Practical chiller refrigerant choices to optimize your bottom line

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Topics

1. Framework for decision making: regulatory, codes and standards changes at a glance
2. Available refrigerant options
3. Economic and environmental trade-offs between choices
4. Implications of refrigerant choice

Refrigerant Regulations: What has happened?

- **Regulating Ozone Depletion Refrigerants**
  - Montreal Protocol
    - Phase Out HCFC in New Equipment after Dec. 31, 2019 (Dec. 31, 2029 for developing nations)
    - Phase Out HCFC Production after Dec. 31, 2029 (Dec. 31, 2039 for developing nations)

- **Regulating Efficiency and High GWP Refrigerants in Europe**
  - Eco-Design drives for higher energy standards, and responsible use of refrigerants with greater reporting and tracking of usage and leaks
  - F-Gas European Regulation -79% by 2030 (2015 baseline)

- **Enabling the Use of Flammable Refrigerants**
  - Many countries allow for very limited quantities of flammable refrigerants in residential or small-charge systems

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Refrigerant Regulations: What is being considered?

- **Potential Regulations on Ozone Depletion Refrigerants**
  - High Ambient Applications
    - Montreal Protocol considering potential extension of R-22 use for high ambient applications due to insufficient low-GWP alternatives

- **Potential Regulations on High GWP Refrigerants**
  - US EPA SNAP Proposal – 2024?
  - US EPA Canada Proposal – 2025?

- **Potential Regulations for the Use of Flammable Refrigerants**
  - European (EN-378) standard – 2016-2017?
    - Defines safety and environmental requirements for use of refrigerants with updates to address new A2L flammable refrigerants
    - Differentiates between direct and indirect systems

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What are the refrigerant options?

Natural Refrigerants	CFC and HCFC	HFC	HFO and HFO Blends
▪ Biggest Concern: Application Capabilities	▪ Biggest Concern: Ozone Depletion Potential	▪ Biggest Concern: GWP	▪ Biggest Concern: low efficiency leads to high emissions
▪ Flammability, toxicity, technical design complications	▪ CFCs phased out ▪ HCFC phase-out underway	▪ Refrigerant technology of choice used worldwide	▪ Cost and availability questions ▪ Some are flammable
▪ Examples: Propane, ammonia, CO2	▪ Examples: R-11, R-12, R-123, R-22	▪ Examples: R-134a, R-32, R-410A	▪ Examples: R-1234ze, R-513A

* *Examples are representative list and not comprehensive list of options for each category*

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What are the refrigerant options?

Low pressure (centrifugal chillers)	**Medium pressure** (centrifugal & screw chillers)	**High pressure** (scroll chillers)
▪ Biggest Concerns: long-term stability & larger components	▪ Biggest Concerns: performance & cost	▪ Biggest Concern: flammability
▪ R-123 alternative pressures are too high, or lose capacity ▪ Non-flammable options ▪ Lower and higher toxicity options	▪ Most widely used refrigerant for screw & centrifugal chillers ▪ Non-flammable and flammable options exist	▪ Cost and availability questions ▪ All are flammable
▪ Examples: R-1233zd, R-1336mzz, R-514A	▪ Examples: R-134a, R-513A, R-1234ze	▪ Examples: R-32, DR-5a

* *Examples are representative list and not comprehensive list of options for each category*

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How do I choose between the refrigerant options?

Picking a chiller based on refrigerant alone can result in unintended consequences for the owner and the environment

- Safety code compliance
- Operator training
- Insurance cost
- Reliability
- Legal risk
- Stability

- Efficiency
- Capacity
- Low GWP

- Availability
- Cost of ownership
- Customer preference
- Intellectual property
- Regulatory certainty
- Other industry uses

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What about using flammable refrigerants?

Need to protect your best interests

- Supporters of the newer low-GWP refrigerants that have flammability are promoting use before our commercial customers are ready…

1. Equipment safety standards are being revised.....But the are not complete!
2. Building codes need to adopt new standards.....But they are not written yet!
3. Technicians need to be trained .....But A2L specific training doesn't exist!

Critical Items:
- Safety standards
- Building codes
- Technician training

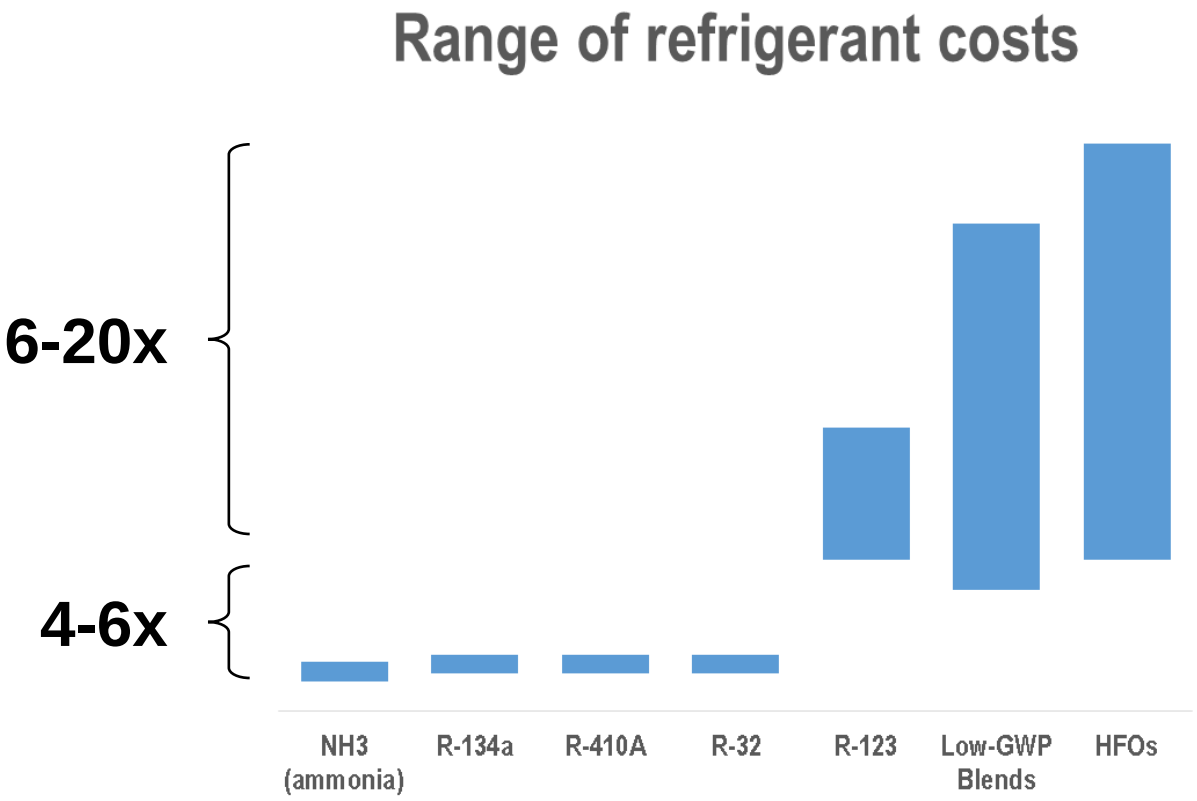
will pace the use of flammable refrigerants in commercial applications

I have facilities where we deal with flammable materials and I am accustomed to the higher level of safety precautions.

So what's my best choice?

How does the current cost of low-GWP refrigerants compare with HFCs?

Expensive, about 4-6x HFC costs



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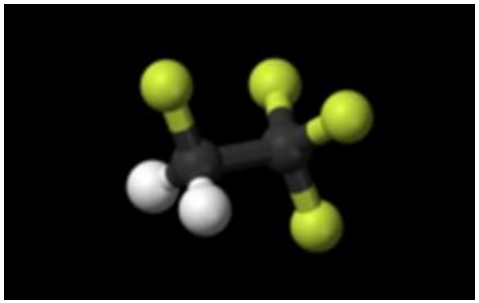
Will the cost of low GWP refrigerants come down?

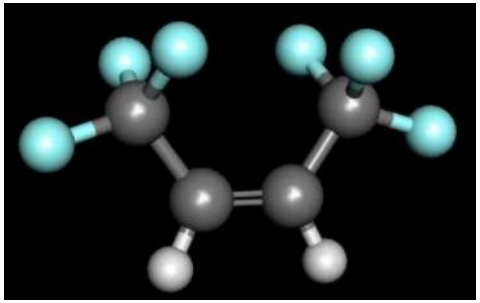
Yes, except…not to the level of today's refrigerants

- Low-GWP refrigerants are described by the refrigerant manufacturers as more complex and larger molecules…
  1. Larger molecules = more material **= higher cost**
  2. More complex = more complex production and more steps **= higher cost**



R-134a

- On average refrigerant costs will rise due to a refrigerant transition if HFC availability is restricted and the market is forced to fundamentally higher cost alternatives



HFO example

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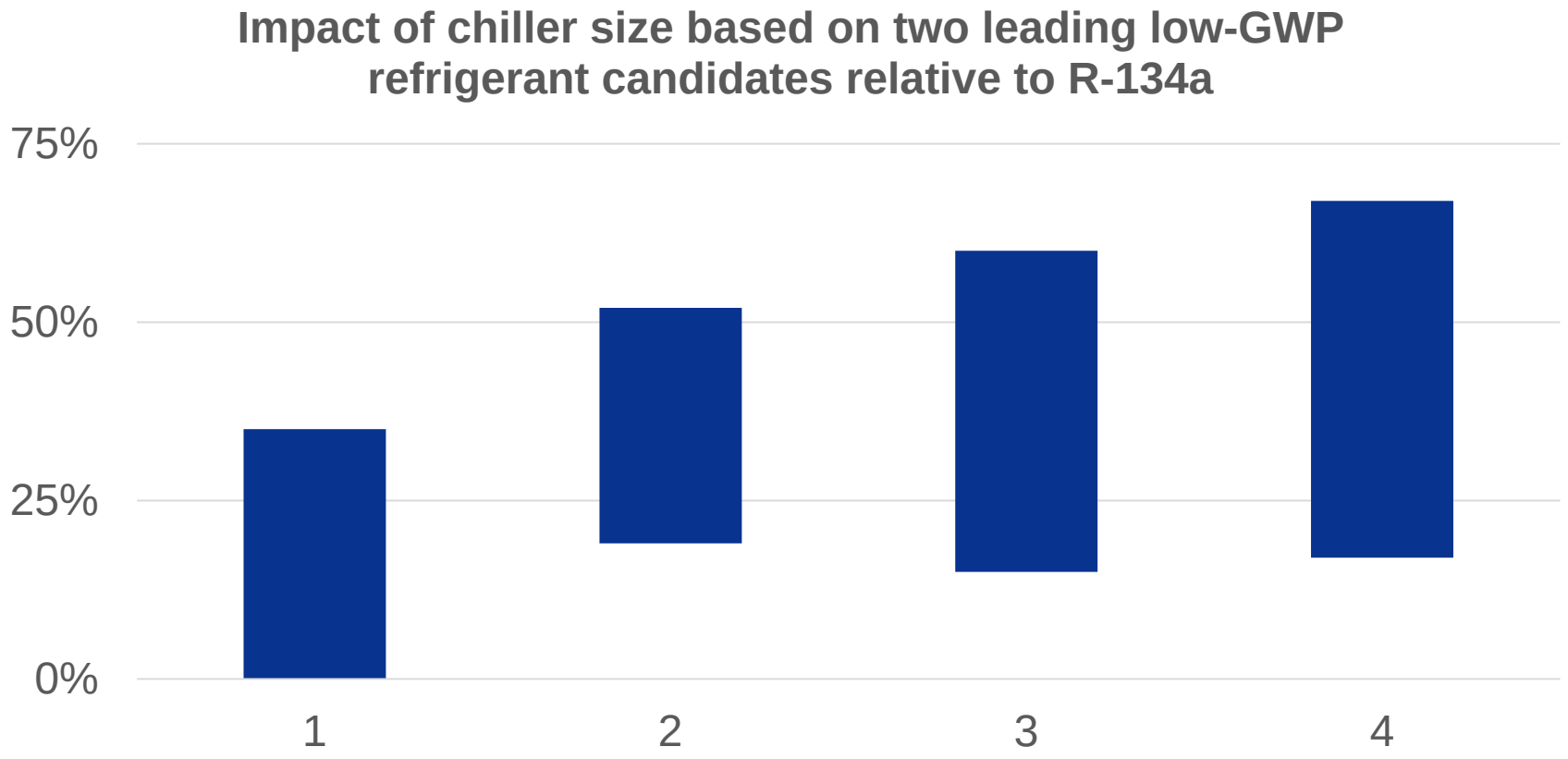
How does refrigerant choice impact the cost of the equipment?

Refrigerant choice can drive component size to off-set less desirable refrigerant properties



NOTE: ***equipment configurations are for the same customer specified performance (capacity and efficiency)***

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How does refrigerant choice impact my operating costs?

A refrigerant choice based on GWP has many hidden costs to the owner

Energy

- As a “drop-in” most refrigerants yield lower performance vs. HFC…less efficient means higher energy costs
- Energy can be offset by buying more expensive (higher efficiency) equipment…but HFC would show the same benefits

Safety Precautions

- Many alternatives are flammable and require special handling and training, less common in commercial applications

Higher Expenses

- Maintenance cost increases to address any leakage and recharge of equipment
- Insurance costs due to higher risk using flammable refrigerants
- Operator training and expenses to handle flammable refrigerants

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I am willing to pay a premium to improve my carbon footprint and reduce greenhouse gas emissions.

So what's my best choice?

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Greenhouse gas emissions or carbon footprint can be measured through equipment life-cycle climate performance

Energy consumption driven by burning of fossil fuels (indirect impact)

+

Leakage of refrigerant over the life of the equipment (direct impact)

=

TOTAL equivalent greenhouse gas emissions

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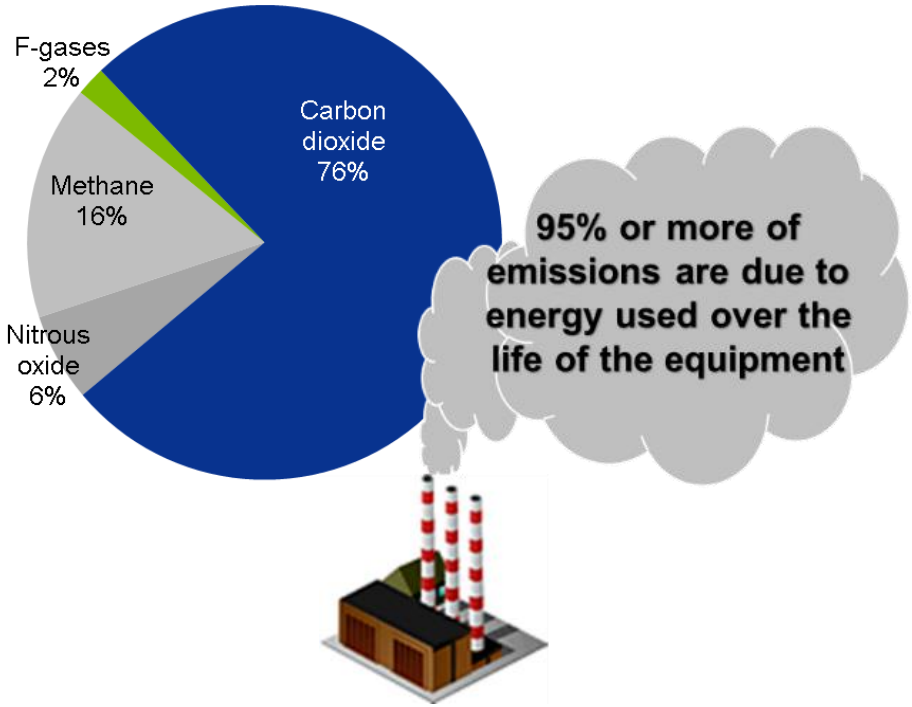
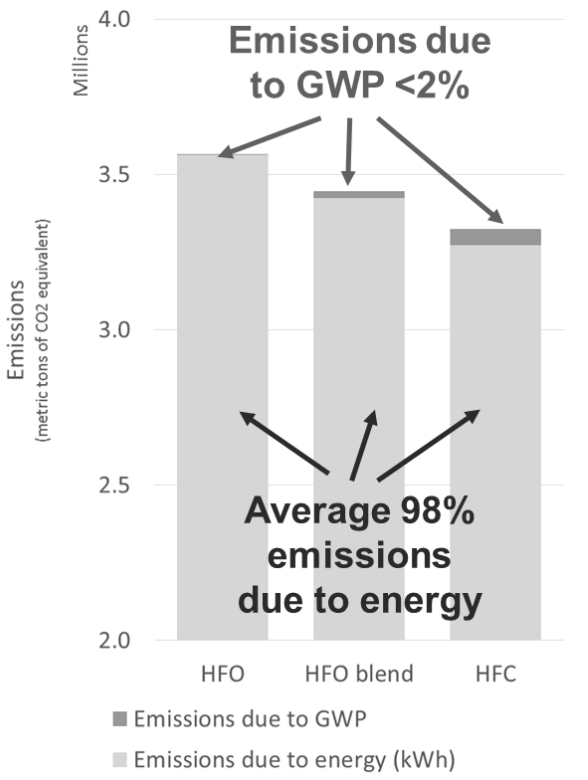
What has the greatest impact on the environment? Refrigerant GWP or Emissions?

- Most electricity consumed by the chiller is produced by burning fossil fuels

Global greenhouse gas emissions
(Source: US EPA)





1% improvement on chiller efficiency = 63% refrigerant GWP reduction vs. R-134a

1.6% improvement on chiller efficiency = Off-sets R-134a direct emissions completely

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Alternatives come at a significant premium and do not provide the same benefits

Refrigerant	Selection Criteria				
	Availability	**Environment**	**Efficiency**	**Flammability**	**Cost**
HFC*	Readily available throughout the world in local distribution networks	Lower energy consumption results in lowest net CO2 emissions	Highest efficiency	Non-flammable (A1)	Lowest refrigerant cost and lowest cost to operate
HFC/HFO Blend	Availability is an operating risk. Limited capacity & distribution but expanding	Low-GWP	Neutral to 5% lower efficiency	Non-flammable (A1)	• Refrigerant 5X or higher than base HFC • Product cost ***15-25% higher***
HFO	Availability is an operating risk. Limited capacity & distribution but expanding	Single-digit GWP	Neutral to approx. 10% less efficient	Flammable (A2L)	• Refrigerant 5X or higher than base HFC • Product cost ***20-50% higher***

* *Analysis assumes R-134a for a baseline due to its market significance in usage and acceptance.*

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I am willing to pay a premium for low-GWP at the same performance.

So what's my best choice?

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A premium is best invested in improving the chiller and/or building system performance

Refrigerant	Chiller Price Premium					
	0%	1-15%	15-25%	25-40%	40-50%	50%+
HFC	Base Unit	Invest in higher chiller & system performance				
HFC/HFO blend	Not available		Base unit performance	Invest in higher chiller & system performance		
HFO	Not available			Select models **may** meet base chiller performance	Base unit chiller performance	Invest in higher chiller & system performance

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Consider the bigger picture