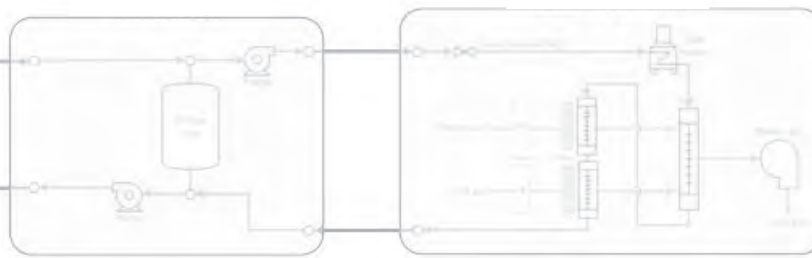
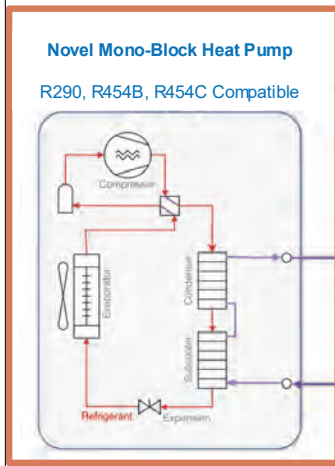
Graphic: Simplified diagram illustrates a novel mono-block heat pump, high density TES, and a fuel flexible AHU

credit: Conrado Ermel, Eric Kozubal

A2L / A3 Compatible Dual Fuel DOAS with TES

NLR Dual Fuel Concept:

- 30%-50% site HVAC energy savings: Blends **heat pump**, **TES** and **gas** to achieve minimum cost
- Expected to achieve a climate specific annualized COP = 4.5 to 5.5 (2X that of today's DOAS)



Graphic: Simplified diagram illustrates a novel mono-block heat pump, high density TES, and a fuel flexible AHU

credit: Conrado Ermel, Eric Kozubal

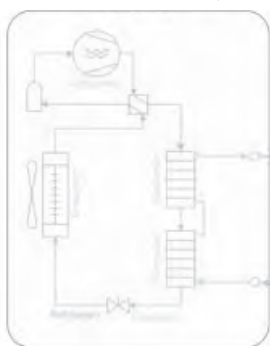
National Laboratory of the Rockies | 17

A2L / A3 Compatible Dual Fuel DOAS with TES

NLR Dual Fuel Concept:

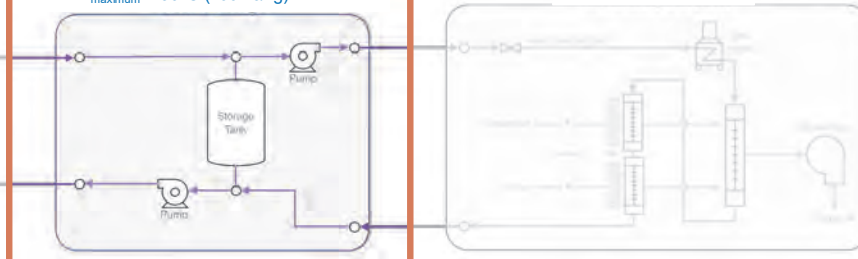
- 30%-50% site HVAC energy savings: Blends **heat pump**, **TES** and **gas** to achieve minimum cost
- Expected to achieve a climate specific annualized COP = 4.5 to 5.5 (2X that of today's DOAS)

Novel Mono-Block Heat Pump
R290, R454B, R454C Compatible



Sensible Thermal Energy Storage

$T_{hot} = 50^{\circ}\text{C} \rightarrow 75^{\circ}\text{C}$
 $T_{cold} = -15^{\circ}\text{C} \rightarrow 10^{\circ}\text{C} (T_{ambient} + 10^{\circ}\text{C})$
 $\Delta T_{maximum} = 90^{\circ}\text{C} (266 \text{ kJ/kg})$



Graphic: Simplified diagram illustrates a novel mono-block heat pump, high density TES, and a fuel flexible AHU

credit: Conrado Ermel, Eric Kozubal

National Laboratory of the Rockies | 18

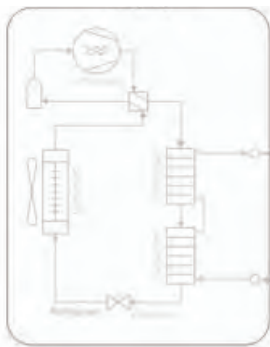
A2L / A3 Compatible Dual Fuel DOAS with TES

NLR Dual Fuel Concept:

- 30%-50% site HVAC energy savings: Blends heat pump, TES and gas to achieve minimum cost
- Expected to achieve a climate specific annualized COP = 4.5 to 6.0 (2X that of today's DOAS)

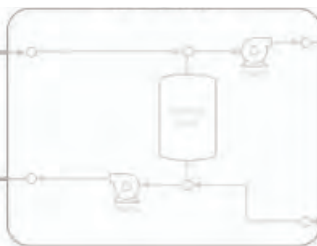
Novel Mono-Block Heat Pump

R290, R454B, R454C Compatible



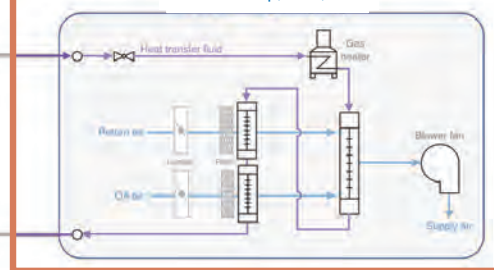
Sensible Thermal Energy Storage

$T_{hot} = 50^{\circ}\text{C} \rightarrow 75^{\circ}\text{C}$
 $T_{cold} = -15^{\circ}\text{C} \rightarrow 10^{\circ}\text{C} (T_{ambient} + 10^{\circ}\text{C})$
 $\Delta T_{maximum} = 90^{\circ}\text{C} (266 \text{ kJ/kg})$



Air Handling Unit

Flexible Heat Source:
Heat Pump, TES, Gas



Graphic: Simplified diagram illustrates a novel mono-block heat pump, high density TES, and a fuel flexible AHU

credit: Conrado Ermel, Eric Kozubal

National Laboratory of the Rockies | 19

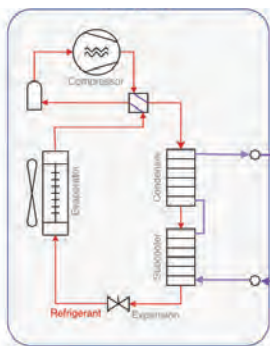
A2L / A3 Compatible Dual Fuel DOAS with TES

NLR Dual Fuel Concept:

- 30%-45% site HVAC energy savings: Blends **heat pump**, **TES** and **gas** to achieve minimum cost
- Expected to achieve a climate specific annualized COP = 4.5 to 5.5 (2X that of today's DOAS)

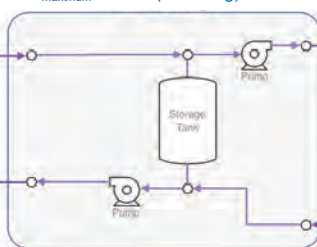
Novel Mono-Block Heat Pump

R290, R454B, R454C Compatible



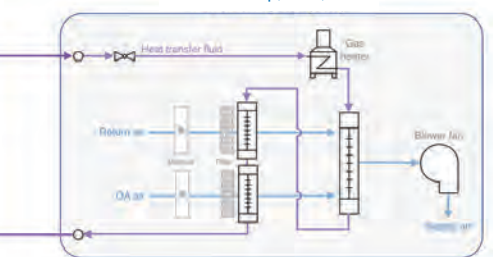
Sensible Thermal Energy Storage

$T_{hot} = 50^{\circ}\text{C} \rightarrow 75^{\circ}\text{C}$
 $T_{cold} = -15^{\circ}\text{C} \rightarrow 10^{\circ}\text{C} (T_{ambient} + 10^{\circ}\text{C})$
 $\Delta T_{maximum} = 90^{\circ}\text{C} (266 \text{ kJ/kg})$



Air Handling Unit

Flexible Heat Source:
Heat Pump, TES, Gas



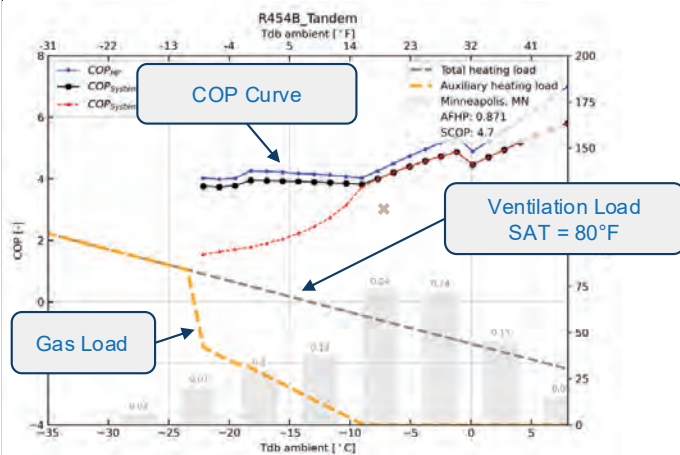
Graphic: Simplified diagram illustrates a novel mono-block heat pump, high density TES, and a fuel flexible AHU

credit: Conrado Ermel, Eric Kozubal

National Laboratory of the Rockies | 20

Performance: Minneapolis, MN

Hydronic – R454B

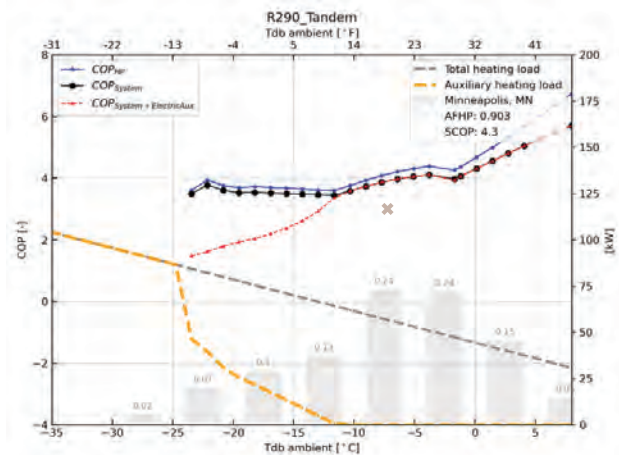


* Commercial DOAS performance

Q_{cond} 50.4kW COP 3.47
 W_{comp} 14.5kW T_{supply} 83°F

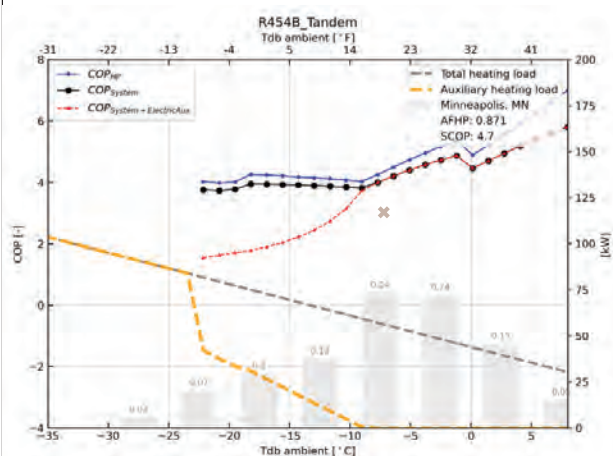
<https://files.hvacnavigator.com/p/100.54-eg2.pdf>

Hydronic – R290



Performance: Minneapolis, MN

Hydronic – R454B

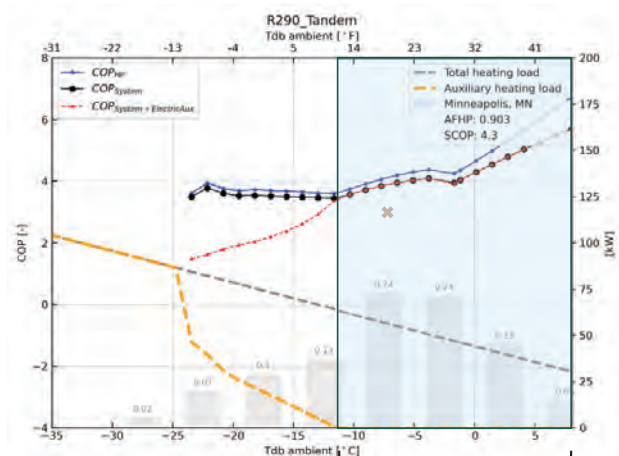


* Commercial DOAS performance

Q_{cond} 50.4kW COP 3.47
 W_{comp} 14.5kW T_{supply} 83°F

<https://files.hvacnavigator.com/p/100.54-eg2.pdf>

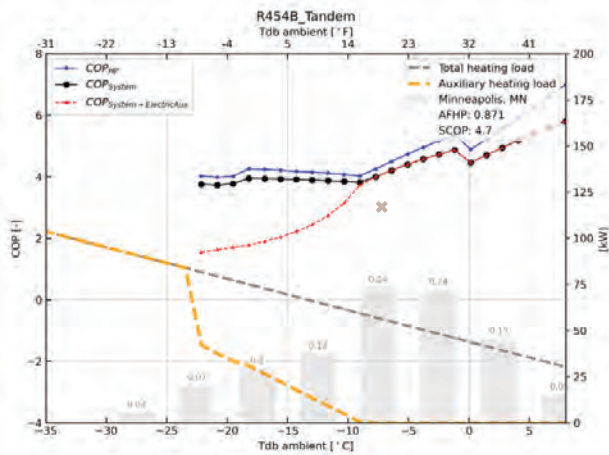
Hydronic – R290



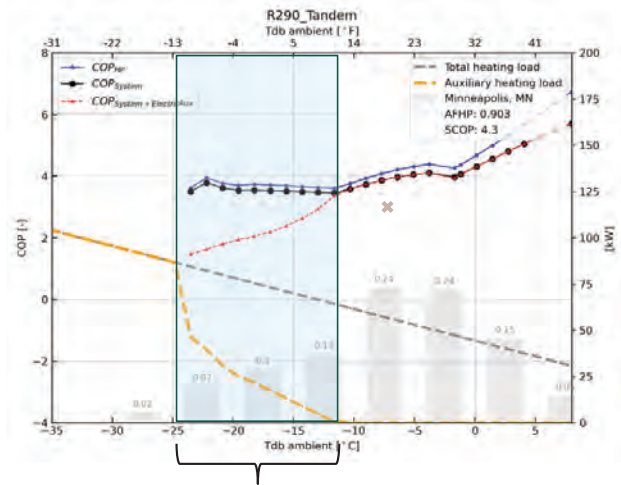
100% Heat Pump

Performance: Minneapolis, MN

Hydronic – R454B



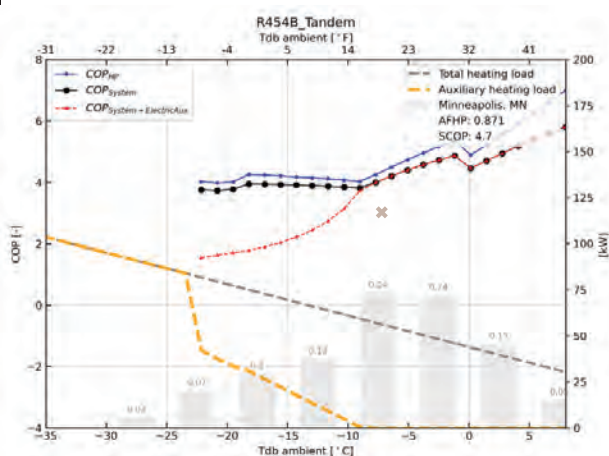
Hydronic – R290



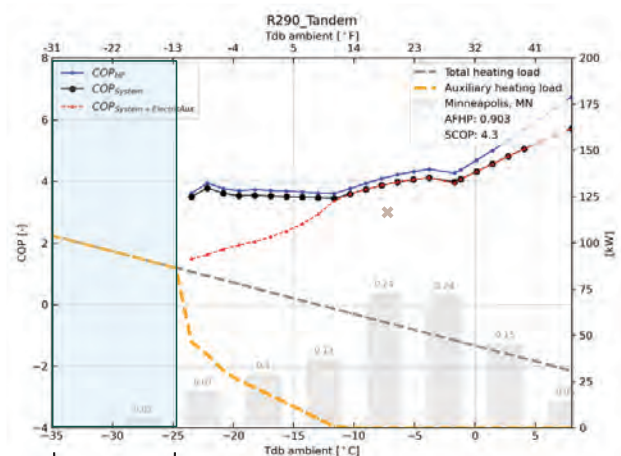
Hybrid Gas + Heat Pump

Performance: Minneapolis, MN

Hydronic – R454B



Hydronic – R290



100% NG / Aux

System performance summary

		R454B				R290			
Tandem compressor	Parameters / City	AHPF	SCOP	Onset Q _{aux}	LowOp	AHPF	SCOP	Onset Q _{aux}	LowOp
		[-]	[-]	[°C]	[°C]	[-]	[-]	[°C]	[°C]
	Atlanta, GA	1	5.66			1	5.34		
	Baltimore, MD	0.99	5.33			1	4.98		
	Boston, MA	0.99	5.26	-10.3	-22.14	0.99	4.94	-11.6	-23.45
	Chicago, IL	0.93	4.91	(13.4°F)	(-7.8°F)	0.97	4.63	(11.2°F)	(-10.2°F)
	Minneapolis, MN	0.87	4.7			0.91	4.35		
	Duluth, MN	0.81	4.5			0.87	4.15		

AHPF: Annual fraction of heating load supplied by the heat pump
 SCOP: Seasonal coefficient of performance (site specific)
 Onset Q_{aux}: Temperature where the gas heater starts its operation
 LowOp: Lowest temperature where the heat pump can operate.

System performance summary

		R454B				R290			
Tandem compressor	Parameters / City	AHPF	SCOP	Onset Q _{aux}	LowOp	AHPF	SCOP	Onset Q _{aux}	LowOp
		[-]	[-]	[°C]	[°C]	[-]	[-]	[°C]	[°C]
	Atlanta, GA	1	5.66			1	5.34		
	Baltimore, MD	0.99	5.33			1	4.98		
	Boston, MA	0.99	5.26	-10.3	-22.14	0.99	4.94	-11.6	-23.45
	Chicago, IL	0.93	4.91	(13.4°F)	(-7.8°F)	0.97	4.63	(11.2°F)	(-10.2°F)
	Minneapolis, MN	0.87	4.7			0.91	4.35		
	Duluth, MN	0.81	4.5			0.87	4.15		

The heat pump covers
81 - 100% of the
annual heating needs

AHPF: Annual fraction of heating load supplied by the heat pump
 SCOP: Seasonal coefficient of performance (site specific)
 Onset Q_{aux}: Temperature where the gas heater starts its operation
 LowOp: Lowest temperature where the heat pump can operate.

System performance summary

Parameters / City	R454B				R290			
	AHPF	SCOP	Onset Q _{aux}	LowOp	AHPF	SCOP	Onset Q _{aux}	LowOp
	[-]	[-]	[°C]	[°C]	[-]	[-]	[°C]	[°C]
Atlanta, GA	1	5.66			1	5.34		
Baltimore, MD	0.99	5.33			1	4.98		
Boston, MA	0.99	5.26	-10.3	-22.14	0.99	4.94	-11.6	-23.45
Chicago, IL	0.93	4.91	(13.4°F)	(-7.8°F)	0.97	4.63	(11.2°F)	(-10.2°F)
Minneapolis, MN	0.87	4.7			0.91	4.35		
Duluth, MN	0.81	4.5			0.87	4.15		

High seasonal
COP's

AHPF: Annual fraction of heating load supplied by the heat pump
 SCOP: Seasonal coefficient of performance (site specific)
 Onset Q_{aux}: Temperature where the gas heater starts its operation
 LowOp: Lowest temperature where the heat pump can operate.

Tandem performance summary

Parameters / City	R454B				R290			
	AHPF	SCOP	Onset Q _{aux}	LowOp	AHPF	SCOP	Onset Q _{aux}	LowOp
	[-]	[-]	[°C]	[°C]	[-]	[-]	[°C]	[°C]
Atlanta, GA	1	5.66			1	5.34		
Baltimore, MD	0.99	5.33			1	4.98		
Boston, MA	0.99	5.26	-10.3	-22.14	0.99	4.94	-11.6	-23.45
Chicago, IL	0.93	4.91	(13.4°F)	(-7.8°F)	0.97	4.63	(11.2°F)	(-10.2°F)
Minneapolis, MN	0.87	4.7			0.91	4.35		
Duluth, MN	0.81	4.5			0.87	4.15		

HP operation under
very cold temperatures
(-7.6 to -10.2°F)

AHPF: Annual fraction of heating load supplied by the heat pump
 SCOP: Seasonal coefficient of performance (site specific)
 Onset Q_{aux}: Temperature where the gas heater starts its operation
 LowOp: Lowest temperature where the heat pump can operate.

Thank You



National Laboratory
of the Rockies

Photo from Getty Images 181828180