Refreshing Refrigerants

Understanding and Transforming Refrigerants

February 28, 2019
Presented to PHNW 2019
Refreshing Refrigerants

What are refrigerants’ true impact on global warming? We will delve into natural alternatives, and a case study that achieved thermal comfort with low refrigerant use intensity (RUI).

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Learning Objectives

1. Understand what refrigerants are and their impacts on the environment.

2. Become familiar with how refrigerants have typically been used and what quantities are present in different HVAC systems.

3. Understand how to quantify impacts of refrigerants on global warming.

4. Identify natural alternates for projects.

Learning Level – Intermediate
What is a refrigerant?

re-frig-er-ant

*noun*
plural noun: refrigerants

A substance used for refrigeration.
What is a refrigerant?

re-frig-er-ant

noun
plural noun: refrigerants

A substance used for refrigeration.

Refrigerants are also hazardous chemicals that can be toxic and flammable.
What is a Refrigerant?

“Weather will NOT get you high, but it can kill you.”

– HVAC TECHNICIAN
Refrigerants Matter
DRAWDOWN
THE MOST COMPREHENSIVE PLAN EVER PROPOSED TO REVERSE GLOBAL WARMING
EDITED BY PAUL HAWKEN
<table>
<thead>
<tr>
<th>Rank</th>
<th>Solution</th>
<th>Sector</th>
<th>Total Atmospheric CO2-Eq Reduction (GT)</th>
<th>Net Cost (Billions US $)</th>
<th>Savings (Billions US $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Refrigerant Management</td>
<td>Materials</td>
<td>89.74</td>
<td>N/A</td>
<td>-902.77</td>
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<td>2</td>
<td>Wind Turbines (Onshore)</td>
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<td>$7,425.00</td>
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<td>3</td>
<td>Reduced Food Waste</td>
<td>Food</td>
<td>70.53</td>
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<td>N/A</td>
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<tr>
<td>4</td>
<td>Plant-Rich Diet</td>
<td>Food</td>
<td>66.11</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>5</td>
<td>Tropical Forests</td>
<td>Land Use</td>
<td>61.23</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>6</td>
<td>Educating Girls</td>
<td>Women and Girls</td>
<td>59.60</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>7</td>
<td>Family Planning</td>
<td>Women and Girls</td>
<td>59.60</td>
<td>N/A</td>
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<td>8</td>
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<td>10</td>
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<td>$453.14</td>
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<td>11</td>
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<td>Food</td>
<td>23.15</td>
<td>$57.22</td>
<td>$1,928.10</td>
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<tr>
<td>12</td>
<td>Temperate Forests</td>
<td>Land Use</td>
<td>22.61</td>
<td>N/A</td>
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<td>13</td>
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<td>Land Use</td>
<td>21.57</td>
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<td>14</td>
<td>Tropical Staple Trees</td>
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<td>20.19</td>
<td>$120.07</td>
<td>$626.97</td>
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<td>15</td>
<td>Afforestation</td>
<td>Land Use</td>
<td>18.06</td>
<td>$29.44</td>
<td>$392.33</td>
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</tbody>
</table>
Refrigerant Management

Estimated Global Refrigerant Recovery Rates

World | OECD90 | Eastern Europe | Asia (sans Japan) | Middle East & Africa | Latin America | China | India | EU | USA
Refrigerant Management

Estimated Global Market Value

- VRF: $25,000,000,000
- Chillers: $10,000,000,000
- Boilers: $5,000,000,000
Case Study: The Manufacturer’s Building
CASE STUDY: THE MANUFACTURER’S BUILDING
EXISTING MASONRY WALLS

THICK BRICK WALLS HAVE AMPLE CAPACITY TO CARRY GRAVITY LOADS
EXISTING HEAVY TIMBER FRAMING

FIRE RESISTANT HEAVY TIMBER FRAMING PROVIDES 7 FLOORS OF ADAPTABLE SPACE
NEW LATERAL SYSTEM

STEEL BRACED FRAMES ON NEW FOUNDATIONS RESIST SEISMIC FORCES
DECADES OF AD-HOC TENANT IMPROVEMENTS HAVE LEFT THE BUILDING’S CORE FUNCTIONS SCATTERED AND DISORGANIZED
CONSOLIDATED INFRASTRUCTURE

A COMPACT CORE MAXIMIZES LEASABLE AREA AND ALLOWS FOR 360° VIEWS OUT ON ALL FLOORS
NEW EXTERIOR STAIR TOWER

GLAZED STAIR OFFERS DRAMATIC ALLEY VIEWS. USERS KEEP A WATCHFUL EYE ON THE ALLEYS BELOW.
CROSS LAMINATED TIMBER

ROOF, STAIR TOWER, AND PENTHOUSE ARE CONSTRUCTED OF MODERN HEAVY TIMBER CLT PANELS
INTENSIVE GREEN ROOF SLOWS STORMWATER RUNOFF MITIGATING COMBINED SEWER OVERFLOWS
THE RAILSPUR TOMORROW
FEDERAL HISTORIC TAX CREDIT

• THE 20% TAX CREDIT HELPS OFFSET THE HIGH COST OF REHABILITATION AND IS ESSENTIAL TO THE FINANCIAL VIABILITY OF THIS PROJECT.

• QUALIFICATION REQUIREMENTS ARE EXTENSIVE. AN AVERAGE OF 10 TAX CREDITS ARE AWARDED PER YEAR IN WASHINGTON STATE.

• THE OVERARCHING REQUIREMENT IS THE PRESERVATION OF “CHARACTER DEFINING ELEMENTS”.
• AMONG THE “CHARACTER DEFINING ELEMENTS” OF THIS 1907 WAREHOUSE ARE UNINSULATED BRICK WALLS AND ORIGINAL SINGLE PANE WINDOWS.

• HOW CAN AN UNINSULATED BRICK BUILDING MEET CURRENT ENERGY CODE REQUIREMENTS?
TOTAL BUILDING PERFORMANCE MODELING

AN ENERGY CODE COMPLIANCE PATH THAT ALLOWS HIGH EFFICIENCY SYSTEMS, ON-SITE POWER GENERATION, AND OTHER MEASURES TO COMPENSATE FOR POOR ENVELOPE PERFORMANCE.
STEP 1: HIGH EFFICIENCY MECHANICAL PLANT

- A HIGHLY EFFICIENT HVAC SYSTEM WAS A FUNDAMENTAL REQUIREMENT
- TWO AIR SOURCE HEATPUMP SYSTEMS COUPLED WITH A DOAS (DEDICATED OUTSIDE AIR SYSTEM) WERE IDENTIFIED AS Viable OPTIONS.
STEP 2: MAXIMIZE ON SITE SOLAR

AN EFFICIENT MECHANICAL PLANT ALONE COULD NOT COMPENSATE FOR POOR ENVELOPE PERFORMANCE.

48.5KW (LARGEST ARRAY WE COULD PROVIDE GIVEN BUILDING CODE AND PRESERVATION LIMITATIONS)
STEP 3: TARGETED ENVELOPE IMPROVEMENTS

EFFICIENT MECHANICAL PLANT AND MAXIMIZED ON-SITE SOLAR ARE STILL NOT ENOUGH... BUT TARGETED ADDITION OF INSULATION AND INTERIOR STORM WINDOWS CLOSED THE GAP!

PENTHOUSE ADDITION AND ROOFS EXCEED PRESCRIPTIVE ENVELOPE REQUIREMENTS

INTERIOR INSULATION AND STORM WINDOWS ON WEST WALL
Selecting the Mechanical System

Why Air Source Heat Pump Technology?
Selecting the Mechanical System

Why Air Source Heat Pump Technology?
Selecting the Mechanical System

- Ceiling Height
- First Cost
- Life Cycle Cost
- Maintenance
- Tenant Flexibility
- Aesthetics
- Energy Cost
- Greenhouse Gas Impact
- Roof Area
- Leasable Area
- Acoustics
Selecting the Mechanical System

Top Priority: “Appealing Now and in 100 Years”
- First Cost
- Aesthetics
- Tenant Flexibility
- Life Cycle Cost
- Greenhouse Gas Impact

Second Priority: “Manage Impacts”
- Roof Area
- Ceiling Height
- Leasable Area

Third Priority: “Really important, but not to the detriment of the above”
- Energy Cost
- Water Efficiency
- Maintenance
Project Example – VRF
Project Example – VRF
Selecting the Mechanical System

Two Efficient Systems with Different RUI’s - “Refrigerant Use Intensity”

VRF = High “RUI”
Uses refrigerant as the medium to move heat around the building.

ASHP = Low “RUI”
Uses water as the medium to move heat around the building.

The risk of refrigerants on the environment and indoor air quality was one of the deciding factors.
VISION – Comfort with Friendly Refrigerants
What are Refrigerants?
What is a Refrigerant?
What is a Refrigerant?
History

1st Generation
1830's-1930's

Engineering Challenges

2nd Generation
1930's-1990's

Ozone Depletion

3rd Generation
1990's-2010's

Global Warming Impacts

4th Generation
2010-NOW

Goal - Half-life in Days
Global Warming Potential of Refrigerants

- Ammonia (NH3)
- Carbon Dioxide (CO2)
- Propane
- HCFC-123
- ARM-70a (A2L)
- L41a (A2L)
- R466A
- HFC-245fa
- HFC-134a
- HFC-407C
- HCFC-22
- HFC-410A
- HFC-404A
- HFC-507A
- CFC-502
GWP

- R466A: 700
- R410A: 1,900
What is a Refrigerant?

Figure 1. ASHRAE Standard 34-2007 Safety Classifications

<table>
<thead>
<tr>
<th>Flammability</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No flame</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Propagation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Toxicity</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher</td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>
## Zero ODS, Low GWP Alternatives

<table>
<thead>
<tr>
<th>Natural Refrigerants</th>
<th>HCs (hydrocarbons)</th>
<th>e.g. R-290 (Propane), R-600a (Isobutane), R-1270 (propene)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ammonia</td>
<td>R-717</td>
</tr>
<tr>
<td></td>
<td>CO₂ (Carbon dioxide)</td>
<td>R-744</td>
</tr>
<tr>
<td>Synthetic HFCs</td>
<td>Saturated HFCs</td>
<td>e.g., R-161, R-152a</td>
</tr>
<tr>
<td></td>
<td>Unsaturated HFCs</td>
<td>e.g. R-1234yf, R-1234ze</td>
</tr>
<tr>
<td></td>
<td>(known as “hydrofluoroolefins” or “HFOs”)</td>
<td></td>
</tr>
</tbody>
</table>
Leakage Issues
R410a Refrigerant - 25 lb cylinder - New factory sealed tank

Price: $169.95 & FREE Shipping

In Stock.
Get it as soon as April 2 - 5 when you choose Standard Shipping at checkout.
Ships from and sold by True Blue Parts.

New (2) from $169.95 & FREE shipping.

Specifications for this item:

<table>
<thead>
<tr>
<th>Brand Name</th>
<th>Honeywell</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAN</td>
<td>0783583693233</td>
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<tr>
<td>Part Number</td>
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</tr>
<tr>
<td>UNSPSC Code</td>
<td>52141501</td>
</tr>
<tr>
<td>UPC</td>
<td>783583693233</td>
</tr>
</tbody>
</table>
410a Reviews

⭐⭐⭐⭐⭐ R410a Refrigerant - 25 lb cylinder - New factory sealed tank
By Michel Morin on March 21, 2014
Verified Purchase
the ac service men keep putting 1/2 pound of refrigerant about every 6 mount that a new unit and they can not found the leak. I can do that and save on service call price.

⭐⭐⭐⭐⭐ at least until the leak gets much worse!
By Scott W. on April 26, 2015
Verified Purchase
I can top off my AC as necessary and that of a few friends for much less than cost of one visit by the AC guy.at least until the leak gets much worse!

⭐⭐⭐⭐⭐ Ice Cold
By doc on May 22, 2014
Verified Purchase
My Trane HVAC heat pump system that was installed in 2009 has a very slow leak. Had it charged exactly one year ago. Tech says it took 2.2lbs. Had to pay $220 ($100 per pound!) for the refrigerant, plus diagnostic fee, and service call fee. That added up quick. He didn't bother to use a leak detector. Got a quote for lead detection with nitrogen: $480. No guarantee and who knows what other charges would be added. Screw that.

⭐⭐⭐⭐⭐ It's a great deal, you save money
By Lisandro R. Duran on November 30, 2017
Verified Purchase
My a/c line had a very small leak and my ac unit needed 4lbs to refill. The A/C company was charging me around 50$ per lbs. With this purchase it's around 5.50$ per lbs. It's a great deal, you save money. Also I think you'll need a license to purchase after January 2018 so if you need some, hurry up.
LEED Method

2%

10%
Agreements & Regulations
Kigali Agreement

National Reduction in Controlled Substances - HFC Consumption

- HCFCs & HFCs
  - R-404A
  - R-123
  - R-134a
  - R-407C
  - R-410A

Larger Chillers
VRF + Smaller Refrigeration Units
Kigali Agreement

The countries to have ratified in date order:

1. Mali 31/3/17
2. Micronesia 12/5/17
3. Marshall Islands 15/5/17
4. Rwanda 23/5/17
5. Palau 29/8/17
6. Norway 6/9/17
7. Comoros 16/9/17
8. Chile 19/9/17
9. Tuvalu 21/9/17
10. North Korea 21/9/17
11. Australia 27/10/17
12. Canada 3/11/17
13. Maldives 13/11/17
14. UK 14/11/17
15. Finland 14/11/17
16. Germany 14/11/17
17. Laos 16/11/17
18. Luxembourg 16/11/17
19. Slovakia 16/11/17
20. Sweden 17/11/17
21. Trinidad and Tobago 17/11/17
22. Malawi 21/11/17
23. Côte d’Ivoire 29/11/17
24. Ecuador 22/1/18
25. Netherlands 8/2/18
26. Gabon 28/2/18
27. Togo 8/3/18
28. Ireland 12/3/18
29. Benin 19/3/18
30. Samoa 23/3/18
31. France 29/3/18
32. Barbados 19/4/18
33. Vanuatu 20/4/18
34. Niue 24/4/18
35. Bulgaria 1/5/2018
36. Costa Rica 23/5/18
37. Grenada 29/5/18
38. Belgium 4/6/2018
39. Uganda 21/6/18
40. Portugal 17/7/18
41. Lithuania 24/7/18
42. Burkina Faso 26/7/18
43. Latvia 17/8/18
44. Niger 29/8/18
45. Senegal 31/8/18
46. Uruguay 12/9/18
47. Hungary 14/9/18
48. Tonga 17/9/18
49. Mexico 25/9/18
50. European Union 27/9/18
51. Estonia 27/9/18
52. Czech Republic 27/9/18
53. Austria 27/9/18
54. Sri Lanka 28/9/18
55. Panama 28/9/18
56. Greece 5/10/18
57. Guinea-Bissau 22/10/18
58. Kiribati 26/10/18
59. Paraguay 1/11/18
60. Switzerland 9/11/18
2018 World Cup stadiums using potent climate pollutants

The FIFA World Cup 2018 is using HFCs to air condition all the stadiums.

A World Cup 2018 Stadium in Nizhny Novgorod, Russia.
Kigali Agreement

TELL WASHINGTON LAWMAKERS: RATIFY THE KIGALI AMENDMENT

America Must Lead!

The Kigali Amendment will create American jobs, boost our economy, and help American companies capture global market share.
EPA (40 CFR Part 82, Subpart F)

Under Section 608 of the Clean Air Act
EPA (40 CFR Part 82, Subpart F)

Under Section 608 of the Clean Air Act
EPA (40 CFR Part 82, Subpart F)

Under Section 608 of the Clean Air Act
Chain of Supply is Key
GHG Emission Impacts
Full Emissions Analysis

GGEA
Greenhouse Gas Emissions Analysis

REA
Refrigerants Emissions Analysis

GGLCA
Greenhouse Gas Lifecycle Assessment
Design Solutions
Solutions

- Set Aggressive Goals
- Reduce Loads
- Opt for Renewables
- Choose Efficient Systems
- Analyze the Climate
- Verify Performance

Low Refrigerant Charge
New Building Metric? **RUI** (refrigerant use intensity)

**Total Refrigerant Charge for Project**

- **VRF Refrigerant**
- **Minisplit Refrigerant**
- **ASHP + hydronic distribution**

**GOAL**
Seattle – VRF Impacts

- Embodied: 75%
- Refrigerant: 12%
- Operating (non heat/cool): 12%
- Operating (heat/cool): 3%
Hydronic Solutions
Future Buildings

Comfort without more than 2lbs? CO2e/SF total refrigerant charge. Comfort without high GWP refrigerant.
New Refrigerants

<table>
<thead>
<tr>
<th>Refrigerant Safety Groups</th>
<th>Higher Flammability</th>
<th>Lower Flammibility</th>
<th>Lower Burning Velocity</th>
<th>No Flame Propagation</th>
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<tr>
<td>Class 3</td>
<td>A3</td>
<td>B3</td>
<td>A2</td>
<td>B2</td>
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<tr>
<td>R-290 Propane</td>
<td></td>
<td></td>
<td>R-152a</td>
<td></td>
</tr>
<tr>
<td>Class 2</td>
<td></td>
<td></td>
<td>A2L</td>
<td>B2L</td>
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<tr>
<td>R-123</td>
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<td></td>
<td>R-32</td>
<td>R-717 Ammonia</td>
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<tr>
<td>Class 2L</td>
<td></td>
<td></td>
<td>A1</td>
<td></td>
</tr>
<tr>
<td>R-1234yf R-1234ze</td>
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<td>R-22 R-134a R-410A R-744 CO2</td>
<td>B2</td>
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<tr>
<td>Class 1</td>
<td></td>
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<td>B2</td>
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</tr>
<tr>
<td>R-22 R-134a R-410A R-744 CO2</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Lower Toxicity | Higher Toxicity

- Lower Burning Velocity Class 2L includes R-32, R-1234yf, and R-1234ze.
- No Flame Propagation Class 1 includes R-22, R-134a, R-410A, and R-744 CO2.
## Future

<table>
<thead>
<tr>
<th>Natural Refrigerants</th>
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<tbody>
<tr>
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<td></td>
<td>e.g. R-290 (Propane), R-600a (Isobutane), R-1270 (propene)</td>
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<tr>
<td></td>
<td>R-717</td>
</tr>
<tr>
<td></td>
<td>R-744</td>
</tr>
</tbody>
</table>
‘Natural’ Refrigerants

Potentials for Ammonia & CO2
Richard Branson just launched a $3 million prize for a better air conditioner

When people move out of poverty, one of the first things they buy is an air conditioner—and the world can't handle the emissions that are going to come from an air conditioning boom.
Innovation

REDEFINING COOLING

Our panels turn the sky into a renewable resource and reduce the electricity use of air conditioning and refrigeration systems.
Audience Questions
Allan Montpellier, PE, LEED AP
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David Mead, CPHC, AIA, LEED AP BD+C
Building Performance Specialist
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