Life Cycle Analysis Of Systems – Sampling Of Emerson Experience

Bachir Bella
Eric Winandy
Emerson – Global Player Offering Products Across Entire Refrigerants Landscape

<table>
<thead>
<tr>
<th>Markets</th>
<th>Refrigerants</th>
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</thead>
<tbody>
<tr>
<td>Industrial</td>
<td>NH₃, R134a, R404A/507, R290</td>
</tr>
<tr>
<td>Transport</td>
<td>R134a, R404A</td>
</tr>
<tr>
<td>Food Retail</td>
<td>R404A/507, R407A, R134a, CO₂</td>
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<tr>
<td>Food Service</td>
<td>R404A/507, R407A, R134a, R290</td>
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<tr>
<td>A/C Commercial</td>
<td>R410A, R407C</td>
</tr>
<tr>
<td>Comfort</td>
<td>R410A, R407C</td>
</tr>
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</table>
Refrigerants Should Be Evaluated On Life Cycle Climate Performance

LCCP (Life Cycle Climate Performance) = Direct Global Warming + Indirect Global Warming

- Refrigerant Leakage
  - Leak during life
  - End of life recovery leak
  - Leak during production
- Energy Consumption
  - Energy used during life
  - Source of energy
  - Embodied energy of all material used for manufacturing of fluid

We Communicate This As Often As We Can!

Energy Consumption (Annual And Peak) Could Be 90% Or More Of Environmental Impact Of A HVAC&R System
Energy Consumption Plays Major Role In Life Cycle Climate Impact

Life Cycle Performance: Typical Low Charge/Leak HFC Systems (AC And Refrigeration)

- 2 - 5% Direct Warming Impact (Refrigerant Leakage)
- 95 - 98% Indirect Warming Impact (Energy Consumption)

For Hermetic Systems, Global Warming Is An Efficiency Issue* (Therefore, Future Refrigerants Must Be Equal Or Higher Efficiency)

* Simple US Based Analysis To Show Relative Impact Only; Not Field Data

Life Cycle Performance: Typical Large And/Or High Leak HFC Systems (Refrigeration)

- 60% Direct Warming Impact (Refrigerant Leakage)
- 40% Indirect Warming Impact (Energy Consumption)

Example Analysis For A 3000 lb, R404A System With 20% Annual Leak, Medium & Low Temperature*

1. Reduce Refrigerant Leak To 10% Per Year*
   - Eliminate 30% Of Global Warming Impact
   - Reduce Direct Impact By 92%

2. Reduce Refrigerant Leak To 10% Per Year & Reduce Refrigerant GWP By 50%*
   - Eliminate 55% Of Global Warming Impact

3. Reduce Refrigerant Leak To 10% Per Year, Refrigerant GWP By 50%, And Reduce Charge By 65%*
   - Eliminate 65% Of Global Warming Impact
   - Reduce Direct Impact By 92%

For Large Systems, Global Warming Becomes An Efficiency Issue If Charge/Leaks Are Reduced (Therefore, Future Refrigerants Must Be Equal Or Higher Efficiency)

* Simple US Based Analysis To Show Relative Impact Only; Not Field Data

Refrigerant And System Architecture Choice Is Not A One-Dimensional Problem!
# System Architecture Drives LCCP in Commercial Refrigeration

<table>
<thead>
<tr>
<th>System Technology</th>
<th>Centralized DX</th>
<th>DX Distributed</th>
<th>Cascade</th>
<th>Secondary</th>
<th>CO₂ Booster</th>
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<thead>
<tr>
<th>Case #</th>
<th>1 = Base</th>
<th>2</th>
<th>3</th>
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<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<th>11</th>
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<tbody>
<tr>
<td>LT</td>
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<td>R404A</td>
<td>R407 A/F</td>
<td>R404 A</td>
<td>R407 A/F</td>
<td>CO₂</td>
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</table>

**Refrigerant:**

- LT
  - R404A
  - R407 A/F
  - R404 A
  - R407 A/F
  - CO₂
  - CO₂
  - CO₂

- MT
  - R404A
  - R134a
  - R407 A/F
  - R404 A
  - R407 A/F
  - R134a
  - R410A Chiller
  - R290 Chiller
  - HFO Chiller
  - CO₂

**Compressor Technology**

- LT
  - Scroll EVI
  - Semi ¹
  - Semi ²
  - Scroll EVI
  - Scroll EVI
  - Scroll
  - Scroll
  - Scroll
  - Scroll
  - Scroll or Semi

- MT
  - Scroll
  - Semi ¹
  - Semi ²
  - Scroll
  - Scroll
  - Scroll
  - Scroll
  - Scroll
  - Semi

![System Architecture Diagrams](image-url)
Refrigeration Systems Comparison In Cool Climate

25°C Avg. Condensing

Indirect Emissions for EU represent more than 50% of the total emissions.

(Tons-CO₂/10-years)

1. R404A Scroll (Base)
2. R404A Recip.
3. R404A/R134a Recip.
4. R407A/F Scroll
5. R404A Scroll
6. R407A/F Scroll
7. R744/R404A Scroll
8. R744/R407A/F Scroll
10. R744/R134a Scroll
11. R744/R410A Scroll
12. R744/R290 Scroll
13. R744/HFO Scroll

Indirect Emissions (Energy Consumption) Direct Emissions (Refrigerant Leakage)

Sample Supermarket Analysis In North EU

Refrigeration Systems

Comparison In Cool Climate

Indirect Emissions for EU represent more than 50% of the total emissions.
1. System Architecture Can Reduce CO₂ Emissions By ~50%
2. Cascade CO₂/DX System Is Annual Energy Neutral
3. Distributed System Shows Least Annual Energy Consumption
## Air Conditioning LCCP Analysis

1. Direct Contribution is ~5% for R410A; Energy Plays Major Role
2. For R32, Direct Is Less Than 1.5% of Total; Diminishing Returns

### LCCP Analysis

<table>
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<tr>
<th></th>
<th>R410</th>
<th>HFO#3</th>
<th>R32</th>
<th>HFO#1</th>
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<tr>
<td><strong>LCCP</strong></td>
<td>100.0%</td>
<td>97.1%</td>
<td>96.3%</td>
<td>95.6%</td>
<td>97.1%</td>
<td>100.1%</td>
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### Bar Chart

- **3-ton H/P**
- **13.0 SEER / 7.7 HSPF**
- **kg CO2**
- **15 Year Life**
- **4% Annual Leak Rate**
- **30% End Of Life Loss**
- **0.65 kg CO2/kWh**

Copeland®

Climate Technologies

1. Direct Contribution is ~5% for R410A; Energy Plays Major Role
2. For R32, Direct is Less Than 1.5% of Total; Diminishing Returns Pursuing GWP
NA Proposal To Phase-Down High GWP Refrigerant Gases – Driving Global Interest In Alternatives

Latest Proposal For Global Phase-down Of “HFC’s GWP” – Applies To All Sectors Including Mobile, Foam And Stationary Applications
Need To Take A Holistic Approach To Lower GWP Refrigerant Selection

Integrated Analysis Leading To The Selection Of The Best Refrigerant
Need To Sustain Efficiency – US Example

Residential AC

North
- 13 SEER 14 SEER
- 8.2 HSPF

South
- 14 SEER
- 8.2 HSPF

Southwest
- 12.2 / 11.7 EER
- <45K / >45K
- 14 SEER
- 8.2 HSPF

Commercial AC

Voluntary Standards Driving Increased Efficiency

<table>
<thead>
<tr>
<th>Application</th>
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<td>Refrigeration</td>
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Efficiency Standards Continue To Improve – Will Be A Challenge When Designing New Equipment And Refrigerant Choice Constrained By GWP Alone
Summary

  - Does Not Account For Climate Effect Of Refrigerant Production; Sometimes Exclude End Of Life Impact
- Concerns About Global Warming Drives Interest In Controls On Use Of HFCs And Lower GWP Alternatives
- Lower GWP Does Not Always Translate To Lower Energy Consumption
  - Annual And Peak Load Energy Consumption Are Both Important
- Leak Considerations Lead To System Architecture Decisions Which Impact Energy Consumption As Well
- A Common Method Of Calculating LCCP Will Be Of Value For Communicating These Ideas
  - Order Of Magnitude Analysis To Determine If All The Terms Of LCCP Are Relevant For All Applications