Lessons Learned: Successfully Using Hydrofluoroolefin (HFO) Refrigerant Blends for Retrofits in Cold Chain Applications

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Kersey has worked in various sectors before coming to U.S. EPA. Most recently, he worked for 3.5 years at the California Air Resources Board implementing an incentive program for cleaner agricultural equipment and ensuring that Cap-and-Trade incentive programs benefitted disadvantaged communities. Prior to that, he worked with state agencies to plan hydrogen fueling infrastructure for fuel cell electric vehicles. He holds engineering degrees all from the University of California, Irvine.
Today’s Host

Kirsten Cappel
U.S. Environmental Protection Agency (U.S. EPA)
Stratospheric Protection Division
GreenChill Partnership
Phone: 202-343-9556
Email: cappel.kirsten@epa.gov

Kirsten has worked for more than fifteen years at the U.S. EPA in the Office of Air and Radiation, managing both regulatory and voluntary programs. Most recently, she managed a voluntary EPA program that worked cooperatively with the solid waste industry to encourage the beneficial use biogas from landfills. She began her tenure at the Agency in the Stratospheric Protection Division, and is excited to return to the Division and work with the supermarket industry.
Questions and Webinar Feedback

Question and Answer Session

- Participants are muted
- Questions will be moderated at the end
- To ask a question, enter your comment into the chat box

Feedback Form

- We value your input!
- The link to a feedback form will appear in the chat window
Webinar Materials

Recording and Slides

- Webinar is being recorded
- Materials will be posted on the GreenChill website under Events and Webinars: [www.epa.gov/greenchill](http://www.epa.gov/greenchill)
- To receive notification when materials are posted email: [EPA-GreenChill@abtassoc.com](mailto:EPA-GreenChill@abtassoc.com)
Program Overview

GreenChill is a voluntary partnership program that works collaboratively with the food retail industry to reduce refrigerant emission and decrease stores’ impact on the ozone layer and climate system.

GreenChill works to help food retailers:
- Lower refrigerant charge sizes and eliminate leaks
- Transition to environmentally friendlier refrigerants
- Adopt green refrigeration technologies and best environmental practices

www.epa.gov/greenchill
GreenChill’s Mission: Reduce Refrigerant Emissions

Corporate Emissions Reductions Program
- Commit
  - Partners measure corporate-wide emissions, set annual goals, and report annually on progress

Store Certification Program
- Demonstrate
  - Individual stores earn GreenChill certification for meeting highest standards: low charge size, use of less harmful refrigerants, and low leak rates

Advanced Refrigeration Program
- Share
  - Promote advanced refrigeration technologies, strategies, and practices through social media, webinars, and guidelines
Celebrating 30 Years of Climate Partnership

This year, EPA is celebrating the 30th Anniversary of the founding of Green Lights, the Agency’s first climate partnership program. As a Friend of GreenChill, we invite you to join in the celebration, and help us spread the word about our impacts! We wanted to thank and celebrate you! We’re excited to share these results with the world to show how businesses and organizations like yours are tackling the climate crisis and leading the way to a clean energy economy.

www.epa.gov/30climate
GreenChill Annual Recognition

- Join us virtually on September 9 at 2:00 pm EST as we recognize achievements by GreenChill Partners and Certified Stores

- Learn more: [www.epa.gov/greenchill/events-and-webinars](http://www.epa.gov/greenchill/events-and-webinars)
Today’s speakers...
“This presentation will provide technical and engineering information to commercial refrigeration operators to enable safe and efficient refrigerant retrofits of existing systems from legacy refrigerants to lower global warming potential (GWP) options. In compliance with anti-trust laws, this presentation WILL NOT address topics or questions of a commercial nature, including but not limited to, pricing, product quantities, distribution channels, markets or specific product comparisons. We will only address questions and comments of a technical nature. Thank you for your cooperation.”
Chuck Allgood, PhD
Chemours
Refrigerant Technology Leader
charles.c.allgood-1@chemours.com

Chuck has over 30 years in the heating, ventilation, air-conditioning, and refrigeration (HVACR) industry, having held a variety of research, development, business, and technical service positions with Chemours. He holds a PhD in Chemistry and prior to joining DuPont worked for the National Institute of Standards and Technology. A frequent speaker at many industry events, Chuck currently leads the technical service, training, and applications development activities for the Freon™ and Opteon™ brand refrigerants.
Andrew Pansulla
Chemours
Technical Service Engineer
267-315-3561
Andrew.r.pansulla@chemours.com

Andrew has been working on next generation refrigerant development at Chemours for the last 8 years. His primary areas of focus includes refrigerant retrofit implementation/training, energy optimization, and the development of refrigerant management plans.
Doug Starasinic
Honeywell
Senior Applications Engineer
210-273-4051
Douglas.Starasinic@honeywell.com

Doug has over 30 years of experience in commercial refrigeration. His experience includes refrigeration design, construction, maintenance, energy management, and technical marketing.
1. Brief Regulatory Overview
2. Focus on Existing Stores
   - Regulatory Baselines, Calculations and Goals
3. Setting up for Success
   - Converting R-404A, R-507, and R-22 to R-448A/449A
4. What Success Looks Like – Learnings from the Last ~ 5 years
   - R-448A/449A performance post conversion
   - Optimizing Set-Points, Controls, Subcooling, Thermostatic Expansion Values (TXVs), Discharge Temp
5. Looking Ahead
   - New Architectures, New refrigerants, New Regulations
6. Question and Answer Session
Environmental Challenges Driving Industry Transitions

Global Warming Potential (GWP):
The potential for a gas to trap heat in the atmosphere, resulting in climate change.

Ozone Depletion Potential (ODP):
The potential for substances to reduce the amount of ozone in the atmosphere that blocks harmful radiation from the sun.

Kigali Amendment
[Hydrofluorocarbon (HFC)]
Phase *Down*

Montreal Protocol
[Chlorofluorocarbons (CFC)/
Hydrochlorofluorocarbons/(HCFC)]
Phase *Out*
Regulatory Landscape

International Level

Montreal Protocol
Phaseouts, like R-22

Kigali Amendment
Phasedowns, like R-410A

US State Level

California Air Resources Board (CARB)
2025 timeline for air conditioning (A/C)
Avg GWP requirements Food Retail

Climate Alliance
24 states following similar plans

US Federal Level

American Innovation and Manufacturing (AIM) Act
Passed late 2020

Significant New Alternatives Policy (SNAP) Rule 23
A2L refrigerants in certain A/C applications

The international community has been operating under Kigali

In the absence of Federal activity, the states began regulating

New Federal regulations should re-align the industry

Federal regulations will offer guidance to the market
aim act – hfc refrigerant phase down

the aim act

what to know

the goal is to initiate the phasedown of the production and consumption of hydrofluorocarbons (hfc) over the next 16 years.

how it works

the epa will use an allowance system to meet the phasedown schedule.

rulemaking begins in q1 2021 and is expected to end in q4.

the rule will:
- define the co2-eq baseline for the u.s. market
- outline distribution of allowances
- provide details on the phasedown schedule

co2: carbon dioxide
AIM Act Supports the Transition in 3 primary ways:

1. HFC Production/Consumption
   Baseline, Allowances, Phasedown, Trading, etc.

2. HFC Management
   Standards for servicing, repair, recovery, reclaim

3. Sector Based Controls
In September 2018, the California Cooling Act (Senate Bill 1013) passed SNAP Rules 20 and 21.

<table>
<thead>
<tr>
<th>Stationary Refrigerant limits – New Systems</th>
<th>Year</th>
<th>GWP Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Refrigeration containing &gt;50 pounds (lbs.)</td>
<td>2022</td>
<td>150</td>
</tr>
<tr>
<td>New Chillers (AC &amp; Refrigeration)</td>
<td>2024</td>
<td>150</td>
</tr>
<tr>
<td>AC systems containing &gt;2lbs</td>
<td>2025</td>
<td>750</td>
</tr>
</tbody>
</table>

Companies owning or operating retail food facilities with refrigeration systems charged with > 50lbs must collectively meet a **1,400 GWP average or 55% reduction** in greenhouse gas emission potential (GHGp) reduction over 2018 levels by **Jan 1, 2030**.

Additionally, companies owning or operating > 20 retail food facilities with refrigeration systems charged with > 50lbs must collectively meet a **2,500 GWP average or 25% reduction** in greenhouse gas emission potential (GHGp) reduction over 2018 levels by **Jan 1, 2026**.
Regulatory Compliance: Define your Store Footprint

“Green House Gas Potential” or “GHGp”

GHGp = \( \sum (\text{Charge} \times \text{GWP}) \) where \( \sum \) is the sum of the products of charged multiplied by the GWP for each separate type of refrigerant.

“Weighted Average GWP (WAGWP)” means \( \frac{\sum (\text{charge} \times \text{GWP})}{\sum \text{charge}} \). Where the charge equals the pounds of each separate type of refrigerant, refrigerant blend, or heat transfer fluid used in refrigeration equipment and systems.

### Breakdown

<table>
<thead>
<tr>
<th>Refrigerant Fleet Totals</th>
<th>Initial Fleet Charge</th>
<th>Final Fleet Charge</th>
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</thead>
<tbody>
<tr>
<td>R-404A</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>R-22</td>
<td>3,500</td>
<td>3,500</td>
</tr>
<tr>
<td>R-407A</td>
<td>2,000</td>
<td>2,000</td>
</tr>
<tr>
<td>R-134a</td>
<td>1,500</td>
<td>1,500</td>
</tr>
<tr>
<td>R-408A</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>R-507A</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>CO2</td>
<td>2,000</td>
<td>2,000</td>
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</table>

Baseline WAGWP

<table>
<thead>
<tr>
<th></th>
<th>Baseline WAGWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHGp</td>
<td>35,904,450</td>
</tr>
</tbody>
</table>

Baseline GHGp

<table>
<thead>
<tr>
<th></th>
<th>Baseline GHGp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35,904,450</td>
</tr>
</tbody>
</table>

Target WAGWP

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>GHGp</td>
<td>16,157,003</td>
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</table>

Target GHGp

<table>
<thead>
<tr>
<th></th>
<th>Target GHGp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,400</td>
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Calculated WAGWP

<table>
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<tr>
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<th>Calculated WAGWP</th>
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<tbody>
<tr>
<td>GHGp</td>
<td>2,394</td>
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</table>

Calculated GHGp

<table>
<thead>
<tr>
<th></th>
<th>Calculated GHGp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35,904,450</td>
</tr>
</tbody>
</table>

*Target WAGWP and GHGp are based on the CARB regulation to reach GWP <1400 or 55% reduction in GHGp by Jan 1st 2030. End users with >20 retail food facilities need to achieve an WAGWP of <2500 or a 25% reduction in GHGp by 2025.
### GHGp and WAGWP Example

<table>
<thead>
<tr>
<th>Store #</th>
<th>R-404A (lbs.)</th>
<th>R-22 (lbs.)</th>
<th>R-407A (lbs.)</th>
<th>R-134a (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Store 1</td>
<td>0</td>
<td>3000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Store 2</td>
<td>3000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Store 3</td>
<td>3000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Store 4</td>
<td>0</td>
<td>0</td>
<td>2000</td>
<td>1000</td>
</tr>
<tr>
<td>Store 5</td>
<td>0</td>
<td>0</td>
<td>3000</td>
<td>0</td>
</tr>
</tbody>
</table>

#### Refrigerant AR4 GWP

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>AR4 GWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-404A</td>
<td>3900</td>
</tr>
<tr>
<td>R-22</td>
<td>1810</td>
</tr>
<tr>
<td>R-407A</td>
<td>2107</td>
</tr>
<tr>
<td>R-134a</td>
<td>1430</td>
</tr>
</tbody>
</table>

\[
GHGp = (3000 \times 1810) + (3000 \times 3900) + (3000 \times 3900) + (2000 \times 2107) + (1000 \times 1430) + (3000 \times 2107) = 4.08 \times 10^7 \text{ lbs CO}_2\text{eq}
\]

\[
WAGWP = \frac{4.08 \times 10^7}{15000} = 2720
\]

AR4: Fourth Assessment Report of the United Nations Intergovernmental Panel on Climate Change

CO₂eq: Carbon dioxide equivalent
## GHGp and WAGWP Example

<table>
<thead>
<tr>
<th>Store #</th>
<th>R-404A (lbs.)</th>
<th>R-22 (lbs.)</th>
<th>R-407A (lbs.)</th>
<th>R-134a (lbs.)</th>
<th>R-448A (lbs.)</th>
<th>R-449A (lbs.)</th>
<th>CO₂ (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Store 1</td>
<td>0</td>
<td>-3000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+3000</td>
<td></td>
</tr>
<tr>
<td>Store 2</td>
<td>-3000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+3000</td>
<td></td>
</tr>
<tr>
<td>Store 3</td>
<td>-3000</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+3000</td>
<td></td>
</tr>
<tr>
<td>Store 4</td>
<td>0</td>
<td>0</td>
<td>2000</td>
<td>1000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Store 5</td>
<td>0</td>
<td>0</td>
<td>3000</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* One for one charge differences assumed for simplicity

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>AR4 GWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-404A</td>
<td>3900</td>
</tr>
<tr>
<td>R-22</td>
<td>1810</td>
</tr>
<tr>
<td>R-407A</td>
<td>2107</td>
</tr>
<tr>
<td>R-134a</td>
<td>1430</td>
</tr>
<tr>
<td>R-448A</td>
<td>1387</td>
</tr>
<tr>
<td>R-449A</td>
<td>1397</td>
</tr>
<tr>
<td>CO₂</td>
<td>1</td>
</tr>
</tbody>
</table>

\[
GHGp = (3000 \times 1397) + (3000 \times 1387) + (3000 \times 1) + (2000 \times 2107) + (1000 \times 1430) + (3000 \times 2107) = 2.03 \times 10^7 \text{ lbs CO}_2 \text{ eq}
\]

\[
WAGWP = \frac{2.03 \times 10^7}{15000} = 1355
\]
Tips for Compliance – Existing Stores

1. Maintenance and Leak Reduction

2. Retrofit to a lower GWP refrigerant → Extend the life of the existing equipment

3. Reduce Charge → Effective way to reduce store carbon footprint but will still be reliant on the incumbent gas

4. Remodel and Redesign → useful for equipment at end of life
Successful Retrofitting of HCFCs and HFCs

Key items
Energy impacts
Reasons to retrofit
Key Items for Retrofits

- Survey
- Compressor compatibility
- System review (upgrades & opportunities)
- Expansion valves
- Oil
- Leak prevention measures
- Line sizes
- Commissioning
Energy Results

- With R-404A retrofits a 5-10% energy efficiency gain is expected.

- With R-22 retrofits energy reductions can be achieved when combined with simple commissioning measures.

COP: coefficient of performance
Retrofits - 3 Steps

**Step 1 – Site Survey**
- Compressors
- System issues & opportunities
- Review expansion valves
- Leak prevention
- Record baseline data
- Line sizes
- Test oil and refrigerant
- Forward completed survey form to the customer

**Step 2 – Store coordination**
- Order parts and refrigerant
- Technician training
- Perform system changes / upgrades
- Change oil from mineral to Poly Olester (POE)
- Change suction and liquid filters and driers
- Upgrade controller with Solstice® N40 (R-448A) pressure (PT) curves
- Leak check and repair
Three steps

Step 3 – The Retrofit

- Remind store personnel the day prior to retrofit
- Secure food safety (dry ice, plastic sheeting, signs on coolers, etc.)
- Recover existing refrigerant
- Record amount of refrigerant removed (including refrigerant previously removed)
- Break vacuum from recovery machine
- Replace seals, gaskets, and valves as needed

- Replace expansion valves and add adjustment kits as determined in survey
- Replace driers and filters
- Evacuate system
- Charge system
- Adjust expansion valves
- Adjust pressure controls
- Label components and systems

Years of energy efficiency and low maintenance realized
Success factors

With a well-executed retrofit the end-user can expect:

- Reduced leaks (<$)
- Reduced energy (<$)
- Upgraded system for long term
- Better food quality (depending on commissioning scope of work)
Why transition to R-448A / R-449A?

1. Long-term replacement for R-404A, R-507, R-22, R-408A, R-402A
2. Non-flammable A1 refrigerant
3. Lowered GWP for regulatory compliance and for meeting sustainability goals [R-448A (1287) vs R-404A (3922)]
4. Lower energy usage than R-404A & R-507
5. Simple retrofit and maintenance
6. Industry leading support and distribution

HFO 448A / 449A blends are non-toxic, non-flammable, non-corrosive, energy-efficient, has have lowered GWPs.
Learning from the Past

Key Learnings
Compressor Capacities
Key Learnings From the Field

- Save time that night
  - Do oil ahead of time
  - Replace valves ahead of time when possible
- Beware of overnight leaks
- Prevent flooding
- Setting TXV next day
- Food safety
- Adequate vacuum pumps
- Project Process management

**Train technicians on glide ahead of time!!**

<table>
<thead>
<tr>
<th>retrofit</th>
<th>Oil</th>
<th>Leaks</th>
<th>Discharge temp</th>
<th>TXV’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-22 retrofit</td>
<td>change</td>
<td>Med – High</td>
<td>Lower</td>
<td>Good</td>
</tr>
<tr>
<td>R-404A retrofit</td>
<td>Not likely</td>
<td>Low</td>
<td>Higher</td>
<td>Power head change to R-22 may be needed</td>
</tr>
<tr>
<td>R-402A/408A retrofit</td>
<td>change</td>
<td>Med - High</td>
<td>Higher</td>
<td>Power head change to R-22 may be needed</td>
</tr>
</tbody>
</table>
Control Optimization

Settings

- Evaporator Superheat = dewpoint
- Subcooling = bubble point
- Pressure settings and valves = mid point

USE PRESSURE BASED PT CHARTS TO MAKE GLIDE EASY!!

<table>
<thead>
<tr>
<th>Pressure (psig)</th>
<th>Avg</th>
<th>Bubble</th>
<th>Dew</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>6</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>40</td>
<td>11</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>45</td>
<td>15</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>50</td>
<td>19</td>
<td>14</td>
<td>24</td>
</tr>
<tr>
<td>55</td>
<td>23</td>
<td>23</td>
<td>28</td>
</tr>
</tbody>
</table>
Compressor Capacity Ratings Can Be Misleading

Compressor Heat transfer using different rating selections

<table>
<thead>
<tr>
<th></th>
<th>Dew and Comp. Heat transfer</th>
<th>Dew with Net Effect</th>
<th>Midpoint with Comp. Heat transfer</th>
<th>Midpoint with Net Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-404A</td>
<td>26000</td>
<td>21700</td>
<td>26100</td>
<td>21800</td>
</tr>
<tr>
<td>R-448A / 449A HFO BLEND</td>
<td>~24500</td>
<td>~21600</td>
<td>~25400</td>
<td>~22600</td>
</tr>
</tbody>
</table>

COMPRESSOR INCREASES ARE NOT NEEDED!
Common Questions from the Industry

- Will fractionation cause any issues when using R-448A/R-449A?
  - No, the system effects of fractionation on refrigerants like R-448A/R-449A are insignificant

- What are the largest changes I will need to make to my system (R-22 and/or R-404A)?
  - R-22 → Oil/Elastomeric Seals
  - R-404A → TXVs/demand cooling needs
  - R-402A/R-408A → Oil/seals/TXVs/demand cooling needs

- How do I maximize energy efficiency using R-448A/R-449A?
  - Factor for glide, use proper superheats/subcooling measuring techniques, manage set points

- Since R-448A/R-449A are very similar can they be mixed?
  - No, although similar in performance, different refrigerants should not be mixed

- Will my current leak detection system be able to detect new refrigerants?
  - Any leak detector that can detect an HFC can be used with these refrigerants
Looking Ahead

New System Architectures

New Refrigerants

New Regulations
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- Kersey Manliclic, U.S. EPA  
  Manliclic.Kersey@epa.gov

**Upcoming Events**

<table>
<thead>
<tr>
<th>Date</th>
<th>Webinar Topic</th>
</tr>
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<tbody>
<tr>
<td>9/9/2021</td>
<td>Annual GreenChill Recognition Event (virtual)</td>
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</tbody>
</table>

Join our webinar invitation list or request today’s slides: EPA-GreenChill@abtassoc.com
Access past webinar slides: www.epa.gov/greenchill/events-and-webinars