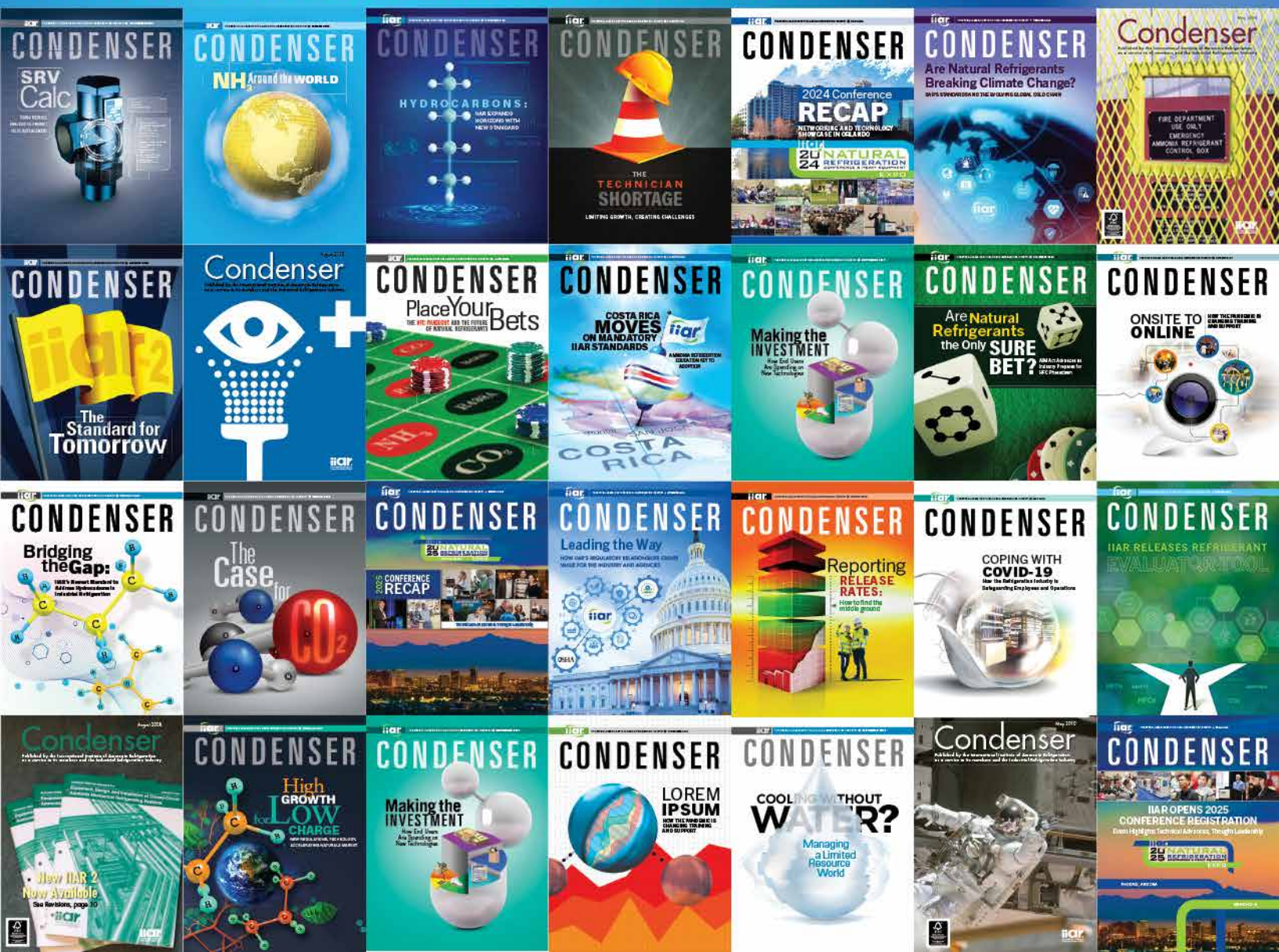
iiar®

THE OFFICIAL MAGAZINE OF THE ALL-NATURAL REFRIGERATION INDUSTRY ▪ **FALL 2025**

# CONDENSER

## Condenser Debuts Name Change

### FLAGSHIP PUBLICATION TO BECOME THE NATURAL REFRIGERATION REVIEW



FALL 2025

# contents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## 06 COVER story | Condenser Debuts Name Change

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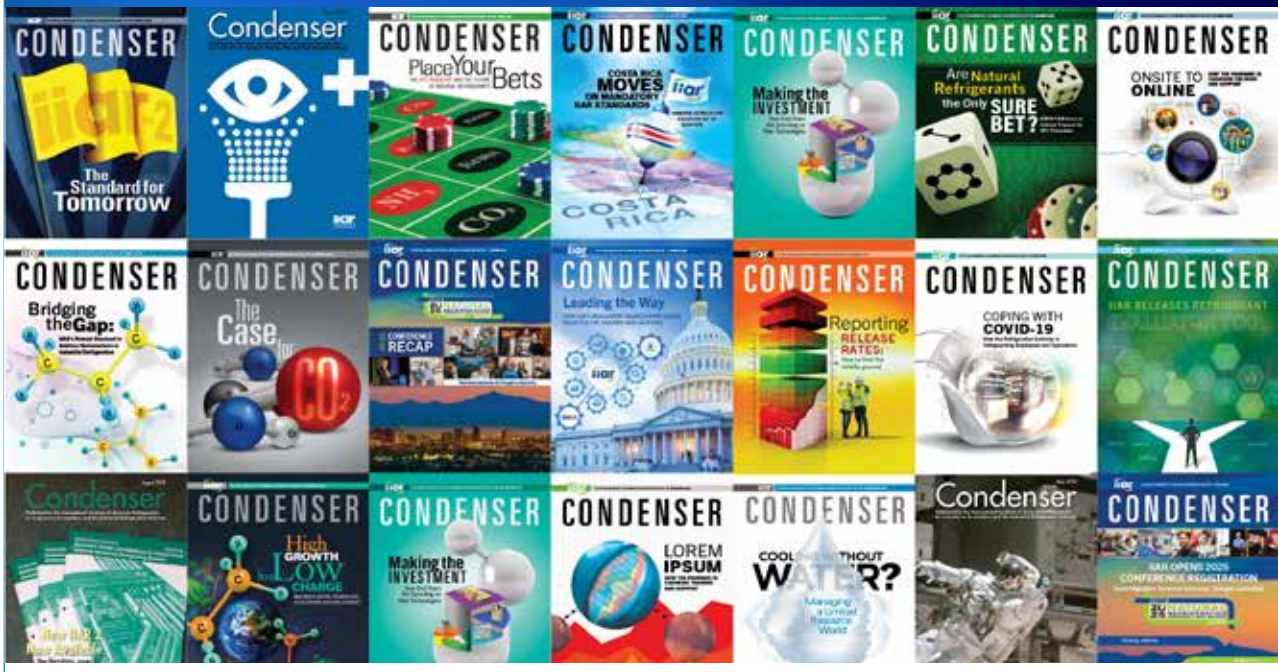

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# PRESIDENT'S MESSAGE

**BY GARY SCHRIFT**

One of the greatest strengths of IIAR is our ability to turn out educational and informational resources with the technical rigor you'd expect from a group of engineers that first convened to develop safety standards for their industry and haven't quit since.

In these days of information overload, our commitment to producing real, vetted resources for our industry – and each other – carries that energy forward. It comes out at our meetings, where I can't make it down a hallway without hearing a new proposal for a new fact sheet, whitepaper, policy analysis or obscure detail that needs addressing in our ever-evolving suite of standards. Or, if you're part of one of our many committees, you no doubt experience that energy in the lively discussions and meetings required to transform an idea that started at our annual meeting into a finished product.

What sets us apart from other groups is this unflinching commitment to making our industry the best when it comes to safety and the depth of specialized knowledge that we're capable of offering to the rest of the world.

That's why I'm pleased to share an exciting IIAR update – we're about to unveil an IIAR Resource Site where you can find and track all the many different projects we've published in one place. The resource site is also meant to highlight the wealth of technical and informative materials IIAR has developed over the years.

Our goal is simple: to ensure that every member, partner, and stakeholder throughout the world can easily find and use the tools that support their work. Many of our most valuable resources—hosted on IIAR and NRF pages—have historically been difficult to locate. We're changing that. The redesigned Resource Site will serve as a centralized hub, linking directly to existing and new content.

In addition to our websites core categories of Education (IIAR's online training classes) and Publications (IIAR's Standards, handbooks and Guidelines), the resource site will include:

- **Informational Papers**, including the *State of the Industry* reports, the updated 2025 *IIAR Green Paper*, refrigerant fact sheets, and a new PFAS fact sheet—along with future informational sheets and papers as they're produced.
- **Informational Videos**, featuring foundational content about IIAR, natural refrigerants, and the NRF, plus new promotional videos focused on $CO_2$, decarbonization, hydrocarbons, and ammonia.
- **Natural Refrigeration Career Center**, offering a public-facing job board listing internship and entry level job openings of our members to connect talent with opportunity across our growing sector.
- **Natural Refrigeration Directory**, offering a public-facing and searchable listing of manufacturers, contractors, engineers, consultants and end users who are experts in the use of natural refrigerants.
- **Natural Refrigeration Training Programs**, offering a public-facing detailed and searchable listing of training programs available for natural refrigeration.
- **Refrigerant Evaluator Tool**, offering a public-facing online tool that will assess and compare all refrigerants, synthetic and natural, by providing information on the refrigerants chemical make-up, GWP, ODP, safety class, flammability, toxicity, combability, thermodynamic properties, relative efficiency & USA EPA SNAP approval.
- **Ammonia Refrigeration Global Standards & Regulations**, offering a one-stop location to learn which standards and regulations apply for countries throughout the world.
- **Magazine Access**, with a direct link to our newly rebranded publication, *Natural Refrigeration Review*—formerly *Condenser Magazine*.

These updates are more than technical improvements—they're part of a broader strategy to position IIAR as the go-to source for natural refrigerant facts and information. By streamlining access and expanding visibility, we're empowering our members to lead with confidence, advocate with clarity, and build with purpose.

If you work on one of our committees, or you contribute to our work by attending the annual conference, by getting involved in the Foundation, or even just by participating in IIAR training or showing up for a webinar on an interesting technical topic, you are participating in our collective work to advance this essential industry.

Thank you for your work, and I look forward to hearing about it the next time I bump into you in a conference hallway!

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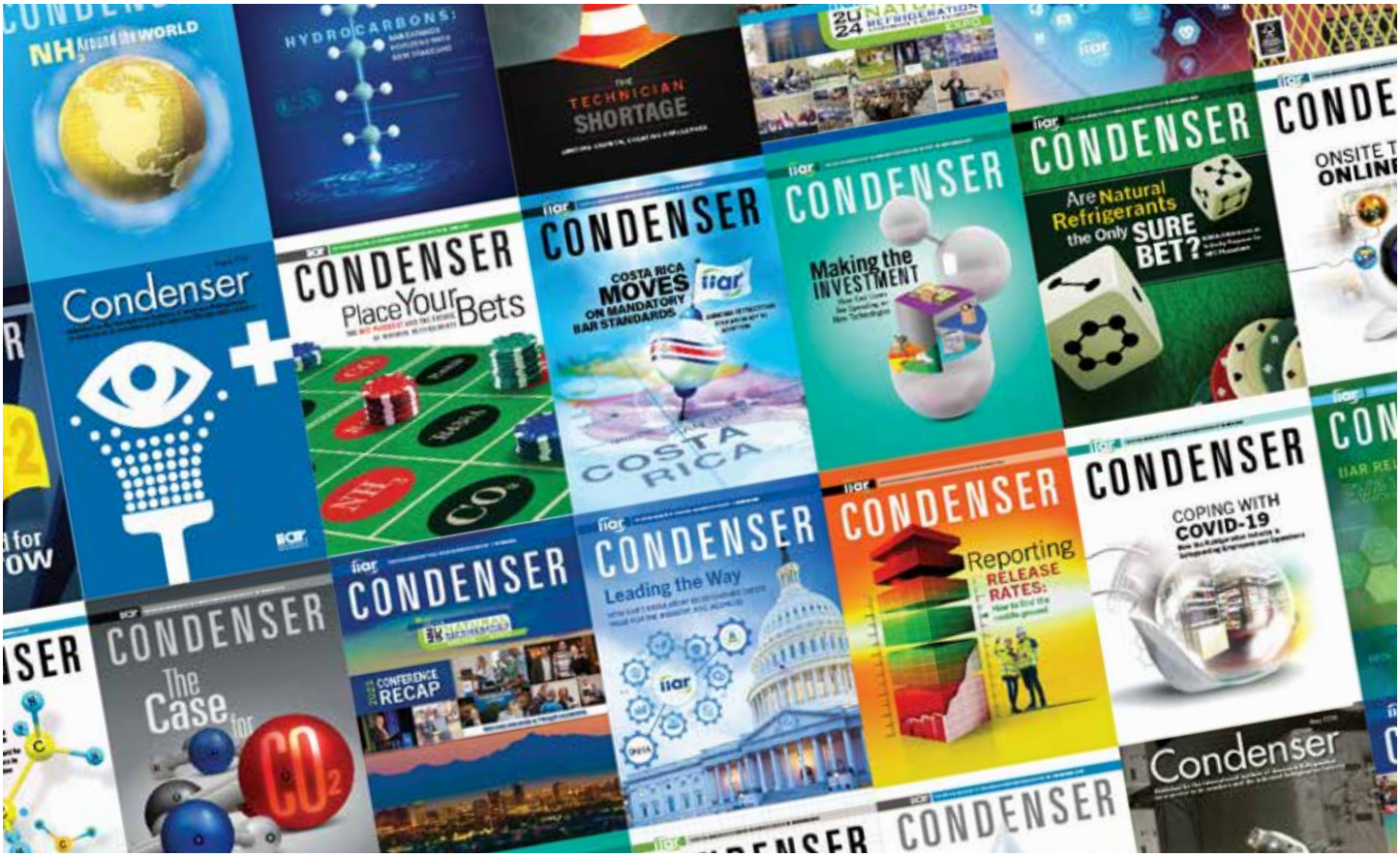


After a 30-plus-year run as the Condenser magazine, the International Institute of All-Natural Refrigeration said its long-running member journal will be rebranded in 2026 to become the Natural Refrigeration Review. IIAR said the organization's Board of Directors voted for the change as a way to reflect the expansion of the publication in recent years.

The rebranding follows the IIAR's name change for both the Institute and the Foundation, (The Natural Refrigeration Foundation), said IIAR President Gary Schrift.

“Our representation of our industry has evolved from an original scope that focused solely on ammonia and industrial applications to a scope that includes CO2 and hydrocarbon refrigerants, and commercial and residential applications., and everything relating to the use and application of natural refrigerants," said Schrift. "We've seen an overall expansion in our industry itself. These days we're tackling the AIM Act in the USA, HFC phase outs worldwide, and many other big changes that didn't exist when IIAR formed – and our mission and vision have expanded and changed to keep pace."

The decision to change the longstanding name of the Condenser, IIAR's over three-decades-old publication, to The Natural Refrigeration Review was made by the IIAR Board of Directors and staff during the organization’s Fall 2025 Board meeting, where IIAR leaders voted to choose the new name and approved a plan to expand the publication as part of the rebrand effort.

“This rebrand is an exciting opportunity to expand the depth of the information we produce as an organization,” said Andrea Fischer, Editor-in-Chief. "It's a shift that positions our publication as a central engine for IIAR's growth, outreach, and leadership in natural refrigerants."

As IIAR has found new ways to expand membership, it has also begun communicating in different ways, producing technical references and articles to attract the attention of commercial, industrial, or policy-focused groups. The rebranding also reflects the ever-growing scope of natural refrigerants.

The Natural Refrigeration Review will include a new emphasis on producing technical guides and references for the industry, such as white papers and case studies. It will also provide IIAR members with more opportunities to showcase their expertise on equipment and issues through sponsored "product showcase”-style articles.

“This name change mirrors the IIAR and NRF name changes and really completes our transition from an education and communications standpoint,” said Schrift. “We've changed our educational and

advocacy mission to deliver a wider scope of resources to our members, and now, an expanded Natural Refrigeration Review is going to make that effort even more relevant than ever."

In tandem to this magazine name change and rebranding efforts, IIAR will launch a suite of new content products, and new IIAR Resource webpage, designed to meet the practical needs of decision-makers — especially those unfamiliar with natural refrigerants, said Schrift.

Meanwhile, The Review will continue to expand on many of the industry's most pressing issues.

Over the past year, the magazine followed an ongoing shift in the industrial refrigeration landscape: the worldwide growth of natural refrigerants as a global climate solution. From regulatory breakthroughs to technical innovation, 2024–2025 marked a period of accelerated adoption.

IIAR attended the IDEA District Energy Conference and the IIR World Refrigeration Day, two events that featured new groups interested in the applications of natural refrigerants and the IIAR standards that enable their use.

## STANDARDS AND TOOLS: BUILDING THE INFRASTRUCTURE FOR GROWTH

IIAR also advanced many of its standards in 2025. Revisions to IIAR 5, 6, and 7 were ANSI-approved, while IIAR 2, 4, 8, and 9 entered review. The long-anticipated Hydrocarbon Safety Standard is nearing completion, with ANSI approval targeted for late 2025. Meanwhile, IIAR released a new Refrigerant Evaluator Tool to help users compare refrigerants amid the HFC phase-down, and will launch fact sheets and new videos for $CO_2$, ammonia, and hydrocarbons.

## SAFETY, PREPAREDNESS, AND COMPLIANCE

Safety remained a core theme of IIAR's communication in 2025. Articles explored ammonia incident investigations, emergency preparedness, and updates to the EPA's Risk Management Program (RMP) rule. IIAR also continued its work on Critical Task Guidance for ammonia emergency planning, reinforcing the importance of proactive safety culture.

## POLICY AND MARKET SIGNALS

The regulatory landscape, as always, underwent constant changes throughout the year. The AIM Act's future faced uncertainty amid federal deregulatory efforts, while states like New York advanced restrictions on HFCs. Internationally, IIAR's standards mapping project provided a comparative view of industrial refrigeration codes across 14 countries, supporting global harmonization. This information will soon be available on the IIAR Resource site.

## EDUCATION, OUTREACH, AND RECOGNITION

IIAR expanded its training footprint with on-site programs, such as the Trident Seafoods initiative, and training collaborations with RETA. The 2025 Natural Refrigeration Conference in Phoenix set new attendance records, while the upcoming 2026 San Antonio conference promises to be the largest yet.

## PFAS REGULATIONS SIGNAL A TURNING POINT FOR REFRIGERANTS

Meanwhile, a growing wave of state and federal regulations is reshaping the conversation around perfluoroalkyl substances (PFAS)—a class of persistent chemicals now under scrutiny for their environmental and health impacts. PFAS are increasingly viewed as a liability, with U.S. states introducing or adopting regulations. Until recently, refrigerants were not a central focus of these discussions, but that is rapidly changing.

Internationally, the European Union's REACH proposal is expected to be finalized in 2025 and could ban up to 10,000 chemicals related to PFAS. This would directly impact nearly all current and emerging low-GWP HFC/HFO refrigerant blends, with estimates suggesting that 95% of synthetic alternatives could fall under the PFAS classification.

The implications for the refrigeration industry are significant. Supermarkets, in particular, face heightened regulatory pressure due to leak rates. Fortunately, PFAS-free, climate-friendly refrigerant solutions are already available for the supermarket sector, while the HVAC industry continues to face a more limited set of low-GWP options.

Industry leaders are urging a shift toward future-proof refrigerants—those not at risk of being swept up in evolving PFAS regulations. Natural refrigerants, such as $CO_2$, ammonia, and hydrocarbons, offer a stable path forward, free from the regulatory uncertainty surrounding synthetic alternatives.

Staying ahead of the numerous issues and innovations driving natural refrigerants in the next decade will require constant technical expertise and communication, a task that IIAR and the Review are ready to undertake with the magazine's rebrand, said IIAR's Schrift. "I'm excited to see what's ahead for us as we delve into the stories and develop the kinds of resources our industry's decision makers need to really advocate for naturals as the best refrigerant choice in the years ahead."

The Condenser magazine website will undergo a gradual transition to the new Natural Refrigeration Review branding, which IIAR expects to complete in early 2026.

The Natural Refrigeration Review will include a new emphasis on producing technical guides and references for the industry, such as white papers and case studies.

# IIAR Delivers IIAR 9 Training at RETA

The International Institute of All-Natural Refrigeration delivered its IIAR 9 Certificate Course at the RETA 2025 National Conference Oct 18 and 19 in Spokane, WA. IIAR said it plans to deliver a course for IIAR 6-2025 during the RETA 2026 National Conference.

IIAR 9 provides the minimum safety requirements for existing closed-circuit ammonia refrigeration systems as well as provides a method to determine if existing stationary closed-circuit refrigeration systems using ammonia as a refrigerant comply with the minimum system safety requirements.

Tony Lundell, IIAR's Senior Director of Standards and Safety delivered the course, which he said is very important at this time as the refrigeration industry approaches a January 1st, 2026 deadline for IIAR 9. Yesenia Rector of IIAR provided support for this event and Lisa Berryman of IIAR provided remote administrative support during this event. Each participant received a printed copy of the IIAR 9 Standard and a copy of the Minimum System Safety Evaluation Checklist.

"The 2024 IFC Model Code adopted IIAR 9 in 2024, which means that jurisdictions can start checking for IIAR 9 being met, if they have an existing (older) closed-circuit ammonia system," said Lundell.

He added that the IIAR certificate course, and IIAR 9 is important for anyone with an existing (older) closed-circuit system. "It's important that people address any possibility of issues in their existing systems, especially where they are ten or more years old," said Lundell. "Or where there may be safety items that have come forward over the years that are required or recommended for consideration to make systems safer." When the latest IIAR 2 is used to meet a new design, it typically covers that system as its design RAGAGEP for a period of at least five years.

The IIAR 9 course is IIAR's second course to be held at the RETA National Conference. The two organizations have agreed to teach courses during each organization's respective conferences.

"This is the second year in a row that we've held a course with RETA and it's been successful enough that we've decided to continue during future events," said Lundell, adding that 24 participants passed the IIAR 9 course (2025), while 26 participants passed the IIAR 6 course the year before (2024). "The advantage of holding a full, in-person course live at the RETA conference is that participants get the benefit of full focus without disruption. We have expert information and review sessions that help attendees become very familiar and comfortable with the standards."

IIAR 9 helps with a vital decision-making process, said Lundell. Before IIAR 9, owners and/or owners designated representatives questioned if their refrigeration systems fit the updated requirements for their existing (older) refrigeration systems – depending on how their system was designed where older codes and/or standards were used or may no longer exist or be in effect at this time.

We have expert information and review sessions that help attendees become very familiar and comfortable with the standards.

**IIAR recognizes the twenty-four (24) IIAR 9 course participants who earned their IIAR 9 Certificate at the RETA 2025 National Conference:**

| | |
|---|---|
| Alexander Mefford | Dollar General Corp. |
| Shilo Reyes | North Valley Mechanical Inc. |
| Dan Parks | North Valley Mechanical |
| Robert Krieg | Janssen Refrigeration Company, Inc. |
| Brian Tiemeier | Darling Ingredients |
| Dennis Helmers | Dollar General Corp. |
| Ken Rhoades | Warren Refrigeration & Consulting |
| Gregory Hummel | Tyson Foods, Inc |
| William Murphy | Cargill Meat Solutions - Wyalusing, PA |
| Brian Capua | AMS Mechanical Systems Inc. |
| Troy Clark | AMS Mechanical Systems Inc. |
| Dustin Irwin | Lineage Logistics |
| Shane Hall | George's Inc. - Springdale, AR |
| Kimberly Proffitt | Swaggerty's Sausage Co, Inc |
| Dustin Kinsey | Swaggerty's Sausage Co, Inc |
| Omar Martinez | Swaggerty's Sausage Co, Inc |
| James Craig | ABC Engineering/Thermocarb |
| Alexander | Thermocarb |
| Steven Owen | Darigold Inc. |
| Amy English | Quality Refrigeration/ Processing Services |
| Bradley Cauble | Cooper River Partners, LLC |
| Jon Kwok | C&L Refrigeration |
| Sean Nicholls | Zero-C |
| Michael Donaldson | Fisher Refrigeration |

## IIAR DELIVERS IIAR 9 TRAINING AT RETA (continued from page 8)

According to the course description, "IIAR 9 provides a method to determine if your existing closed-circuit ammonia refrigeration system complies with minimum system safety requirements or if modifications to the existing system are needed. It is up to the owners to understand these requirements and apply them to their current system, identify any gaps, and put a plan in place to mitigate any identified gaps."

IIAR 9 requires an initial safety evaluation to be conducted for each closed-circuit ammonia refrigeration system to ensure compliance with minimum system safety requirements. As mentioned previously, that deadline is specified in IIAR 9 as January 1st, 2026.

"Reviewing this information in person helps everyone reinforce information retention and keeps that deadline at the top of their minds," said Lundell. During the courses, attendees earn Professional Development Hours (PDHs) that meet the Registered Continuing Education Program (RCEP) requirements. "It's a really good way for companies to educate their personnel on IIAR standards. The certification course also allows networking with other refrigeration professionals in the industry who take the course themselves. It builds exposure to the depth of knowledge that others have as well, so we can all challenge each other to learn and also network."


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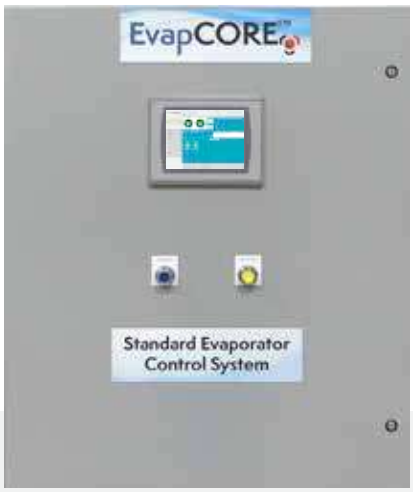


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# IIAR TO RELEASE
# Hydrocarbon and Ammonia Fact Sheets

The International Institute of All-Natural Refrigeration (IIAR) has released two new fact sheets – the Hydrocarbon and Ammonia fact sheets to meet growing demand for accessible, technically sound guidance on natural refrigerants. The newly released fact sheets are part of a trio of refrigerant summaries, including one previously released for CO2. All three cover safety considerations, system guidelines, and design considerations.

The IIAR Marketing Committee developed fact sheets to help business owners and stakeholders navigate the growing landscape of natural refrigerants alongside IIAR's other resources, such as the Refrigerant Evaluator Tool, released earlier this year, said Stephanie Smith, IIAR's Marketing Committee Chair.

Smith said the proliferation of regulations around refrigerants and the growing number of refrigerants available as options make the challenge of simplifying the decision process more important than ever. "Whether you're an end user evaluating options or someone new to natural refrigerants trying to learn the basics, these IIAR fact sheets offer clear, accessible information that IIAR is uniquely positioned to provide," said Smith.

IIAR's new fact sheets are part of a bigger effort led by IIAR to communicate safety standards that support the adoption of ammonia, $CO_2$, and hydrocarbons. With a robust library of technical resources, the new refrigerant-specific fact sheets offer a streamlined way to compare refrigerants and understand their applications.

"Hydrocarbons and ammonia are both gaining traction across sectors, and there's a real need for broader understanding," said Smith. "A one-pager that highlights the essentials is a great way to introduce the benefits and considerations of these refrigerants. It's a gateway to IIAR's deeper technical guidance, like standards."

Hydrocarbons—such as propane and butane—have long been used in industrial settings, but their role in refrigeration is expanding rapidly.

IIAR's hydrocarbon refrigerant summary advances several main ideas essential to the adoption and wider use of these refrigerants.

## HYDROCARBONS ARE SUCCESSFULLY BEING USED AND EXPANDING IN COMMERCIAL AND RESIDETIAL APPLICATIONS.

In the past year, industrial refrigeration projects have increasingly adopted hydrocarbons—especially propane and isobutane – as low-GWP alternatives to HFCs. This shift is evident across Europe, North America, and Latin America, where manufacturers have expanded the use of hydrocarbon-based systems in large-scale applications. And hydrocarbon chillers have been deployed in industrial facilities across Europe, with over 4.6 million hydrocarbon refrigerated display cases now in use across North American commercial and industrial sites, according to Natural Refrigerants: State of the Industry 2024, a report from ATMOsphere. These projects reflect a broader trend toward climate-friendly refrigerants that meet both performance and regulatory demands.

## MOST NEW HOME APPLIANCE REFRIGERATORS AND DRINK COOLERS USE ISOBUTANE AS A REFRIGERANT.

Isobutane has rapidly become the refrigerant of choice in new home appliance refrigerators and drink coolers over the past few years, driven by its ultra-low global warming potential and ozone-friendly profile. Manufacturers worldwide have embraced isobutane as a replacement for high-GWP hydrofluorocarbons (HFCs), especially in compact, self-contained systems.

According to a report by research company 24 Chemical Research, the global R-600a refrigerant market has seen steady growth, with widespread adoption in household refrigeration equipment across North America, Europe, and Asia-Pacific. Meanwhile, innovations in vapor compression cycle design — such as those led by Oak Ridge National Laboratory and Whirlpool — have further improved energy efficiency and system performance using isobutane, according to the Department of Energy.

Hydrocarbon refrigerants are increasingly being used in large-charge industrial applications worldwide due to their ultra-low global warming potential. Their adoption reflects a global shift toward sustainable, high-performance cooling solutions that meet both environmental and operational goals, said the International Institute of Refrigeration in a statement.

IIAR's hydrocarbon fact sheet complements IIAR's forthcoming Hydrocarbon Safety Standard, which is currently undergoing final review. The standard outlines best practices for system design, installation, startup, inspection, and maintenance, and is modeled after IIAR's $CO_2$ standard. It also addresses training and general safety needs, making it a critical resource for facilities transitioning to hydrocarbons or expanding their use.

Alongside the hydrocarbon fact sheet release, IIAR is also publishing a new Ammonia Refrigerant Fact Sheet—an updated overview of the refrigerant that has long been the backbone of industrial refrigeration. The ammonia fact sheet offers a clear summary of its properties, applications, and safety considerations, reinforcing its continued relevance in a low-GWP future.

The ammonia fact sheet complements IIAR's existing suite of ammonia standards and technical handbooks, offering a quick-reference guide for engineers, technicians, and facility managers who need to evaluate ammonia's role in new or existing systems.

The release of IIAR's hydrocarbon, ammonia, and CO2 fact sheets comes at a pivotal moment. With regulatory pressure mounting—from the HFC phase-down to state-level climate mandates—industry professionals are seeking refrigerants that balance performance, safety, and sustainability, said IIAR. Natural refrigerants like ammonia and hydrocarbons fit that profile, but their unique characteristics demand specialized knowledge.

IIAR's fact sheets bridge the gap between technical depth and practical accessibility. They're tailored for engineers, technicians, facility managers, and policymakers who need reliable snapshots of refrigerant capabilities—without wading through hundreds of pages of standards.

"IIAR's fact sheets are a great place to start," said Smith. "They help normalize natural refrigerants and give stakeholders the confidence to explore them further."

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# GOVERNMENT RELATIONS

BY LOWELL RANDEL, IIAR GOVERNMENT RELATIONS DIRECTOR

# EPA Proposes Reconsideration of TECHNOLOGY TRANSITIONS RULE

On September 30th, The Environmental Protection Agency (EPA) announced a proposed rule to reconsider policies contained in the Technology Transitions Rule under the American Innovation and Manufacturing (AIM) Act.

The AIM Act, passed in 2020, directs EPA to address hydrofluorocarbons (HFCs) in three main ways: (1) phasing down HFC production and consumption through an allowance allocation program, (2) promulgating certain regulations for purposes of maximizing reclamation and minimizing releases of HFCs from equipment and ensuring the safety of technicians and consumers, and (3) facilitating the transition to next-generation technologies through sector-based restrictions.

IIAR was one of the first organizations to submit a petition under the AIM Act suggesting GWP limits for multiple uses of HFCs related to refrigeration. IIAR's petition was granted and helped form the basis of the agency's October 2023 rule - Phasedown of Hydrofluorocarbons: Restrictions on the Use of Certain Hydrofluorocarbons under Subsection (i) of the American Innovation and Manufacturing Act of 2020, otherwise known as the Technology Transitions Rule.

The new rule being proposed by EPA is part of a broader effort to consider deregulatory actions that was announced on March 12, 2025. The proposal also responds to a petition submitted in March 2025 by the Coalition for the Use of Safe and Efficient Refrigerants, Inc. (CUSER), which focuses on requesting EPA to raise the GWP limit for cold storage warehouses from 150 GWP to 700 GWP. Other policies addressed in the proposed rule relate to intermodal refrigerated transport, industrial process refrigeration and chillers used in semiconductor manufacturing, certain types of refrigerated laboratory equipment, retail food refrigeration systems for supermarkets and remote condensing units, and residential and light commercial air conditioning and heat pump systems.

EPA has stated that the proposed rule is intended to increase flexibility and relax certain restrictions on the use of HFC refrigerants previously established under the Technology Transitions section of the AIM Act by changing compliance dates and/or global warming potential thresholds for various applications. EPA is also proposing to remove the installation compliance date for residential and light commercial air conditioning and heat pump (AC/HP) systems, using components manufactured or imported prior to January 1, 2025. Below are specific changes proposed for cold storage warehouses and retail food (supermarkets):

IIAR has been actively engaged with EPA throughout the rulemaking process. IIAR President Gary Schrift met with EPA and Office of Management and Budget (OMB) representatives to share concerns about potential policy changes ahead of the EPA's release of the proposed rule. Schrift and Vice President, Technical Director, IIAR, Eric Smith also provided oral comments at an EPA hosted public meeting on October

**OLD STORAGE WAREHOUSES:**

**Current Policy** –

Starting January 1, 2026: 150 or 300 threshold (depending on charge size and equipment configuration)

**Proposed Change** –

Starting January 1, 2026: 700 threshold

Starting January 1, 2032: 150 or 300 threshold (depending on charge size and equipment configuration)

**RETAIL FOOD (SUPERMARKETS)**

**Current Policy** –

Starting January 1, 2027: 150 or 300 threshold (depending on charge size and equipment configuration)

**Proposed Change** –

Starting January 1, 2027: 1,400 threshold

Starting January 1, 2032: 150 or 300 threshold (depending on charge size and equipment configuration)

**RETAIL FOOD (REMOTE CONDENSING UNITS) -**

**Current Policy** –

Starting January 1, 2026: 150 or 300 threshold (depending on charge size and equipment configuration)

**Proposed Change** –

Starting January 1, 2026: 1,400 threshold

Starting January 1, 2032: 150 or 300 threshold (depending on charge size and equipment configuration)

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 (continued from page 12)

20th, after the proposal had been published. Schrift and Smith asserted that extending the compliance deadline could cause further market disruption as well as increase the potential exposure to PFAS chemicals. Both of these are unnecessary risks given the already wide adoption of safe, efficient and readily available natural refrigeration technologies.

Schrift also took the opportunity to highlight that over 90 percent of cold storages currently use natural refrigerants and that reducing the burdens of ammonia regulations would have a much larger impact on businesses across the food supply chain. For example, IIAR is requesting EPA to reconsider current Risk Management Program (RMP) regulations as a part of the agency's deregulatory activities. RMP is one of the over 30 regulations identified by EPA for potential reforms and IIAR supports the agency's efforts to modernize the RMP regulation.

With the January 1, 2026 compliance date for several of the Technology Transition Rule provisions rapidly approaching, it is expected that EPA will work to finalize any rule changes prior to that date. However, the extended government shutdown has forced a pause in many EPA activities and could delay final rulemaking action. IIAR will continue to actively engage with EPA throughout the rulemaking process.


IIAR was one of the first organizations to submit a petition under the AIM Act suggesting GWP limits for multiple uses of HFCs related to refrigeration.

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# Creating Your Pressure Vessel Replacement Framework

When it's time to replace a pressure vessel in an industrial refrigeration system, the stakes can be high and the questions are many. To help operators, engineers, and manufacturers navigate this complex process, IIAR recently hosted a member webinar titled ***Considerations for Pressure Vessel Replacement***. The presentation laid out a question-and-answer framework designed to guide decision-making and ensure long-term mechanical integrity for your refrigeration system.

Creating a framework of operating conditions that describe a system before making a repair or replacement decision can help guide decision makers upfront, said David Crement, Director, Quality, ASME Code & Design for vessel manufacturer RVS, Refrigeration Vessels & Systems Corp.

"Part of this is taking good engineering practices and saying – when was the last time we did a thickness check on this vessel, and are the original conditions really what we're operating with," said Crement.

"We find with older vessels, someone may have made a decision with one set of conditions in mind such as higher temperatures, but really, they're operating in a different set of conditions like lower temperatures in a vacuum. We want to make sure we look at all the conditions accurately to make sure if you get audited by an agency, you have a pressure vessel that really fits your operating conditions."

Creating a framework of operating conditions and taking that to the decision process with a manufacturer is vital because a manufacturer may not know a facility's specific operating conditions," said Tony Lundell, IIAR's Senior Director of Standards and Safety. "These questions will help prepare you to communicate effectively with your manufacturer about what you need. These questions are good for anyone to consider, but they're especially useful for someone new to the industry who is responsible for pressure vessels. They remind everyone what we should be asking."

Whether you're planning a replacement now or preparing for future upgrades, these questions yield essential insights every operator can use to build a framework for making vessel replacement decisions:

**1. How long will this replacement pressure vessel need to operate safely once installed?**

This question sets the foundation for replacement decisions. If the system is expected to run continuously, without planned shutdowns or decommissioning, the pressure vessel should be designated as designed for long-term operation. However, if the pressure vessel is intended for a

Creating a framework of operating conditions that describe a system before making a repair or replacement decision can help guide decision makers upfront.

 (continued from page 16)

use period less than 10 years, a similar replacement at the current minimum design pressure may be sufficient and the vessel should be designated as designed for short-term use.

**2. What is the minimum design pressure and the lowest operating temperature of the system that the replacement pressure vessel will be operating under once installed?**

This question is essential for defining the operating envelope of your replacement pressure vessel. The answers help ensure the vessel is designed to withstand the full range of pressures and temperatures it will encounter—both now and in the future.

Start by assessing the minimum design pressure and the lowest operating temperature based on your system type and installation location. These values vary depending on whether your system is water-cooled, evaporative cooled, air-cooled, or operating on the high pressure side or low-pressure side of the refrigeration system.

The pressure vessel must also be stamped with a Minimum Design Metal Temperature (MDMT) that reflects the lowest expected operating temperature. If you plan to reuse the vessel on another system in the future, consider designing for a higher or lower minimum pressure now. This forward-thinking approach can reduce future costs and expand the pressure vessel's versatility across multiple installations.

**3. Will this new pressure vessel be considered for future use on a different system that has a higher minimum design pressure and/or a lower operating temperature?**

If there's a chance your replacement pressure vessel may be reused on a different system in the future, it's worth designing for that possibility now. This question helps operators think beyond the immediate installation and consider long-term flexibility.

A pressure vessel designed for a higher minimum pressure can still be used in a lower-pressure system today, protected by appropriate relief devices. But when that pressure vessel becomes available for reuse, it will already be rated for more demanding conditions—saving time, cost, and complexity down the road.

Ultimately, while higher ratings may increase upfront costs, they also enhance mechanical integrity and future-proof the pressure vessel for broader operational use. If reuse is part of your long-term plan, this is a question worth answering.

**4. Will this new pressure vessel be carbon steel and/or subject to an environment that could result in external corrosion?**

Start by evaluating the installation environment. Is it mild, mildly harsh, or harsh? This determination will guide whether additional wall thickness or protective coatings are needed beyond the standard corrosion allowance included in ASME B&PVC, Section VIII, Division 1 design formulas.

If the pressure vessel is made of carbon steel and exposed to moisture, chemicals, or other corrosive elements, a suitable increase in material thickness is recommended. This helps ensure the pressure vessel maintains its mechanical integrity throughout its service life. Even if the pressure vessel meets minimum thickness requirements, added protection may be necessary depending on the conditions.

Most importantly, manufacturers must be informed of the environmental conditions the pressure vessel will face. This ensures the design accounts for corrosion risks from the onset. If there's any doubt about the severity of the environment, lean and focus on the side of caution—thicker material is a small price to pay for long-term reliability.

**5. Should you install a horizontal or vertical replacement pressure vessel?**

Orientation matters—and in most cases, the replacement pressure vessel will match the original layout. But whether horizontal or vertical, the choice should be informed by space constraints, system function, and separation performance.

**Vertical pressure vessels** are often preferred when floor space is limited, but they require sufficient overhead clearance. Their design is fixed in terms of cross-sectional area, so the vertical distance between the liquid level and the suction outlet becomes critical. If the pressure vessel is used to separate refrigerant liquid from vapor, this spacing must be carefully calculated to avoid liquid carryover and ensure buffer capacity.

**Horizontal pressure vessels**, on the other hand, offer more flexibility. Designers can adjust the high-level cutout or install internal baffle plates to create a dual-flow approach, effectively altering the vessel's capacity and separation dynamics. This can be especially useful in systems with variable flow rates or where fine-tuning is needed to maintain performance.

By evaluating these factors early, operators can ensure the replacement pressure vessel is not only a physical fit—but a functional one.

**6. Should the heads of the pressure vessel be hot-formed or stress relieved after cold-forming?**

This question is all about managing risk—specifically, the risk of Stress Corrosion Cracking (SCC). SCC is the result of stress (from forming, welding, or external forces) interacting with a corrosive environment and oxygen. While it's a relatively low risk in closed-circuit refrigeration systems, it's still a critical factor in vessel design.

If the internal surfaces of the replacement pressure vessel will be exposed to refrigerant, the heads must either be hot-formed or stress relieved after cold-forming. This treatment helps prevent SCC from developing over time. If the pressure vessel will primarily contain oil, the designer should evaluate whether stress relief is necessary based on the specific application.

Post-weld heat treatment (PWHT) is a common method for relieving stress, but it's not always feasible—especially in pressure vessels with internal gaskets, such as specialty chillers. In those cases, hot-forming the heads during fabrication is the preferred approach. If PWHT is used, specifying a purge gas during the process can help minimize scale buildup, which could otherwise impair system performance.

Ultimately, the owner should work closely with the designer to confirm whether SCC mitigation is required. While SCC is less common in closed systems—especially those with water content up to 0.2%, which can scavenge oxygen—it's still a risk worth addressing. Getting this detail right at the design stage can prevent costly nuisances and/or failures later.

Click here to find IIAR's Considerations for Pressure Vessel Replacement webinar, which answers several other questions needed to build out your design framework and built a working "win-win" relationship with the pressure vessel manufacturer.

Led by Tony Lundell, IIAR's Senior Director of Standards and Safety, the webinar features detailed images of pressure vessels to illustrate common issues and practical solutions—bringing clarity to a process that often involves regulatory nuance, design complexity, and operational risk.

Each question covered by IIAR's webinar is paired with technical guidance rooted in IIAR's recognized standards, including the newly revised IIAR 2 Standard, which supports safe design and compliance across the refrigeration industry.

# Financial Tech Tip

# 2025 Tax Law Changes

### REVIEW THE NEW LAW

The President signed the One Big Beautiful Bill Act (OBBBA) on July 4, 2025. This new law addresses the expiration of temporary provisions of the Tax Cuts and Jobs Act of 2017 (TCJA), makes changes to other tax laws, and creates some new tax provisions consistent with the President's campaign promises. The result is an extension and/or modification of most expiring tax laws along with some notable new tax breaks. The information below is a summary of some of the most impactful tax provisions for individuals.

This section lists some of the current tax provisions that were scheduled to expire under the TCJA and how they were impacted.

| CURRENT TAX LAW | NEW LAW | IMPACT OF NEW LAW |
|---|---|---|
| **Reduced ordinary income tax rates:**<br>10%, 12%, 22%, 24%, 32%, 35%, 37% | Current law is made permanent. | No change. |
| **Increased standard deduction** | Current law is made permanent. | The 2025 standard deduction will increase to $15,750 ($31,500 for joint filers) |
| **Personal exemptions are not allowed** | Current law is made permanent except for the following temporary exception:<br>Taxpayers aged 65 or older are eligible for a deduction of $6,000 per person for 2025-2028.<br>This deduction will phase out when income exceeds $75,000 ($150,000 for joint filers). | Eligible taxpayers will benefit from this large deduction in addition to their standard or itemized deductions. |
| **State and local tax deduction capped at $10,000** | State and local tax deduction cap increases to $40,000 in 2025. In 2030, it reverts to $10,000 permanently.<br>The deduction amount between $10,000 and $40,000 is subject to phase-out for income over $500,000. | This could provide a larger deduction for taxpayers below the income phase-out limit.<br>More taxpayers will be able to itemize deductions rather than use the standard deduction. |
| **Reduced mortgage interest expense deduction; deduction for home equity interest repealed** | Current law is made permanent.<br>In addition, mortgage insurance premiums may now be included as mortgage interest expense after 2025. | Taxpayers may receive a larger mortgage interest expense deduction if they are paying mortgage insurance premiums. |
| **No cap on total itemized deductions** | A new reduction to overall itemized deductions applies for taxpayers in the 37% tax bracket after 2025. | High-income taxpayers will lose some of their itemized deductions. |
| **Repeal of 2% miscellaneous itemized deductions (investment advisory fees, tax preparation fees, etc.)** | Current law is made permanent. | No change. |
| **Increased alternative minimum tax exemptions and phase-out thresholds** | Current law is made permanent with some adjustments to the calculation of the phase-out range after 2025. | Most taxpayers will still avoid AMT. However, due to the shortened phase-out calculation, the impact of AMT should still be reviewed annually. |
| **Creation of 20% qualified business income (QBI) deduction**<br>**Increased child tax credit and addition of new credit for other dependents** | QBI deduction remains at 20% with enhancements to phase-out rules after 2025.<br>The child tax credit is increased to $2,200 starting in 2025.<br>The $500 credit for other dependents is made permanent. | The change to the phase-out rules may result in more deductions for eligible business owners<br>Eligible taxpayers will see additional benefit from this tax credit. |
| **Creation of qualified opportunity funds (QOFs) and deferral of capital gains upon investment**<br>**Any gains deferred by investment in a QOF prior to 2027 become taxable on December 31, 2026.** | The tax provisions have been enhanced to allow for:<br>• Designation of new opportunity zones<br>• New five-year deferral periods for capital gains invested after 2026<br>• A 10% increase to cost basis of new capital gain investments made after 2026 when held more than five years (30% for rural investments) | Taxpayers who have deferred gains by investing in these funds will still need to prepare for taxation of those gains in 2026.<br>Taxpayers may choose to defer additional gains by making new investments after 2026. |
| **Increased gift/estate exemption** | Higher exemption amount is made permanent starting at $15,000,000 per person in 2026. | No change. |
| **Bonus depreciation percentage is gradually reduced through 2026** | 100% bonus depreciation is made permanent for property placed in service after January 19, 2025. | Taxpayers will be able to accelerate deductions on eligible purchases of business property. |

## FINANCIAL TECHTIP (continued from page 18)

The following section is a summary of some laws created or reinstated by the OBBBA that will impact individuals.

| NEW LAW | IMPACT OF NEW LAW |
|---|---|
| **Interest expense** up to $10,000 would be deductible on loans for eligible personal use vehicles purchased from 2025-2028.<br>The deduction would phase out for income over $100,000 ($200,000 for joint filers). | Taxpayers may temporarily deduct eligible car loan interest, even if they do not itemize their deductions. |
| **Tip income** up to $25,000 may be excluded from income for 2025-2028.<br>The deduction would phase out for income over $150,000 ($300,000 for joint filers). | Taxpayers may be temporarily eligible to deduct a limited amount of tip income, even if they do not itemize their deductions. |
| **Overtime pay** up to $12,500 (25,000 for joint filers) may be excluded from income for 2025-2028.<br>The deduction would phase out for income over $150,000 ($300,000 for joint filers). | Taxpayers may be temporarily eligible to deduct a limited amount of overtime pay, even if they do not itemize their deductions. |
| **Charitable deductions** are reinstated for non-itemizers up to $1,000 ($2,000 for joint filers) after 2025. Contributions must be made in cash to eligible organizations. | Taxpayers who claim the standard deduction may receive additional tax benefits for eligible charitable contributions up to the allowed limit. |
| **Charitable deductions** for itemizers are allowed only to the extent they exceed 0.5% of income after 2025. | Taxpayers who itemize will reduce their allowed charitable contribution deduction by 0.5% of their income, thereby reducing the tax benefits for their charitable gifts.<br>This reduction applies before the new reduction on overall itemized deductions for high-income taxpayers. |
| **"Trump accounts"** may start to receive contributions 12 months after date of enactment.<br>• Contributions are not deductible, are limited to $5,000 per year, and are allowed only for calendar years ending before the eligible beneficiary reaches age 18.<br>• Account assets may be withdrawn in or after the year the beneficiary reaches age 18. | Taxpayers may consider this new option for setting aside funds for children on a tax-deferred basis. |
| **The definition of qualified expenses for 529 plans is expanded to include:**<br>• K-12 books, materials, tutoring, certain testing or exam fees, and educational therapies; effective for distributions after date of enactment<br>• The annual limit for K-12 expenses increases from $10,000 to $20,000 after 2025<br>• Expenses related to obtaining or maintaining recognized postsecondary credentials including tuition, fees, books, supplies, and equipment; effective for distributions after date of enactment | With an expansion of qualified education expenses, taxpayers may consider increasing their contributions to 529 plans to take advantage of the tax-deferred growth and potential for tax-free distributions. |
| Enhancements to the gain exclusion rules for sale of Qualified Small Business Stock (QSBS):<br>• 50% of gain may be excluded if QSBS is held more than three years.<br>• 75% of gain may be excluded if QSBS is held more than four years.<br>• The 100% exclusion still applies for QSBS held more than five years.<br>• The $10,000,000 gain exclusion limit increases to $15,000,000.<br>• The eligible asset limit increases from $50 million to $75 million. | Small business owners may consider structuring their business as a C Corporation if they may want to take advantage of the QSBS gain exclusion rules upon sale. |

### EVALUATE OPPORTUNITIES IN THE NEW LAW

Your personal tax situation will determine which of these new provisions you need to focus on. For many taxpayers, there may be little change between 2025 and 2026. However, it will be important for others to determine whether the new law provides an opportunity for tax savings bef ore 2026. There is a short amount of time left in the year to act. Work with your team of professionals now to develop strategies that will help you prepare for the impact of the new law. Here are some of the strategies you may consider.

#### Charitable Giving Strategies

With the higher standard deduction amount continuing, it will be important to review your charitable giving methods. If you are no longer itemizing deductions, you are not getting a tax benefit for a charitable contribution deduction in 2025. You may want to explore gifting from your IRA if you are over 70 ½, or evaluate a bunching strategy paired with a donor-advised fund contribution. Gifting appreciated securities instead of cash can also provide additional tax benefits while meeting your charitable goals. Your Stifel Financial Advisor can walk you through these strategies to help you determine which makes sense for your situation.

#### Timing of Income and Deductions

If you are eligible for some of the new or expanded deductions listed above, they may reduce your income in your current tax bracket or shift you into a lower tax bracket. If so, you may want to consider whether or not this is an opportunity to include more income at your current rate (fill up your bracket) or possibly at a lower rate. For example, this may be an opportunity to complete a Roth conversion, exercise employer stock options, or recognize additional capital gains. Estimating your income and deductions before year-end will help you determine any actions to take so that you don't miss an opportunity for tax savings.

### IMPORTANT DISCLOSURES

The IIAR and NRF reserve investment funds are currently managed by Stifel Financial Services under the investment policy established by their respective board of directors. Members of IIAR may use the services of Stifel for personal and business investments and take advantage of the reduced rate structure offered with IIAR membership. For additional wealth planning assistance, contact your Stifel representative: Jeff Howard or Jim Lenaghan at (251) 340-5044.

*Stifel does not provide legal or tax advice. You should consult with your legal and tax advisors regarding your particular situation.*

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# Where's that vapor going?

**BY KEM RUSSELL**

Where's that vapor going? Sooner or later that question must be answered when some type of work is required on an ammonia refrigeration system.

To accomplish the work, the system may have to be opened, and later that portion of the system pressure tested.

The pressure testing process will typically involve some amount of ammonia used in the final test, after which the pressure is removed again before the portion of the system tested is placed back into operation.

Even when a small amount of vapor is vented to atmosphere, several seemingly innocuous details can add up to a big problem if they aren't carefully considered.

In this edition of "Lesson Learned," we'll look at a specific case where those details were overlooked.

It was a routine day and a routine procedure that took the contractor in this case to the facility roof.

In this instance, pressure was applied to the piping associated with a newly installed automatic purger. After installation of the new purger, solenoids at several condenser connection points, and all of the associated piping, a pressure test was done.

The majority of the new valve assemblies and piping was located up near the evaporative condensers, which were mounted above the machine room.

The only new equipment and piping in the machine room was for the purger. The distance from the ground level outside of the machine room to the condensers located directly above the machine room was approximately 35 to 40 feet.

The contractor doing this work knew he was well above ground level and above the roof level.

He also knew that there was not much ammonia vapor to release due to the volume of small size piping and only one circuit of one condenser.

The contractor estimated that the location and the small vapor volume of the ammonia in question would make the decision to vent the ammonia pressure to atmosphere a sound choice.

With the pressure test successfully completed, it only took a few minutes to release the ammonia pressure.

Up to this point things had been uneventful, however, one important detail had not been considered. Where is that ammonia vapor going?

Many times, even normal wind flow can be affected by building structures and other natural barriers such as trees.

As the wind hits these objects, it can create eddies or other temporary changes of wind direction, pushing vapor in unexpected directions.

In this particular case, not only were there building structures, but the prevailing wind was not coming from the normal direction. As the ammonia vapor released, it was quickly taken over the roof of the building where the condensers were mounted, across an alley between buildings, and then, due to an eddy effect, pushed to ground level beyond the next building.

As the vapor went to ground level, it also spread out and traveled through a group of construction workers in the nearby area.

Even though the amount of vapor released was well below the federal reporting quantity of 100 pounds in 24 hours, it was sufficient to cause the workers in the impact area to feel very uncomfortable.

The smell of ammonia was quickly reported to the facility personnel, even as the vapor rapidly dissipated due to the small amount released.


So what lessons were learned from this event?

Probably the first and most obvious one is to make sure you know what direction the wind is blowing before blowing off the vapor. As in this case, it would be wise to not only check the wind direction at the release location but also downstream where there may be eddy effects.

Another important consideration that should have been made before the contractor got to this point in his work is the facility emergency plan. A contractor must understand what to do if there is an emergency, and he should also know what to do and who to call if he causes the emergency.

Along with this, prior to releasing ammonia, the contractor and facility personnel should coordinate as best they can to determine any potential negative impacts to people and the environment.

This coordination should involve making sure there are no downwind concerns, such as people, in this case, that could be affected. With this analysis, the means and method of release would be adjusted to eliminate potential unwanted impacts.

In thinking about releasing pressure, a determination should be made on whether to release the pressure to atmosphere, or purge into water, or use some other means to neutralize the released vapor.

Even when a small amount of vapor is vented to atmosphere, several seemingly innocuous details can add up to a big problem if they aren't carefully considered.

A contractor must understand what to do if there is an emergency, and he should also know what to do and who to call if he causes the emergency.

These methods all have their place and can be very effective if the focus is not only on where the ammonia is coming out, but also on people and the environment in the immediate area, as well as further downwind.

If the decision is made to release to the atmosphere, knowing that ammonia is a natural part of our environment and will usually dissipate quickly, the release of the pressure should be done in a controlled fashion.

In this particular case, the purging valve used to release the pressure was opened quickly to rapidly dump the pressure.

A better approach would have been to partially open the valve and let the pressure slowly bleed down. A slow release would have allowed the vapor to thoroughly mix with the air and would have significantly reduced the downwind distance where a noticeable level of ammonia smell could have gone.

In this case, the lessons weren't over with the actual event. Staff at the facility itself also has a responsibility when an ammonia event occurs.

The question was asked in this example: "Was this a near miss since no one was injured or even affected that much?"

The answer is: No! It was a direct hit! And an incident investigation must be done in a case like this to not only find out what happened, but also to reduce or eliminate the possibility of it happening again.

In addition, just because this was a release that was well under the federal reporting quantity, it does not mean other agencies or groups don't need to be notified.

In the particular location, both the state emergency management division, and the local emergency planning committee were notified. The fire department may also need to be notified.

This event could easily have been a non-event if a few of the above mentioned thoughts had been considered.

Luckily, no one was injured and the lessons learned by both the contractor and the facility were valuable. Hopefully we all can learn from this example, and ask the important question —where's that vapor going? — sooner, rather than too late.

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# To Reduce Energy Expenditure, Lower Cost, Clean Evaporator Coils

Numerous factors can contribute to decreases in a refrigeration system's energy efficiency, not the least of which is its cleanliness. Much of the time, when facility operators see a facility's efficiency drop, they believe that indicates they must replace the systems with larger units, when in fact, they often simply need to clean the systems they're currently using - particularly the evaporators.

The evaporator is the component of a closed-circuit refrigeration system that absorbs heat by vaporizing liquid refrigerant. The evaporator coil is the part of the system not enclosed in a pressure vessel. There are two types of evaporators: forced draft, in which air is pushed through the coils, and induced draft, with air pulled through the coils by fans.

Without proper maintenance, either type of system can be negatively affected in significant ways by various types of contamination, including dust, process or product particles, pollen, mold, and bacteria, according to IIAR materials. Evaporator coils and fan surfaces attract debris, and dirty fans and coils decrease their efficiencies and the system's refrigeration effect while increasing compressor discharge head pressures and delivered supply air temperatures.

The adverse effects of these contaminants all lead to increased energy usage. "A unit may typically be oversized by 10 to 30 percent. Engineers must then select compressors to meet that overage in their design," said Brian Hindt, president of Ecoclear Coil Cleaning. "A clean coil should shut down and quit asking for ammonia periodically during the day – ideally every hour." However, if the coils are dirty, the system can begin running so inefficiently that to maintain the temperature of a particular space, it never stops running.

In fact, according to the manufacturer's maintenance materials, a coil with a layer of contamination just the thickness of a dime will lose up to 21 percent of its efficiency. Therefore, it's imperative that any facility looking to lower its energy usage and associated costs should schedule regular cleaning and maintenance. "Clean evaporator coils deliver improved airflow to provide lower chilled air temperatures and absorb heat at greater efficiencies," said Tony Lundell, Director of Standards and Safety at IIAR.

"[Cleaning] reduces an operation's energy usage, optimizes compressor capacities, and enhances the system's refrigeration effect." The frequency of this required maintenance depends on the type and size of the facility, but Hindt said roughly speaking, a system should be cleaned about once a year or every year and a half. It depends on the load that you're putting through the coil and what type of materials are in the environment you're trying to cool, he added. However, it's not enough to wheel in a pressure washer and hose everything off.

In fact, Hindt said that can often cause more harm than good. By pushing the contaminants to the middle of the coil apparatus, debris can become compacted, degrading airflow through the system and potentially damaging components. There are three levels of cleaning, according to coil manufacturers and IIAR materials: cleaning, sanitizing, and protecting. The objective of cleaning is to remove visible contaminants from fans, coil tubes, fin surfaces, drain pans, and lines. There are four basic types of cleaners to accomplish this: acids, alkalines, solvents, and detergents.

It's imperative that the right chemicals be selected for the right application, coil manufacturers warn. If not, components could be damaged. A step beyond cleaning is sanitization. This removes visible and non-visible growing contaminates from all components, including bacteria, mold and other pathogens. This type of cleaning is particularly important in facilities that handle food products, because avoiding contamination is always a major consideration.

To sanitize a system, proper water temperatures, pressures and techniques must be applied to prevent pushing contaminates deeper into the system, and chemical cleaners must be thoroughly rinsed from every surface of the system. "Removing contamination from evaporator coil surfaces not only reduces energy usage and improves the refrigeration effect, but also reduces or eliminates product safety risks, such as in food and other open-product manufacturing facilities," Lundell said.

Hindt agreed. "These units are huge harborage points for bacteria – the Listeria, the Salmonella, the E. coli that may be found in these food processing plants, most of it is harbored in a dark, wet, cold place," he said. The final level is protection, in which a protective coating is applied to the coils to prevent the accumulation of contaminants, increase overall energy efficiency, and extend equipment life.

According to coil manufacturer's recommendations, there are two basic types of coatings – water attractive and water repellant. Each coating type has its benefits, and which to employ depends on the type of system under consideration. One of the best ways to measure the increased efficiencies of a particular cleaning regimen is to examine the cost savings over time. Hindt says these savings can be tremendous.

"We typically see the cost for cleaning the coils in a facility returned to the customer very quickly through the improved operating efficiencies," he said. By comparison, he noted that replacing standard lighting with LEDs usually takes three to five years to see a return on investment, while proper cleaning can return the cost in five to six months. Unfortunately, proper cleaning is rarely thought about in terms of increasing energy efficiencies and decreasing costs. Most operators fail to consider the operating efficiencies, Hindt said. They just want to keep their facility at the right temperature, and they'll pay whatever it costs to do so. Many don't realize that by simply cleaning their systems, they could realize tremendous cost savings as well as decreased energy consumption.

It's imperative that the right chemicals be selected for the right application, coil manufacturers warn.

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# IIAR Greenpaper Makes Business Case for Natural Refrigerants

Today's headlines are telling a new story about environmental concerns. Ideas like energy efficiency, electricity usage, or the need to streamline global supply chains are translating into stories about data centers straining local electrical grids, world governments building local cold chains to feed the hungriest places on earth, or municipalities using heat recovery.

More than ever, natural refrigerants can offer big solutions to many of the world's climate problems – as long as the people working to solve these problems are aware of the big opportunities natural refrigerants offer.

To communicate those opportunities, the International Institute of All-Natural Refrigeration said it has released the IIAR Green paper as a reference for the history and growing use of natural refrigerants across the world.

"We're excited to release the IIAR Green paper," said IIAR President Gary Schrift. "Now is a very interesting time for our industry as new economic sectors start to discover the payoffs natural refrigerants can provide when it comes to solving some of the biggest energy usage problems."

IIAR Marketing Committee Chair Stephanie Smith led the development of IIAR's Green paper.

IIAR's Green paper walks readers through the many dimensions of natural refrigerants, from their history as one of the oldest energy-efficient technologies to their new uses beyond refrigeration, in the shipping, auto, and even space industries.

Natural refrigerants—including ammonia ($NH_3$), carbon dioxide ($CO_2$), and hydrocarbons like propane (R290)—have long been integral to the global cold chain, powering industrial food production with unmatched efficiency. Their ability to transfer heat effectively makes them ideal for high-performance refrigeration systems, and their environmental credentials—ultra-low Global Warming Potential (GWP) and zero Ozone Depletion Potential (ODP)—are big attention grabbers in an era defined by HFC phase-downs and climate mandates.

Today, natural refrigerants are no longer confined to legacy applications. They drive advanced cooling technologies in modern $CO_2$ and ammonia systems, often outperforming synthetic alternatives in both energy efficiency and environmental impact. Their technical versatility has opened new frontiers: from climate control in data centers to waste heat recovery in district energy networks, and precision thermal management in industrial manufacturing.

Beyond their environmental and engineering advantages, natural refrigerants play a critical role in maintaining the affordability of the global food supply. By delivering energy savings that translate directly into lower operating costs, they help keep food prices accessible, making them a serious contender in the race to curb hunger in the most environmentally vulnerable parts of the world.

Meanwhile, natural refrigerants are beginning to earn attention as a future-ready technology. With zero Ozone Depletion Potential (ODP) and ultra-low Global Warming Potential (GWP), substances like ammonia, carbon dioxide, and hydrocarbons offer ways to cut energy use without pollution risk, unlike PFAS-containing synthetics.

Ammonia in particular plays a central role in sustaining the global food supply. Its high latent heat of vaporization and exceptional energy performance make it indispensable across the cold chain, from processing plants to distribution centers. More than a legacy refrigerant, ammonia is now recognized as a cornerstone of modern food infrastructure.

Carbon dioxide ($CO_2$) has also re-emerged as a powerful option, thanks to advances in system design that overcome earlier limitations. Once constrained by high operating pressures and temperature sensitivity, $CO_2$ systems now rival synthetic refrigerants in both efficiency and environmental performance. Non-toxic and non-flammable, $CO_2$ is gaining traction across industrial and commercial sectors as a safe, scalable alternative.

As refrigeration technologies evolve, natural refrigerants are finding their place at the center of high-efficiency system design. Advances in compressors, heat exchangers, and control systems have enabled ammonia, $CO_2$, and hydrocarbons to power a wide range of applications—from supermarket display cases and cold chain logistics to heat pumps and energy recovery systems.

Industry resources are evolving in parallel. In a notable shift, ASHRAE has formally expanded its Position Document on Refrigerants and Their Responsible Use to include natural refrigerants alongside synthetic options. This update marks a departure from earlier versions that focused primarily on fluorinated compounds like CFCs, HCFCs, HFCs, and HFOs. Today, ASHRAE recognizes ammonia, $CO_2$, hydrocarbons, water, and even air as viable refrigerants within a holistic framework that prioritizes energy efficiency, safety, life-cycle climate performance, and system design.

To support informed decision-making and help members compare all these options, IIAR has introduced the Refrigerant Evaluator Tool—a digital platform that allows users to compare refrigerants across key performance and safety metrics. The tool enables side-by-side analysis of up to three refrigerants, drawing on data from ASHRAE, EPA, and NIST to assess flammability, toxicity, GWP, ODP, energy efficiency, and installation costs. Originally developed to guide users through the phase-out of high-GWP synthetics, the tool now serves a broader purpose: helping stakeholders evaluate the full spectrum of refrigerant options and anticipate future compliance needs.

Once framed narrowly as a compliance solution for ozone protection and climate regulation, natural refrigerants have now emerged as strategic enablers of global decarbonization with roles expanding far beyond traditional cold storage.

Backed by robust industry standards, modern decision tools, and strong policies, natural refrigerants are helping form a new, broad climate economy. Their adoption signals a shift toward systems that are not only more sustainable but also more economically resilient.

Ammonia and carbon dioxide, in particular, offer compelling financial advantages for industrial refrigeration. When compared on an in-kind system basis, these systems often cost less to design and install than those using synthetic refrigerants. Because less refrigerant is needed to meet load requirements—and because leak rates for synthetic refrigerants tend to be higher—natural systems also reduce ongoing operational expenses.

For food processors and cold storage operators, these savings are meaningful. Energy costs are among the most significant operating expenses in the industry, and reductions in energy use directly impact the bottom line. Over time, those savings ripple outward—helping to stabilize food prices and reduce costs for consumers. IIAR's newly published Green paper, covering in depth technology, regulatory landscapes, and efficiency measurements, is available now online on IIAR's Resource Center.

Ammonia and carbon dioxide, in particular, offer compelling financial advantages for industrial refrigeration.

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# IIAR Chile Chapter Breaks Attendance Record, Paraguay Adopts IIAR-2


IIAR's Chile Chapter, along with The Chilean Chamber of Refrigeration and Air Conditioning, said the organizations' twenty-eighth Seminar on Natural Refrigeration for Latin America drew over 350 attendees, the largest number of attendees in the event's history.

"This was the largest IIAR event yet in Chile," said Yesenia Rector, Vice President of Education, Outreach, and Events, adding that IIAR's Latin American chapters typically host at least one event biannually.

"The majority of attendees were companies within Chile," said Rector. Of those attendees, almost 60 percent were end users, many representing Peru's fishing and other export industries.

"Exports are very much front and center in Chile. The meetings [in Latin America] are representative of the whole global industry, but there are regional differences. In Chile, that's the fishing and produce industries and of course, there's a strong wine industry," she said.

Despite regional differences, IIAR's Latin America seminars are global in nature, giving the industry in the hosting country the opportunity not only to network but to share viewpoints, challenges, and opportunities that are happening inside that country and around the world.

At the recent meeting in Chile, attendees from Germany, Italy, Argentina, the U.S., and Spain represented just a few of the countries in attendance. "These seminars are happening at a regional level, but they are really international in nature," said Rector. "They are a way to showcase the region to the world."

According to a statement issued following the event, the Chilean Chamber of Refrigeration and Air Conditioning said the seminar consolidated its position as the most visited in the southern region, offering a program of high-level technical presentations by international and national experts from all over the American continent. Along with the presentations, the seminar included an interactive showroom in which more than 20 exhibiting brands participated.

This space was key to generating networking opportunities and strategic collaboration within the industry, the organization said.

During the day, the election of the new president of the IIAR Chile Chapter was held, a position that fell to Fabián Escalante, from the union's partner company, Frimont, who will assume the responsibility of leading the chapter. With this transition, Giorgio Magnani concluded his presidency.

Meanwhile, at a different event in Paraguay last month to celebrate World Standards Day, IIAR addressed the country's recent adoption of the IIAR-2 standard by the country's National Institute of Technology, Standardization, and Metrology.

"Without the professionalism and coordination of this team, Paraguay would not be celebrating a historic milestone today: its first national standard for the safe design of ammonia refrigeration systems," said Rector in a speech to the INTM and IIAR's Paraguay chapter. "We thank the National Institute of Technology, Standardization and Metrology (INTN) and all members of National Technical Committee 71 (CTN 71) for their prompt response in the study and adoption," said Federico Alarcón López, IIAR's Latin America Programs Manager. "With the adoption of our Standard 2, Paraguay becomes the first country in the Southern Cone to have a national safety standard."

Rector noted that with the adoption of IIAR-2, Paraguay joins the group of countries that have adopted a range of international best practices, including IIAR standards, to strengthen their national industry.

"This standard, based on IIAR 2-2021, represents much more than a technical document. It is a tool for progress for Paraguayan industry, especially for the meat sector, one of the country's economic pillars," said Rector. "In this sector, ammonia is at the heart of industrial refrigeration. It is used because it is efficient, reliable, and environmentally friendly."

## IIAR CHILE CHAPTER BREAKS ATTENDANCE RECORD (continued from page 26)

Rector used her address to emphasize that ammonia as a refrigerant has been proven for over a century to it can offer superior energy efficiency, lower operating costs, and zero impact on global warming.

"We know that no refrigeration system, regardless of the refrigerant used, is risk-free. Therefore, the goal is not necessarily to eliminate risk, but to control it through good design, responsible operation, and continuous education," she said. "That is precisely the essence of this standard: to establish minimum quality parameters that guarantee safety, efficiency, and sustainability."

> "Without the professionalism and coordination of this team, Paraguay would not be celebrating a historic milestone today: its first national standard for the safe design of ammonia refrigeration systems."






# IIAR Participates at the 108th International Packaged Ice Association (IPIA) 2026 Convention & Trade Show

## Nashville, TN | November 10th-14th, 2025

During an **"Insights & Exchange: Expert Talk & Collaborative Roundtables"** session, speaker, Tony Lundell, IIAR's Senior Director of Standards and Safety, delivered a presentation for the, *"Progress in Codes & Standard Related to Natural Refrigerants (CO2, NH3, HCs)."*


The presentation addressed a codes and standards "Road Map Overview for Natural Refrigerants" for the following categories: Significant New Alternatives Policy (SNAP) approvals where the SNAP Program informs EPA of what refrigerants are permitted to be used in the USA, Equipment Safety, Engineering, Service, and Building Codes.

The American Innovation and Manufacturing (AIM) Act was discussed for the global phasedown on the use of hydrofluorocarbon (HFCs) refrigerants underway and is accelerating the adoption of lower global warming potential (GWP) refrigerants. Production and Consumption, Technology and Transitions, and Refrigerant Management for emissions and reclamation program) was covered.

Getting to (ultra) low Global Warming Potential (GWP) refrigerants that are natural refrigerants facilitates the transition to next-generation technologies and will mitigate the risk of future phasedown.

Model Code Adoptions of IIAR Standards was covered for NFPA 70 NEC, IFC, IMC, NFPA 1 Fire Code, and UMC.

The IIAR Suite of Standards for the nine (9) Ammonia Refrigeration Standards were reviewed and the CO2 *Safety Standard for Closed-Circuit Carbon Dioxide Refrigeration Systems.*

It was also addressed and discussed that IIAR is presently developing a *"Safety Standard for Closed-Circuit Refrigeration Systems Utilizing (Natural) Hydrocarbon Refrigeration (HCs)"* for future safe considerations.

The IIAR Standards for Natural Refrigerants address general and specific design, installation, startup, as well as, inspection, testing, and maintenance of new and existing closed-circuit refrigeration systems and additions or modifications. They also apply to heat pumps, use within a cascade system, and where utilized as a secondary fluid, where applicable.

Different "Occupancies" for each of the Natural Refrigerants were reviewed where they can be applied. Pending Industrial, Refrigerated Spaces, Public Assembly, Commercial, Large Mercantile, as well as, Institutional, and Residential Occupancies.

IIAR's Ben Dawes and Tony Lundell exhibited for IIAR during the multiple exhibition hours during the week.

The IPIA originally was founded in 1917 as the National Association of Ice Industries, and represents commercial industry producers of block ice and packaged ice internationally. The hallmark of the IPIA's vision as an association is their member commitment to food safety and education at all levels – regulatory, retailer, and consumer that *"Ice is Food."*

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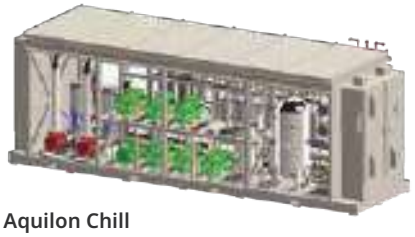

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TECHNICAL PAPER #17

# Decarbonizing With District Energy Systems: When an R744 (CO2) Heat Pump Is the Obvious Choice

**PARHAM ESLAMI-NEJAD,** R744 PROGRAM MANAGER | VITALIS

## ABSTRACT

R744 (CO2) industrial air-source heat pumps (ASHPs) can serve as cost-effective and scalable alternatives to conventional heating and cooling systems. Leveraging the unique thermodynamic properties of CO2, a natural refrigerant, these systems deliver high efficiency and flexibility for certain temperature applications.

This article examines the performance of an R744 ASHP as primary heating equipment for buildings or as a first stage for nodal heat pumps in district-level applications. R744 heat pumps are renowned for delivering a significantly high temperature lift in a single stage and operating efficiently as a first stage for high-temperature heat pumps. In this article, the overall coefficient of performance (COP) of an R744 ASHP is compared against the most efficient commercially available ASHP solutions with synthetic refrigerant for different temperature applications.

A case study of the University of British Columbia Okanagan (UBCO) is also presented to illustrate a promising application of an R744 ASHP for conditioning a low-temperature district energy system (LDES) that serves nodal heat pumps throughout the campus, providing heating and cooling for buildings. It also demonstrates how the heat pump manufacturer integrates energy efficiency control algorithms for optimum operation of the system.

## Introduction

The electrification of heating can be efficiently achieved on a large scale through the use of central heat pumps, either for large buildings or clusters of buildings within districts. Among the various heat pump configurations, air-source heat pumps (ASHPs) stand out as a cost-effective solution. These systems extract heat from the outdoor air and consist of two primary components: the compressor rack, which generates heat and transfers it to a heat transfer fluid (air, water, brine, …), and the air heat exchangers, which absorb heat from the outdoor air.

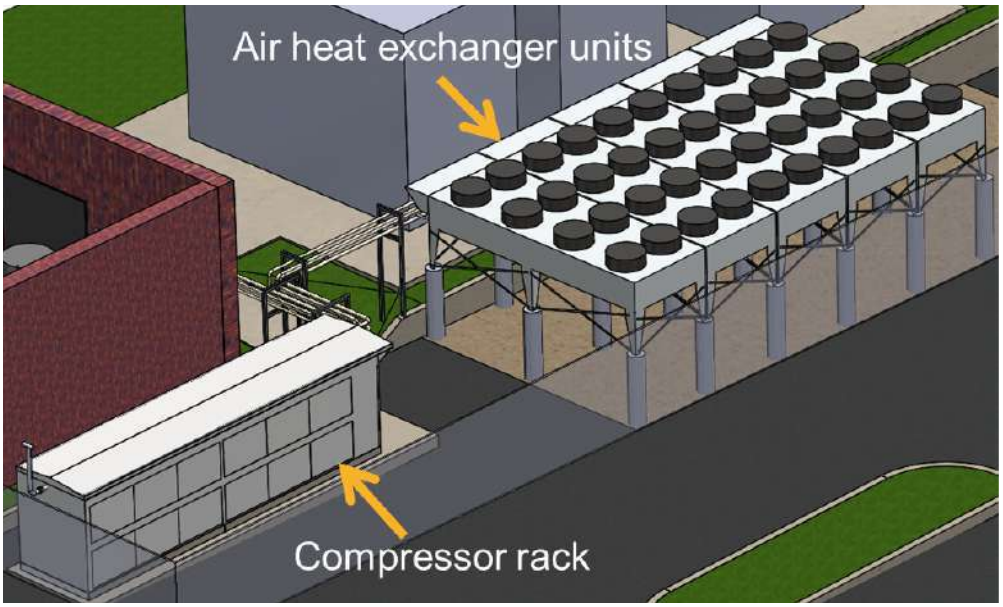


Figure 1. Air source heat pump.

Using industrial heat pumps to supply heat to a district energy system (DES) is a highly efficient approach for serving a network of buildings from a centralized plant. However, the efficiency of air-source heat pumps (ASHPs) in a DES depends significantly on the system's supply temperature and ambient air conditions. Since ASHPs extract heat from the surrounding air, lower ambient temperatures and higher DES supply temperatures both lead to reduced energy efficiency.

With advancements in heat pump technology and the growing shift toward electrification of thermal systems, a new generation of district energy systems, known as low-temperature district energy systems (LDES), has emerged as a highly efficient solution. These systems utilize nodal heat pumps at individual buildings to meet heating demands while enabling thermal energy sharing across the network. This design ensures a consistent source temperature for the nodal heat pumps throughout the year, improving efficiency and offering greater flexibility for integrating diverse energy sources.

To ensure a stable temperature throughout the year, an R744 ASHP can be used to heat and cool the LDES. This approach is more cost-effective and versatile than relying on a network of geothermal boreholes, commonly referred to as a geo-loop.

This paper compares the coefficient of performance (COP) of an R744 ASHP with that of the most efficient commercially available ASHP alternatives with synthetic refrigerant across various temperature applications. The results highlight scenarios where the R744 ASHP emerges as a promising solution for central heating systems in DES.

A primary focus of this study is also the role of the R744 ASHP in efficiently decarbonizing low-temperature district energy systems. The paper also quantifies the energy savings and greenhouse gas (GHG) emissions reductions achieved through the implementation of a LDES utilizing an R744 ASHP.

## System overview and methodology:

R744, classified as a natural refrigerant, is non-toxic, non-flammable, and environmentally safe. Unlike newer generations of synthetic refrigerants (HFOs), R744 poses no risk to watersheds and does not contribute to PFAS or TFA pollution in local ecosystems.

Due to its relatively low critical temperature, R744 heat pumps can operate in two distinct modes depending on the required supply temperatures. For supply temperatures above 27°C (80°F), a transcritical cycle is typically required, involving both supercritical heat rejection and subcritical heat absorption. This mode encompasses nearly all heating applications. In contrast, for a few applications, R744 heat pumps may operate in subcritical mode, where both heat rejection and heat absorption occur below the critical point. Examples include heating low-temperature district energy systems or serving as the first stage of a high-temperature heat pump reducing refrigerant charge of A2, A3, and B2 refrigerants and enhancing safety.

This paper identifies five key heating applications based on the supply and return temperatures of the heating system. These applications represent common scenarios for heating single buildings or districts. For each application, the performance of the R744 ASHP is compared against the most efficient commercially available synthetic refrigerant alternative. These applications are as follows:

**Application 1:** Supply temperature 71°C (160°F) and return temperature 60°C (140°F)

**Application 2:** Supply temperature 60°C (140°F) and return temperature 49°C (120°F)

**Application 3:** Supply temperature 49°C (120°F) and return temperature 38°C (100°F)

**Application 4:** Supply temperature 38°C (100°F) and return temperature 27°C (80°F)

**Application 5:** Supply temperature 27°C (80°F) and return temperature 15.5°C (60°F) (LDES)

For R744, applications 1 to 4 are single-stage heat pumps operating in transcritical mode, employing mechanical desuperheating, parallel compression, or a simple transcritical cycle with a flash gas bypass valve, depending on the return temperature. These configurations are selected to efficiently and economically manage the flash gas. Application 5 is a subcritical single-stage R744 heat pump. All R744 heat pumps applications are not equipped with ejector technology or other advanced energy performance enhancement strategies beyond mechanical desuperheating or parallel compression. Adding an ejector could potentially increase the COP by up to 5%.

The P-H diagrams for the various transcritical R744 heat pump cycles used in this study are presented in Figure 2 at -5°C (23°F) ambient temperature. Applications 1 and 2 utilize mechanical desuperheating, application 3 employs parallel compression, while application 4 uses a simple transcritical cycle due to the relatively low return temperature and the resulting insignificant vapor quality after the first expansion. As previously mentioned, application 5 operates with a conventional subcritical cycle. The P-H diagram for the subcritical cycle will be presented in the next section.

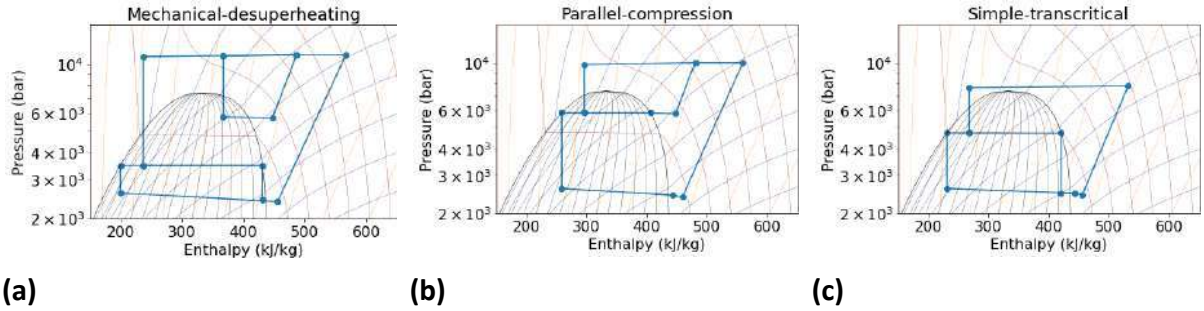


Figure 2. P-H diagrams.

For the first two applications, the alternative solution is a dual-stage heat pump or booster system designed to address the relatively high temperature lift between the heat absorption and heat rejection processes. However, for applications 3, 4, and 5, the alternative solution is a single-stage heat pump, similar to the R744 heat pump. The synthetic refrigerants in this study were selected from HFOs, HFCs, and HFO/HFC blends, including R32, R1234yf, R152a, R515B, and R410A, based on their efficiency and suitability for the application's temperature requirements.

The following figures compare the overall coefficient of performance (COP) of the R744 heat pump with that of the alternative solution using synthetic refrigerants for various temperature applications.

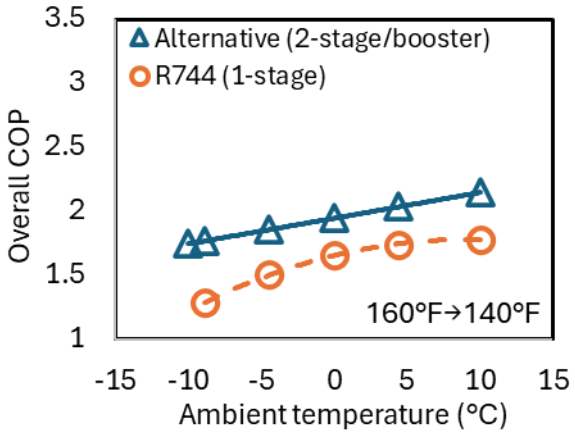


Figure 3. Application 1.

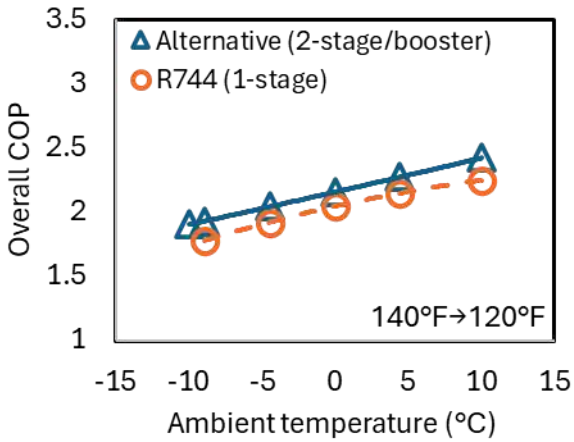


Figure 4. Application 2.

The COP is calculated using the following equation.

$$Overall\ COP = \frac{Heat\ delivered\ by\ the\ heat\ pump}{Work\ input\ to\ compressors\ and\ air\ heat\ exchanger\ fans}$$

For applications 1 and 2, the alternative solution outperforms the R744 heat pump across all ambient temperatures. However, in application 2, the overall COP of the R744 heat pump and the alternative solution is relatively close, with a difference of only 5% to 8%. The lower COP of the R744 ASHP in these applications is primarily due to the high return temperature, which makes the R744 transcritical cycle less efficient compared to the subcritical cycle of the alternative solution. For applications 3 to 5, as shown in Figures 5, 6 and 7, the R744 heat pump begins to demonstrate its performance advantages over the alternative solution.

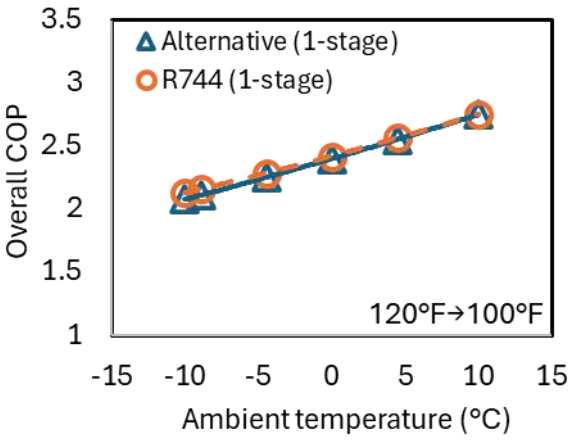


Figure 5. Application 3.

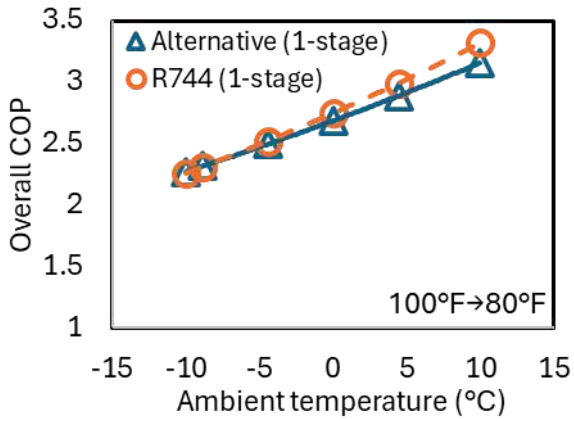


Figure 6. Application 4.

Application 5, in particular, is a promising use case for the R744 ASHP in LDES.

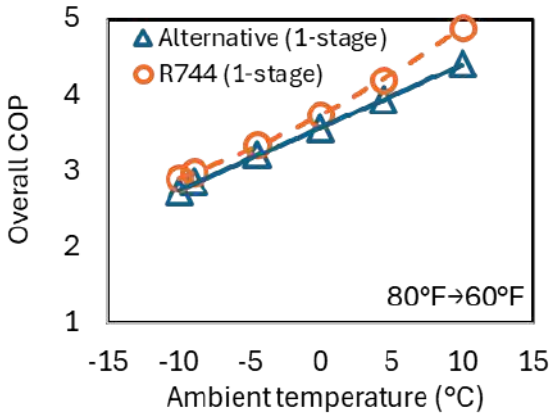


Figure 7. Application 5.

Ground-assisted ambient-temperature thermal network, commonly referred to as geo-loops, with nodal heat pumps are often selected for DES due to their enhanced thermal performance and conceptual simplicity. However, the high upfront costs and complex installation processes associated with geo-loops present significant challenges. In contrast, the R744 ASHP-assisted DES offers a cost-effective and scalable alternative by actively conditioning the LDES, providing precise temperature

control and maintaining optimized system performance throughout the year. Figure 7 compares the overall COP of the R744 ASHP with an alternative synthetic-refrigerant-based ASHP solution for application 5. The next section also presents a case study showcasing the benefits of R744 air-source heat pumps for this application in districts.

Another key advantage of the R744 heat pump is its lower sensitivity to supply temperature in applications with high return temperatures. This is due to the optimal pressure control mechanism implemented in R744 heat pumps, which is governed by the return temperature rather than the supply temperature. As a result, R744 heat pumps can deliver high supply temperatures even with lower return temperatures, without incurring a significant performance penalty.

As illustrated in the following figures, the performance difference between R744 heat pumps and alternative systems using synthetic refrigerants becomes more pronounced—exceeding 10%—when a high temperature differential between supply and return temperatures is maintained.

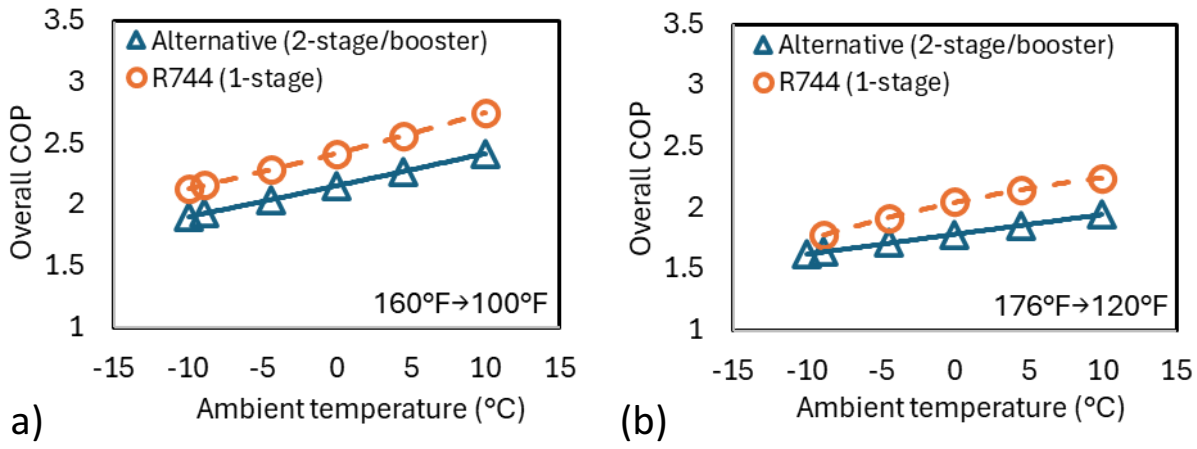


Figure 8. High ΔT applications.

To determine if an R744 ASHP is a suitable solution for heating applications, either of the following conditions should be met:

1. The return temperature is below 49°C (120°F).
2. The temperature difference between supply and return exceeds 30°C (54°F) for applications requiring supply temperatures below 90°C (194°F).

In district energy systems, maintaining a high temperature difference between supply and return is often feasible due to the varied required heating temperatures of different buildings, which depend on the design of their heat distribution systems.

## Case Study

*UBCO District Energy System*

As shown in the previous section, one of the promising applications is to heat the LDES using the R744 ASHP (application 5). In this section, the energy saving and GHG emission reduction is quantified for the energy system of the University of British Columbia Okanagan (UBCO) campus. The UBCO district energy system includes an ambient low-temperature district energy system designed for energy sharing, with supply temperatures maintained in a range of 8°C to 25°C. To decarbonize the district energy system, it is proposed that air-source heat pumps be utilized to meet the base heating load requirements for the central plant. This solution provides significant improvements in efficiency and operational flexibility. The LDES delivers ambient-temperature water to most academic buildings in the campus. Distributed heat pumps within the buildings further utilize this ambient-temperature water as a source for both heating and cooling.

*System characteristics*

The LDES presents a unique opportunity for implementing the most efficient application of the R744 ASHP to replace condensing boilers. Operating the R744 ASHP in subcritical mode at saturation discharge temperature of 20°C enhances operational efficiency. The system's flexibility allows for capacity adjustments based on changing thermal demands, optimizing operational efficiency and cost savings. Utilizing multiple compressors and heat exchangers ensures scalability and modularity, facilitating easy expansion or modifications to meet future energy needs as well.

As mentioned earlier, an air-source R744 heat pump is employed to condition the LDES. Due to the loop's temperature, the heat pump operates in a subcritical thermodynamic cycle in heating mode. The heat pump incorporates two fully independent and identical refrigerant circuits. Figure 9 illustrates the process flow diagram (PFD) of one refrigerant circuit of the heat pump for heating mode. As depicted in Figure 9, each refrigerant circuit comprises two main modules: the air heat exchangers (outdoor evaporator module) and the compressor rack with CO2-to-water heat exchangers. To assess the system's energy performance, a model has been developed for the R744 heat pump that includes both modules and their associated components.

The cycle begins at the compressor suction (1), where CO2 is compressed into high-pressure and high- temperature CO2 (2). This compressed CO2 then passes through the high-pressure side of the internal heat exchanger (IHX), which provides superheat at the compressor suction. In heating mode, CO2 flows to the CO2-to-water heat exchanger to supply heat to the LDES (3). Subsequently, the CO2 passes through the back-pressure regulator (4). Liquid CO2 then absorbs heat from the outside air in heating mode (5), causing it to evaporate (6). The evaporated CO2 then returns to the compressors via the low-pressure side of the IHX, where it gains additional superheat before recommencing the cycle.

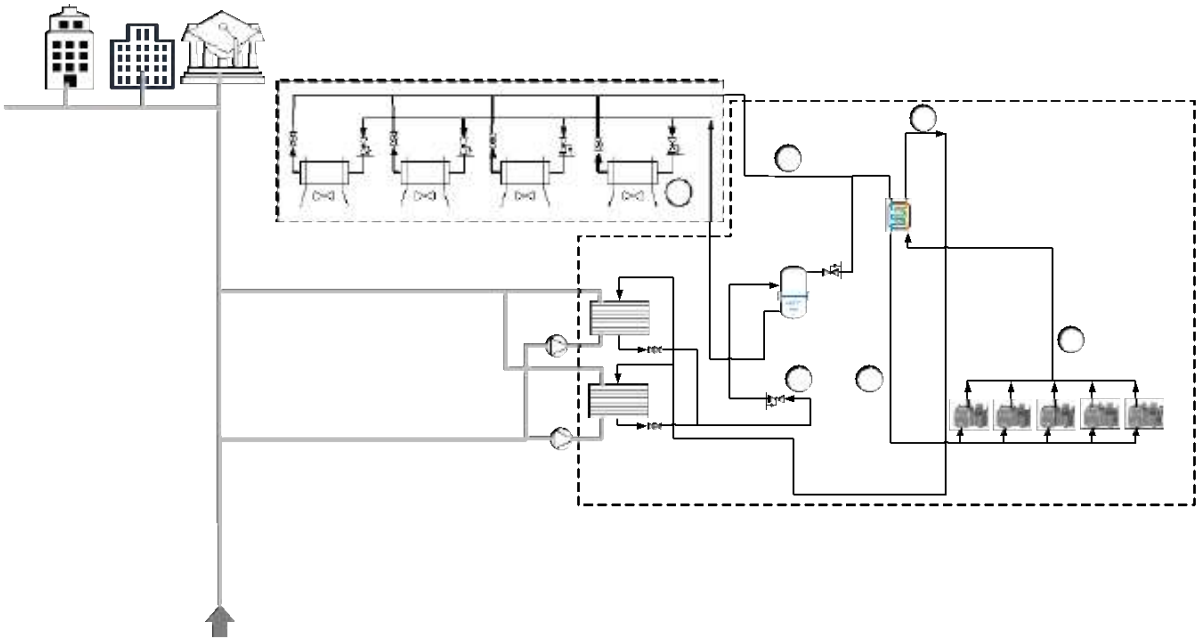

Figure 9. Process flow diagram of the R744 reversible ASHP.

Figure 10 presents the P-H diagram of the cycle with state points which are all marked on the PFD as well.

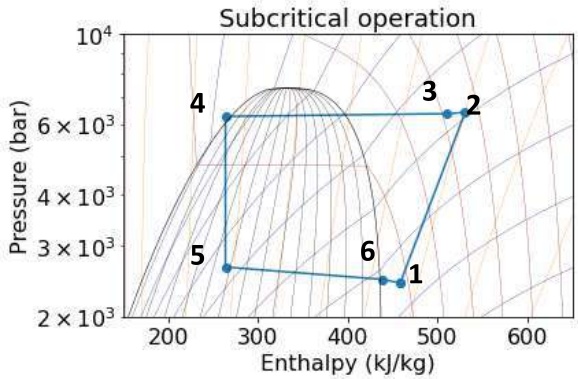


Figure 10. P-H diagram, subcritical cycle.

Each refrigerant circuit utilizes five 6-cylinder 575V/3/60Hz compressors with a total displacement of 272 $m^3$/hr. The compressor is modeled using the correlation provided by the manufacturer. Each refrigerant circuit is connected to three 300kW flat air heat exchanger (AHX) units, each with two coils and eight fans. The power consumption of the AHX fans varies with ambient temperature and the amount of required heat exchanged capacity.

Each refrigerant circuit has 20 fans in operation and 4 reserved when running in heating mode. The required heat exchange capacity is calculated from the energy balance of the cycle. Maximum pressure drops of the heat exchangers and CO2 pressure losses in pipes are considered in the pressure drop calculation of the system. For more details regarding the component models, fan electricity consumptions, and pressure drop calculations please refer to a conference paper presented at the 16th IIR Gustav Lorentzen Conference on Natural Refrigerants, College Park, Maryland, USA 2024 *[P. Eslami-Nejad et al. Decarbonizing District Energy: Leveraging CO2 Heat Pumps at UBC Okanagan (Theoretical evaluation)]*

*UBCO LDES Load Demands*

Based on the heating and cooling demand data of the UBCO LDES, the total heating required from the ASHP are calculated as 14,267 GJ.

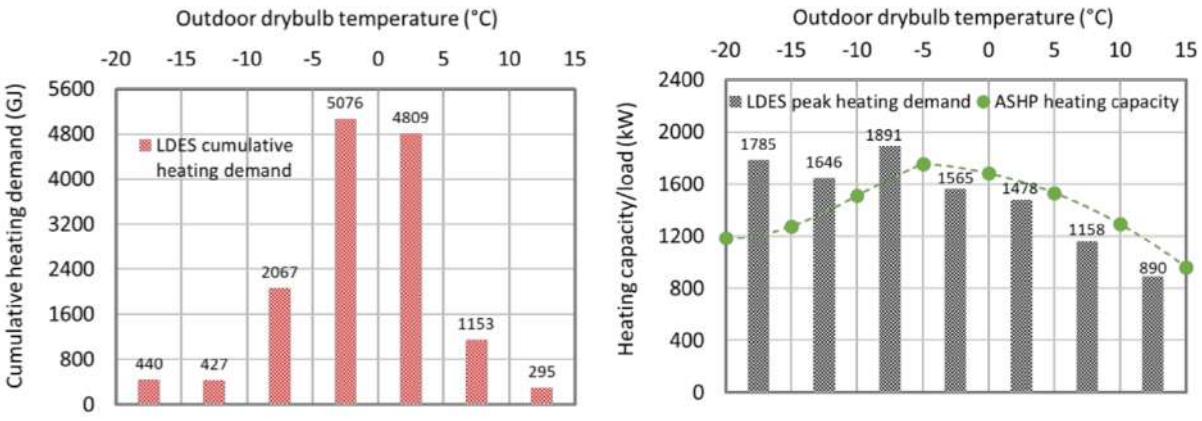


Figure 11. ASHP capacity and LDES cumulative (left) and peak (right) heating demand.

Figure 11 (left) shows the total heating demand in GJ at different ambient temperatures. As shown in this figure, almost 70% (9,885 GJ out of 14,267 GJ) of the demand occurs at temperatures between -5°C and 5°C. Figure 11 (right) presents the peak heating capacity required in kW. According to this figure, the system can fulfill the entire LDES demand at -5°C outdoor dry bulb (ODB) temperature or higher, where 80% of the heating demand occurs. Figure 11 (right) also illustrates the heating capacity of the ASHP with the necessary turndown to meet the LDES peak demand. The system features 10 compressors with a nominal capacity of 1.5 MW at -10°C ODB temperature.

Table 1 outlines the performance and operating conditions of the ASHP in heating mode. For all these conditions, the condensing temperature of the ASHP is 20°C (57 bar, subcritical operation). The system delivers maximum capacity at -5°C ODB temperature with 10 active compressors, achieving an overall COP of 3.4. COP values range from 2.2 at -20°C to 7.3 at 15°C ODB temperatures. At higher ODB temperatures, as LDES demand diminishes, capacity is reduced by switching off compressors. The maximum nominal evaporator capacity is designed at 1500 kW.

| ODB(°C) | Evaporator temperature (°C) | Maximum heating capacity (kW) | Maximum absorbed heat (kW) | Maximum absorbed power (kW) | Compressors working | COP |
|---|---|---|---|---|---|---|
| -20 | -25 | 1176 | 758 | 547 | 9.5 | 2.2 |
| -15 | -23 | 1270 | 842 | 487 | 9.5 | 2.6 |
| -10 | -18 | 1497 | 1055 | 498 | 9.5 | 3.0 |
| -5 | -14 | 1694 | 1247 | 501 | 9.5 | 3.4 |
| 0 | -10 | 1623 | 1253 | 412 | 8 | 3.9 |
| 5 | -5 | 1524 | 1235 | 327 | 6.5 | 4.7 |
| 10 | 0 | 1207 | 1022 | 207 | 4.5 | 5.8 |
| 15 | 5 | 908 | 797 | 125 | 3 | 7.3 |

Table 1. ASHP performance data in heating.

## Results

Using the model, the part-load operation of the ASHP has been evaluated and summarized in the following tables. Table 2 presents part-load operation in heating. The highlighted cells represent the most probable operation points of the ASHP based on the heating and cooling demand data of the LDES from previous years.

| ASHP total delivered heat (kW) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| T_ambient (°C) | -20 | -15 | -10 | -5 | 0 | 5 | 10 | 15 |
| # Compressors | | | | | | | | |
| 10 | 1122 | 1220 | 1461 | 1670 | | | | |
| 9.5 | 1068 | 1162 | 1391 | 1590 | | | | |
| 9 | 1014 | 1103 | 1321 | 1510 | 1720 | | | |
| 8.5 | 959 | 1043 | 1250 | 1430 | 1629 | | | |
| 8 | 904 | 984 | 1179 | 1348 | 1537 | 1779 | | |
| 7.5 | 849 | 924 | 1108 | 1267 | 1444 | 1672 | | |
| 7 | 794 | 864 | 1036 | 1185 | 1350 | 1564 | 1791 | |
| 6.5 | 738 | 803 | 963 | 1102 | 1256 | 1455 | 1666 | |
| 6 | 682 | 743 | 891 | 1019 | 1162 | 1346 | 1541 | 1746 |
| 5.5 | 626 | 682 | 818 | 936 | 1067 | 1236 | 1415 | 1603 |
| 5 | 561 | 610 | 731 | 835 | 971 | 1125 | 1289 | 1459 |
| 4.5 | 507 | 551 | 661 | 755 | 860 | 1014 | 1161 | 1315 |
| 4 | 452 | 492 | 590 | 674 | 768 | 890 | 1034 | 1170 |
| 3.5 | 397 | 432 | 518 | 592 | 675 | 782 | 895 | 1025 |
| 3 | 341 | 371 | 445 | 510 | 581 | 673 | 771 | 873 |
| 2.5 | | | 372 | 426 | 486 | 563 | 644 | 730 |
| 2 | | | | 342 | 390 | 451 | 517 | 585 |
| 1.5 | | | | | | | 388 | 440 |

Table 2. ASHP capacity at part load.

| ASHP heating overall COP | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| T_ambient (°C) | -20 | -15 | -10 | -5 | 0 | 5 | 10 | 15 |
| # Compressors | | | | | | | | |
| 10 | 2.2 | 2.5 | 2.9 | 3.2 | | | | |
| 9.5 | 2.3 | 2.6 | 2.9 | 3.3 | | | | |
| 9 | 2.3 | 2.6 | 2.9 | 3.3 | 3.7 | | | |
| 8.5 | 2.4 | 2.6 | 3.0 | 3.3 | 3.7 | | | |
| 8 | 2.4 | 2.6 | 3.0 | 3.4 | 3.8 | 4.2 | | |
| 7.5 | 2.4 | 2.6 | 3.0 | 3.4 | 3.8 | 4.3 | | |
| 7 | 2.4 | 2.6 | 3.0 | 3.4 | 3.9 | 4.4 | 4.7 | |
| 6.5 | 2.5 | 2.6 | 3.0 | 3.4 | 3.9 | 4.5 | 4.9 | |
| 6 | 2.5 | 2.6 | 3.0 | 3.4 | 3.9 | 4.5 | 5.2 | 5.0 |
| 5.5 | 2.5 | 2.6 | 3.0 | 3.4 | 3.9 | 4.6 | 5.3 | 5.6 |
| 5 | 2.2 | 2.5 | 2.8 | 3.2 | 3.9 | 4.6 | 5.5 | 6.0 |
| 4.5 | 2.3 | 2.5 | 2.9 | 3.2 | 3.6 | 4.6 | 5.6 | 6.3 |
| 4 | 2.3 | 2.5 | 2.9 | 3.3 | 3.7 | 4.1 | 5.7 | 6.6 |
| 3.5 | 2.3 | 2.5 | 2.9 | 3.3 | 3.7 | 4.3 | 4.6 | 6.8 |
| 3 | 2.4 | 2.5 | 2.9 | 3.3 | 3.7 | 4.4 | 5.0 | 4.9 |
| 2.5 | | | 2.9 | 3.3 | 3.7 | 4.4 | 5.3 | 5.8 |
| 2 | | | | 3.2 | 3.7 | 4.4 | 5.4 | 6.3 |
| 1.5 | | | | | | | 5.4 | 6.5 |

Table 3. ASHP overall COP at part load.

The highlighted orange cell indicates the average LDES heating demand at each 5°C ODB temperature interval. The first column on the left shows the number of active compressors required to generate the capacity listed in the corresponding row at different ODB temperatures. Empty cells indicate an ASHP capacity shortage or too-small turndown. Depending on the refrigerant velocity in pipes and the capacity of heat exchangers, the system will have either one or two active refrigerant circuits.

continuing its increasing trend. This fluctuation is due to changes in the number of active refrigerant circuits and the electricity draw of the AHX fans.

A unique approach has been implemented to ensure the system operates consistently under optimal conditions, minimizing unnecessary electricity consumption from fans and pumps. Using performance curves for water pumps and fans, along with specifications for the heat exchanger and air coils, the optimal operating speeds have been pre-calculated and programmed for all fans and pumps in the system.

| Pump speed (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| T_ambient (°C) | -20 | -15 | -10 | -5 | 0 | 5 | 10 | 15 |
| # Compressors | | | | | | | | |
| 10 | 68% | 77% | 88% | 98% | | | | |
| 9.5 | 65% | 72% | 83% | 95% | | | | |
| 9 | 62% | 67% | 80% | 90% | 100% | | | |
| 8.5 | 58% | 63% | 77% | 85% | 97% | | | |
| 8 | 55% | 60% | 73% | 82% | 92% | 100% | | |
| 7.5 | 52% | 55% | 68% | 77% | 87% | 95% | | |
| 7 | 48% | 52% | 65% | 73% | 82% | 88% | 100% | |
| 6.5 | 45% | 48% | 60% | 68% | 77% | 83% | 95% | |
| 6 | 42% | 45% | 55% | 63% | 73% | 78% | 87% | 100% |
| 5.5 | 38% | 42% | 50% | 58% | 68% | 73% | 82% | 90% |
| 5 | 70% | 77% | 88% | 98% | 62% | 68% | 75% | 83% |
| 4.5 | 62% | 67% | 80% | 90% | 100% | 63% | 68% | 78% |
| 4 | 55% | 60% | 73% | 82% | 92% | 100% | 63% | 72% |
| 3.5 | 48% | 52% | 65% | 73% | 82% | 88% | 100% | 65% |
| 3 | 42% | 45% | 55% | 63% | 73% | 78% | 87% | 100% |
| 2.5 | | | 45% | 52% | 60% | 68% | 75% | 83% |
| 2 | | | | 42% | 48% | 58% | 63% | 72% |
| 1.5 | | | | | | | 48% | 55% |

Table 4. Pump speed.

| Fan speed (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| T_ambient (°C) | -20 | -15 | -10 | -5 | 0 | 5 | 10 | 15 |
| # Compressors | | | | | | | | |
| 10 | 100% | 68% | 85% | 100% | | | | |
| 9.5 | 96% | 65% | 81% | 96% | | | | |
| 9 | 92% | 62% | 78% | 92% | 100% | | | |
| 8.5 | 87% | 60% | 74% | 87% | 97% | | | |
| 8 | 83% | 57% | 70% | 83% | 92% | 86% | | |
| 7.5 | 79% | 54% | 67% | 79% | 87% | 82% | | |
| 7 | 75% | 51% | 63% | 74% | 82% | 77% | 91% | |
| 6.5 | 70% | 48% | 59% | 69% | 77% | 72% | 85% | |
| 6 | 66% | 45% | 55% | 65% | 72% | 67% | 79% | 92% |
| 5.5 | 62% | 42% | 51% | 60% | 67% | 62% | 73% | 85% |
| 5 | 100% | 68% | 85% | 100% | 62% | 57% | 67% | 78% |
| 4.5 | 92% | 62% | 78% | 92% | 100% | 52% | 61% | 71% |
| 4 | 83% | 57% | 70% | 83% | 92% | 86% | 55% | 64% |
| 3.5 | 75% | 51% | 63% | 74% | 82% | 77% | 91% | 57% |
| 3 | 66% | 45% | 55% | 65% | 72% | 67% | 79% | 92% |
| 2.5 | | | 48% | 56% | 62% | 57% | 67% | 78% |
| 2 | | | | 46% | 51% | 47% | 55% | 64% |
| 1.5 | | | | | | | 43% | 49% |

Table 5. AHX fan speed.

The control system dynamically adjusts component speeds to their optimal levels based on the number of active compressors and ambient conditions. Tables 4 and 5 display the pre-calculated optimal pump and fan speed values, as configured by the control unit. Shaded (gray) cells represent operation with two refrigerant circuits, while unshaded cells correspond to single-circuit operation.

Each refrigerant circuit includes 20 fans and 2 water pumps, all operating at the speeds specified in the Tables 4 and 5, depending on the ambient and system

operating conditions. These values are subject to adjustment and improvement over time, leveraging operational data to enhance overall system efficiency.

By applying the ASHP capacity and performance metrics to the heating demand profiles of the LDES, energy savings and GHG emissions reductions can be quantified under the following assumptions: the entire heating load is currently supplied by gas boilers with an efficiency of 85%, and the GHG emissions intensity of the British Columbia electricity grid is 7.6 grams of CO2 per kWh. Installing the ASHP results in a significant annual reduction of 815 metric tons of CO2 emissions and 430,000 cubic meters of natural gas consumption. Table 6 summarizes the results of the analysis.

| Annual overall heating COP | Heating capacity delivered (%) | Auxiliary heating supplied by gas boilers (GJ) | Absorbed power (MWh) | Total heating delivered (GJ) | CO2 emission saving (ton) | Natural gas saving ($1000m^3$) | Energy saving (%) |
|---|---|---|---|---|---|---|---|
| 3.5 | 98.4 | 230 | 1150 | 14,267 | 815 | 430 | 75% |

Table 6. Energy analysis results.

## Conclusion

The overall COP analysis shows that R744 air-source heat pumps outperform existing synthetic refrigerants, as long as the return temperature from buildings or districts stays below 49°C (120°F) or when the temperature difference between supply and return exceeds 30°C (54°F) for applications requiring supply temperatures below 90°C (194°F).

This article also highlights the potential of low-temperature district energy systems, where R744 heat pumps provide COP values that exceed those of existing alternatives. We quantified the energy savings and GHG emissions reduction of R744-

based air-source heat pumps as replacements for condensing boilers in the district energy system at the University of British Columbia Okanagan campus.

The article also emphasizes the crucial role of fan and pump control in ensuring efficient system operation. The electricity consumption of air heat exchanger fans can have a significant impact on overall system performance, highlighting the need for a unique approach to optimize their operation.

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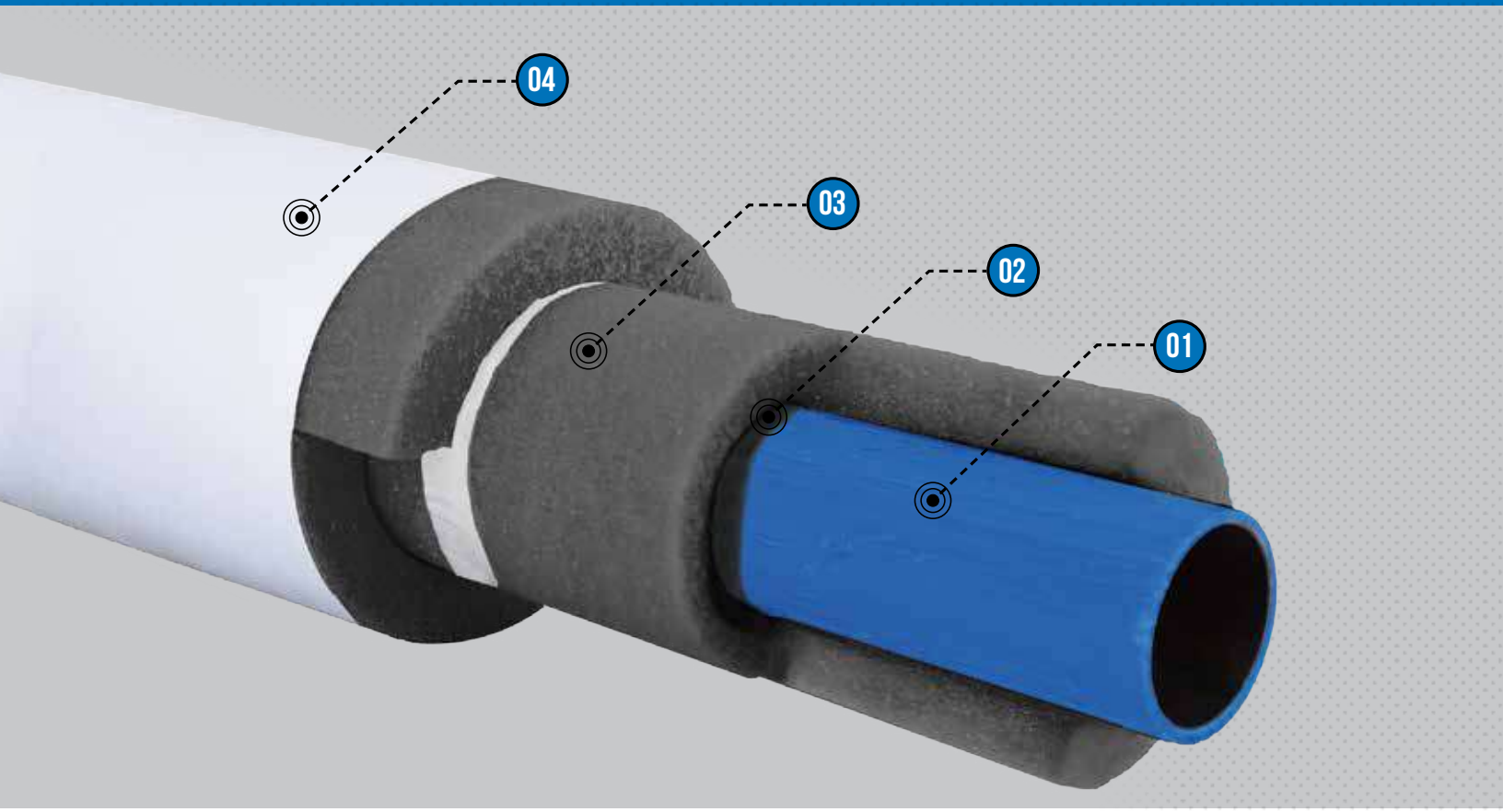


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