Demystifying the Refrigerant Landscape

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Bonneville Power Administration (BPA)

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Livingston Energy Innovations (LEI)

John Bush
Electric Power Research Institute (EPRI)

Emerging Technologies Showcase
September 28, 2017
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Emerging Technologies

Background

Jamie Anthony
Mechanical Engineer, Commercial
Bonneville Power Administration

September 28, 2017
• Main Goal and Takeaways
• Background
• Types of Refrigerants
• International Agreements
• Research
• Utility Incentives
• Conclusion
• Q&A
Main Goal

• Educate, Inform, Learn Language
  – If an end user asks, you can respond: Whitepaper
  – GWP: Global Warming Potential
  – Why BPA Cares
    • Energy Efficiency Opportunity?
    • Environmental Opportunity?
    • Help Utilities and End Users
  – Alternative refrigerants are not easy
  – Incentives are beginning to happen
Alternative Refrigerants are Not Easy

Figure 2-2.
Example showing GWP of current and alternative refrigerants
Incentives are Beginning to Happen
# Background – Types of Refrigerants

<table>
<thead>
<tr>
<th>Refrigerant Quick Reference Table</th>
<th>Global Warming Potential</th>
<th>Ozone Depletion Potential</th>
<th>Phase Out Date</th>
<th>Toxic / Flammable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High GWP</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFC</td>
<td>High</td>
<td>High</td>
<td>1996</td>
<td>No</td>
</tr>
<tr>
<td>HCFC</td>
<td>High</td>
<td>Medium</td>
<td>2030</td>
<td>No</td>
</tr>
<tr>
<td>HFC</td>
<td>High</td>
<td>None</td>
<td>2036 (85%)</td>
<td>No</td>
</tr>
<tr>
<td><strong>Low-Medium GWP</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HFO</td>
<td>Low</td>
<td>None</td>
<td>n/a</td>
<td>Varies</td>
</tr>
<tr>
<td>HFO / HFC Blends</td>
<td>Medium</td>
<td>None</td>
<td>n/a</td>
<td>Low to none</td>
</tr>
<tr>
<td>Natural Refrigerants</td>
<td>Low</td>
<td>None</td>
<td>n/a</td>
<td>Varies</td>
</tr>
</tbody>
</table>
Background – Types of Refrigerants

Figure 1.1: HFC phasedown schedules for North American Montreal Protocol proposal and European F-gas regulation
Background – Global Warming

Headline statements from the Summary for Policymakers*

Observed Changes and their Causes

Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems.
Table 7. Estimated Annual Amount of HFCs Released in BPA’s Service Territory

<table>
<thead>
<tr>
<th>Sector</th>
<th>Estimated thousands of metric tons CO₂ equivalent (100-year GWP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>2,573</td>
</tr>
<tr>
<td>Industrial</td>
<td>746</td>
</tr>
<tr>
<td>Residential</td>
<td>553</td>
</tr>
<tr>
<td>Total</td>
<td>3,871</td>
</tr>
</tbody>
</table>
Background – Refrigerants Leaking

– Refrigerants account for roughly 7 percent as much of the global warming impacts as the entire electric power sector in the region.

– By comparison, all the wind power in the region totaled 7.3 percent of all electricity in 2015.

– So leaking refrigerants “cancel out” essentially all the wind power generated each year in the Northwest from a global warming perspective.
Understanding the types of refrigerants and international treaties

Spencer Sator
September 28, 2017
Refrigerant Types: CFCs \textit{(Chlorofluorocarbons)}

Characteristics:
- Potent ozone destroyers
- Potent GHGs (up to 10k times CO$_2$)
- Non-toxic, non-flammable

Background:
- “Safe” alternative to earliest refrigerants like methyl chloride
- Phased out globally in 1996
- A few legacy systems may still be operating with these compounds

Common varieties:
- R11
- R12
- R113
- R114
- R115

<table>
<thead>
<tr>
<th>Year</th>
<th>Percent reduction in consumption and production from 1989 baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>15%</td>
</tr>
<tr>
<td>1992</td>
<td>20%</td>
</tr>
<tr>
<td>1993</td>
<td>25%</td>
</tr>
<tr>
<td>1994</td>
<td>75%</td>
</tr>
<tr>
<td>1995</td>
<td>75%</td>
</tr>
<tr>
<td>1996</td>
<td>100%</td>
</tr>
</tbody>
</table>
Refrigerant Types: HCFCs (Hydrochlorofluorocarbons)

Characteristics:
- Still major ozone destroyers
- Potent GHGs (up to 2k times CO₂)
- Non-toxic, non-flammable

Background:
- Primary alternative after CFC phase-out
- Currently almost totally phased out
- R22 was among the most common refrigerant used for many years

Common varieties:
- R22
- R123
- R124
- R141b
- R142b
- R225c/a

<table>
<thead>
<tr>
<th>Year</th>
<th>Percent reduction in consumption and production from 1996 baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>35%</td>
</tr>
<tr>
<td>2010</td>
<td>75%</td>
</tr>
<tr>
<td>2015</td>
<td>90%</td>
</tr>
<tr>
<td>2020</td>
<td>99.5%</td>
</tr>
<tr>
<td>2030</td>
<td>100%</td>
</tr>
</tbody>
</table>
Refrigerant Types: HFCs (Hydrofluorocarbons)

Characteristics:
- Not harmful to the ozone!
- Potent GHGs (up to 15k times CO₂)
- Non-toxic, non-flammable

Background:
- Primary alternative after HCFC phase-out
- Global community phasing down 85 percent by 2036 (2045-2047 for some countries)

Common varieties:
- R23
- R32
- R134a
- R404a
- R407c
- R410a

<table>
<thead>
<tr>
<th>Year</th>
<th>Percent reduction in consumption and production from 2011-2013 baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>10%</td>
</tr>
<tr>
<td>2024</td>
<td>40%</td>
</tr>
<tr>
<td>2029</td>
<td>70%</td>
</tr>
<tr>
<td>2034</td>
<td>80%</td>
</tr>
<tr>
<td>2036</td>
<td>85%</td>
</tr>
</tbody>
</table>
Refrigerant Types: Phase Out Timelines

![Graph showing phase out timelines for CFCs, HCFCs, and HFCs.](image-url)
Refrigerant Types: HFOs \textit{(Hydrofluoroolefins)}

Characteristics:
- Not harmful to the ozone!
- Minimal climate pollutant!
- But there’s a catch: to make flammable HFOs safer to handle, they are commonly blended with HFCs

Background:
- New to market; few regulations
- Low market penetration so far

EU and CA:
- Limits at 150/750 GWP
- Europe has ratified
- In CA, the Air Resources Board signaled in March that they intend to adopt same limits

Common varieties:
- HFO-1234yf
- HFO-1234ze
- HFO-1336mzz
Refrigerant Types: Alternative Refrigerants

Characteristics:
- Not harmful to the ozone!
- Minimal climate pollutant!
- But there’s a catch: many are toxic or flammable
- And another catch: not generally “drop-in” replacements for legacy refrigerants
- And another catch: some have “energy penalty” (while others carry an “energy bonus”)

Common varieties:
- R290 – aka Propane
- R600 – aka Butane
- R600a – aka Isobutane
- R717 – aka Ammonia
- R744 – aka CO₂
Why Do We Even Care About Refrigerants?

Why Do We Even Care About Refrigerants?

Kigali Amendment to the Montreal Protocol

- Ratified October 2016 by 197 countries
- Expands scope beyond ozone depletion to GHGs
- This amendment is what prompted HFC reductions
Late Breaking News.....

....And why it may not matter:

- Phase out has widespread industry support
- Environmental groups and industry are appealing
- Trump administration hasn’t opposed the phase down
- Future administrations may be even more forceful in their support
- The whole world plus California may be critical mass even if ruling remains
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Refrigerant Research

John Bush
Senior Engineer
9/28/2017
Research Overview – Key Categories

- Refrigerant Impact
  - Total Equivalent Warming Impact (TEWI) and Life Cycle Climate Performance (LCCP)

- Research into Short-Term Alternatives, Retrofits
  - Air Conditioning, Heating & Refrigeration Institute (AHRI) Program

- Alternative Configurations, New Technologies
  - New systems using natural refrigerants, ultra-low GWP blends

- Different Needs in Different Categories
  - The constraints in supermarkets are not the same as the constraints in residential A/C!

[Graph showing lifetime CO₂ emissions, tonnes (TEWI), Northern Europe]
Drop-In and Retrofit Replacements

- **Large Initiative by HVAC&R Industry**
  - AHRI Alternative Refrigerants Evaluation Program
  - Also others, including EPRI, have tested drop-ins

- **Goals:**
  - Look for retrofit-ready refrigerants to lower GWP and provide adequate capacity, efficiency

- **Key Take-Aways**
  - There’s no magic bullet! Compromises on capacity, efficiency, flammability, toxicity
  - Retrofits should NEVER go from A1 safety designation to any other safety designation without thorough engineering review
  - Some categories better than others:
    - For example, R404A (GWP = 3700) efficiency already relatively low – some alternatives should offer a modest efficiency improvement
    - But, replacing R134a (GWP = 1370) in other applications will be difficult
Alternative Configurations/Technologies - Examples

- Transcritical CO$_2$
  - Alternative to conventional supermarket refrigeration
  - GWP 1.0
  - Efficiency better at low outdoor temp., worse at high
    - *Currently available and emerging solutions to improve high-temp efficiency*

- Ammonia-CO$_2$ systems
  - Use each refrigerant in their “strong suit”
  - Contain ammonia to low-quantity, central charge
  - Results show good efficiency
    - High up front cost will come down with broader adoption

Ongoing Refrigerant Collaborative

- **EPRI Research Project**
  - BPA, Southern California Edison, San Diego Gas & Electric and Southern Company
  - What is the baseline efficiency in supermarkets today?
  - What is the efficiency, demand of alternative-refrigerant systems being installed today?

- **Field monitoring:**
  - 5 sites in Pacific Northwest, 1 upcoming in Southeast
  - CO₂, R404A, R22, R407A

- **Lab-scale multiplex refrigerating and freezing racks**
  - Compressors capable of retrofit to R404A, R407A, R448A, others
  - Can we narrow in on the refrigerant’s impact on efficiency?
  - What hardware changes can be done to maximize efficiency?
Summary Thoughts

- **How should utilities think about refrigerant changes?**
  - *The changes will come – stay aware*
  - *Remember – no magic bullet! Healthy skepticism for “does-it-all” solutions is appropriate*
  - *Be aware of potential for energy/demand savings OR penalties associated with change*
  - *Get involved as early in the process as possible!*
  - *Leverage changes that are already happening to push for other efficiency measures*

- **Look for some early successes!**
  - *Hydrocarbon self-contained refrigerators and freezers are available and efficient*
  - *CO₂ for heat pump water heaters is showing great promise*

- **And stay tuned, the researchers are hard at work!**
How You Can Help

▪ Participate in EPRI projects
  – Contact me – jbush@epri.com

▪ Check out North American Sustainable Refrigeration Council
  – http://nasrc.org/

▪ Upcoming joint effort – EPRI, NASRC, industry partners
  – Assess the current “state of the art” of energy modeling/estimating methods in food retail
    ▪ Why aren’t they universal and accessible?
  – What improvements are needed to get an industry-wide approach to energy comparisons for refrigerants, refrigeration efficiency measures?

  – Goal: Move towards new or improved tools needed so that utilities can easily have efficiency, demand response measures for food retail
SMUD Pilot Natural Refrigerant Incentive Program
Utility Incentive Program

SMUD
Sacramento Municipal Utility District

$25 / Metric Ton CO₂ equivalent

\[
\text{Direct GHG Reduction (tCO₂e)} = \text{Expected or Remaining Life} \times [(\text{GWP}_{\text{Baseline}} \times \text{Charge}_{\text{Baseline}} \times \text{Leak Rate}_{\text{Baseline}}) - (\text{GWP}_{\text{New}} \times \text{Charge}_{\text{New}} \times \text{Leak Rate}_{\text{New}})]
\]
Utility Incentive Program

• Ryan Hammond, P.E.
• Ryan.Hammond@smud.org
• 916-732-5647
Conclusion

• Whitepaper! Read it. Send it. Click on it.
  – Why the refrigerants are important GHG

• Things to remember:
  – 7% of all PNW emissions from Refrigerants
  – Phase-outs are happening: it’s not easy

• We are doing primary research, sharing results
kWh per 100 gallons water delivered

- Resistance Heat Tank
- Tier 1 Unitary HPWH in Garage
- Tier 2 Unitary HPWH in Garage
- Any Unitary HPWH Interior
- Addy WA (Near Spokane)
- Montana (Near Corvallis)
- Portland OR
- Tacoma WA

CO2 Split Systems
Contact Information

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Thank you for attending!

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