

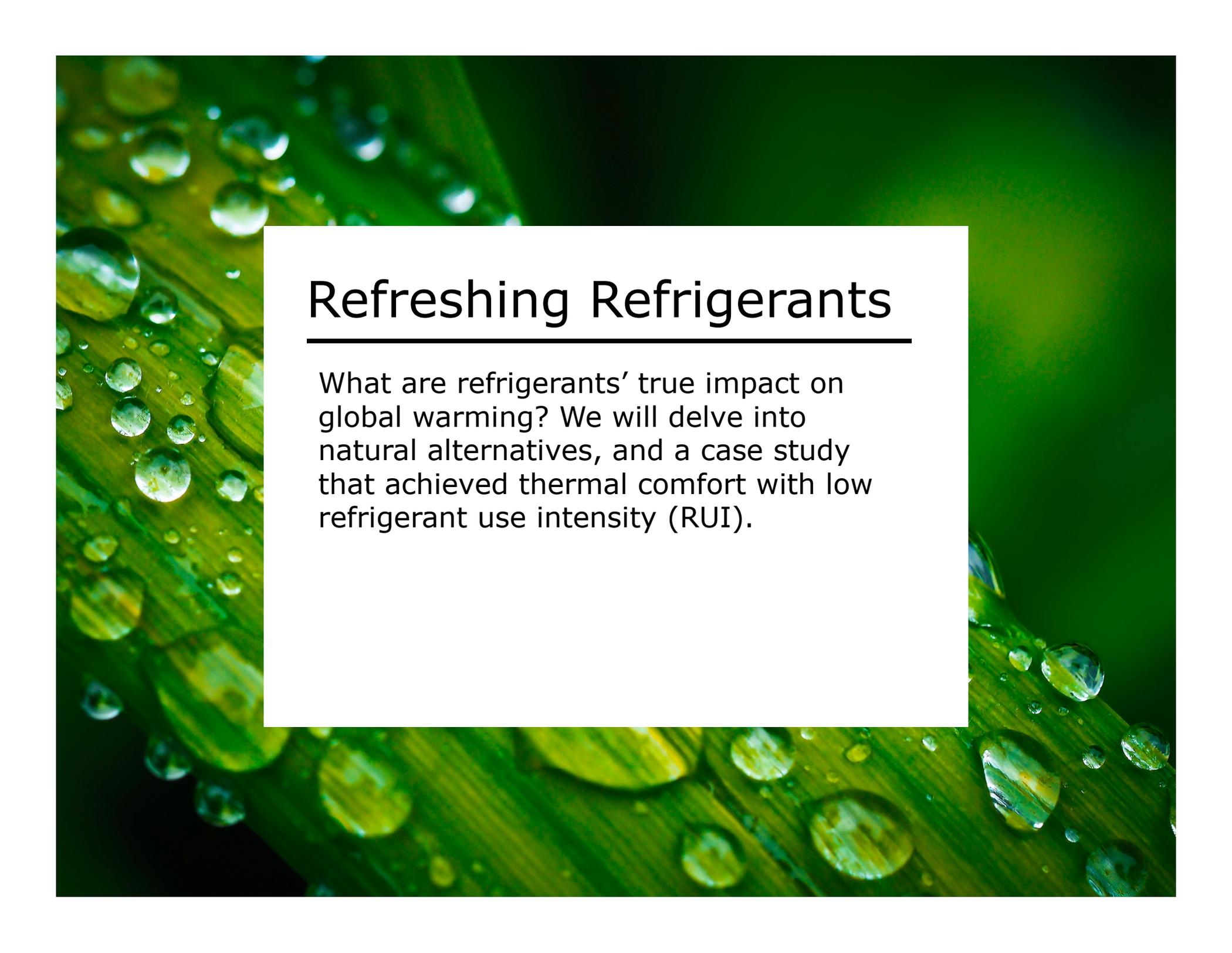


Refreshing Refrigerants

Understanding and Transforming Refrigerants

December 11, 2018

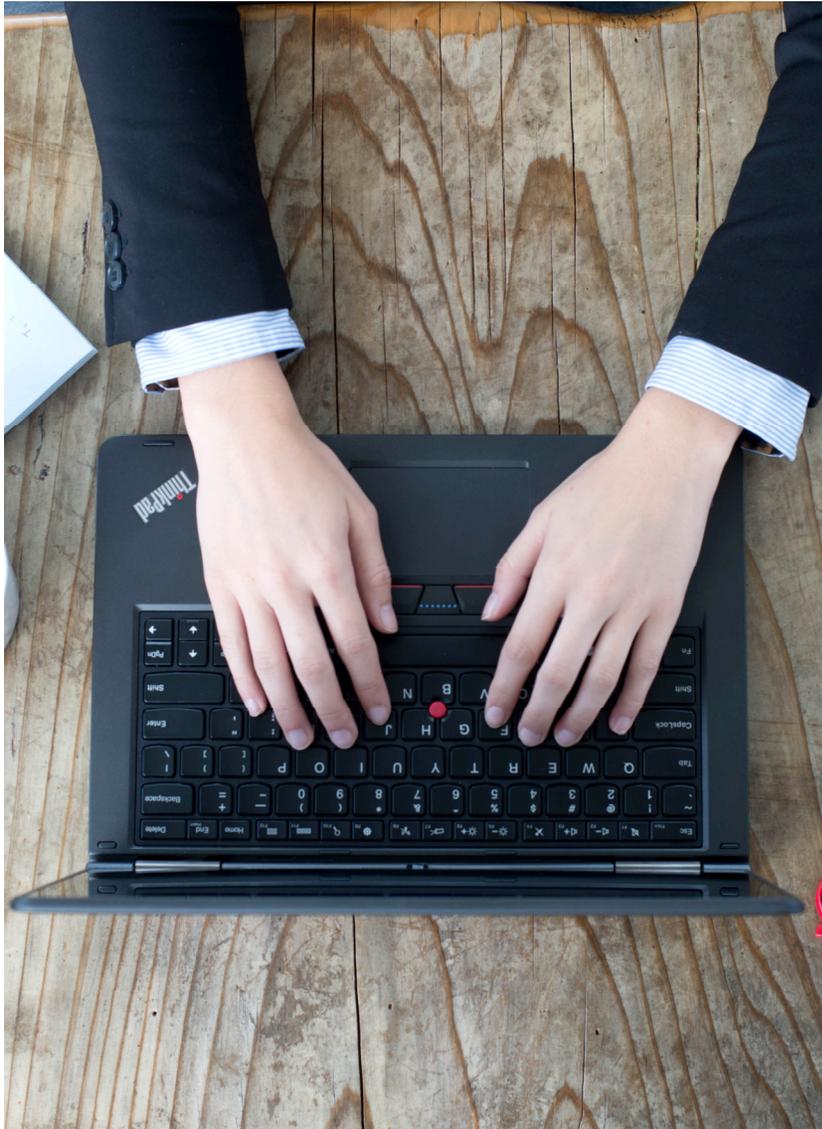




Refreshing Refrigerants

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).

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**

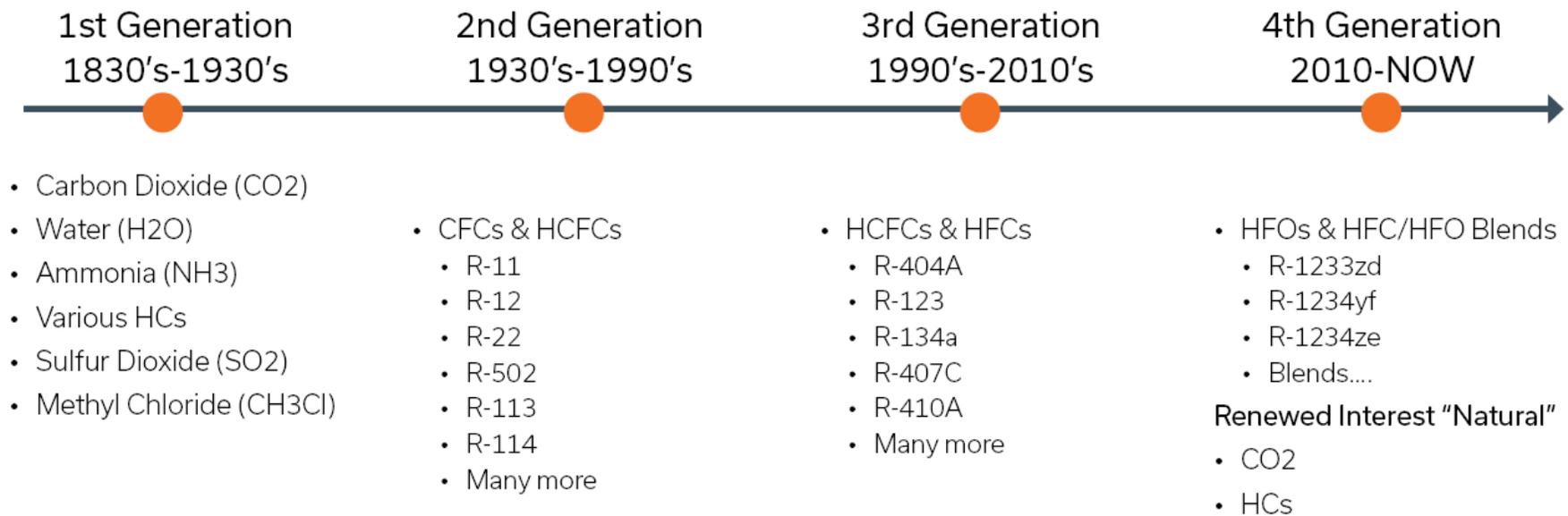
A substance used for refrigeration.

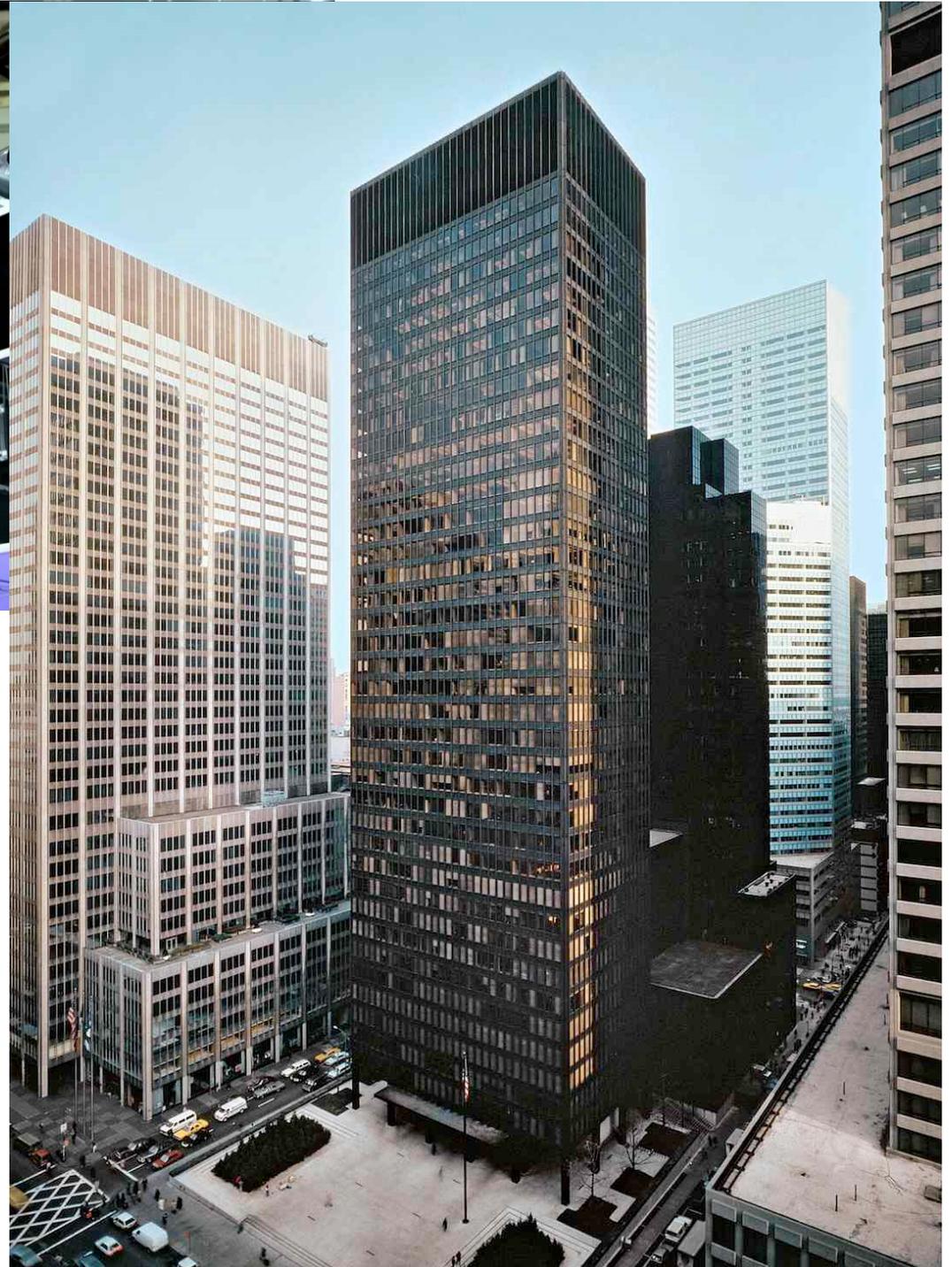
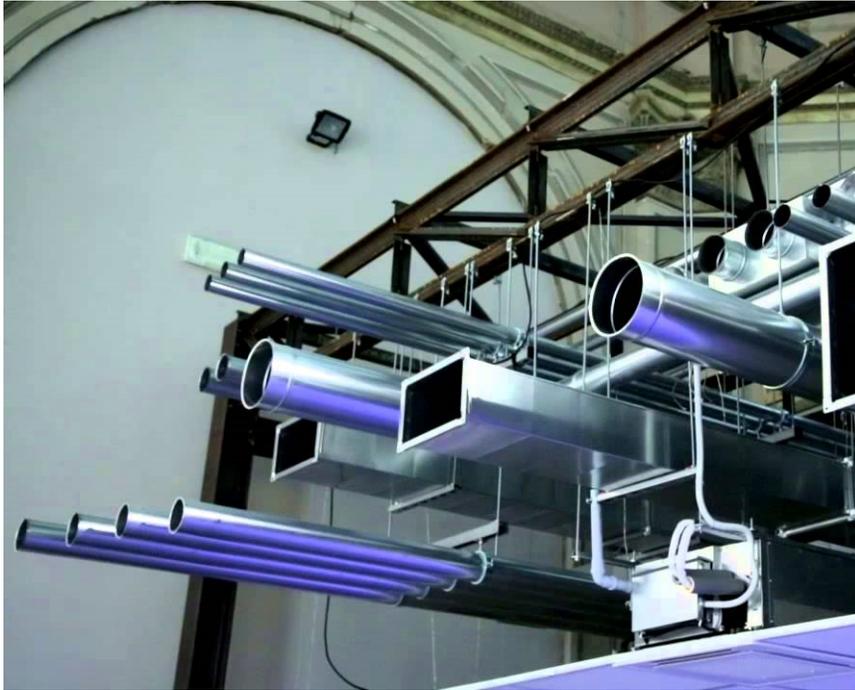
Refrigerants are **also** hazardous chemicals that can be toxic and flammable.



History

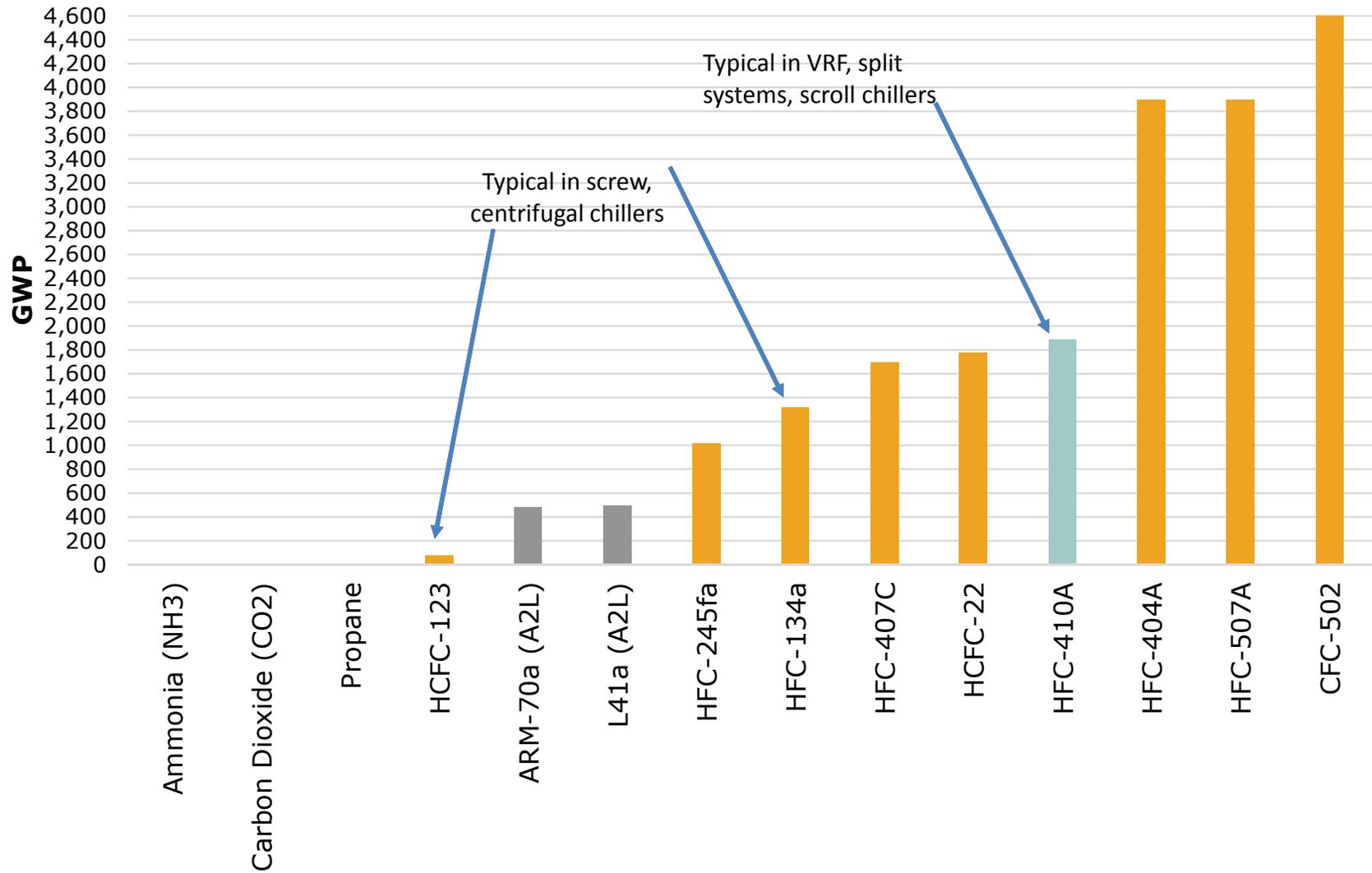
History of HVAC/R Refrigerants





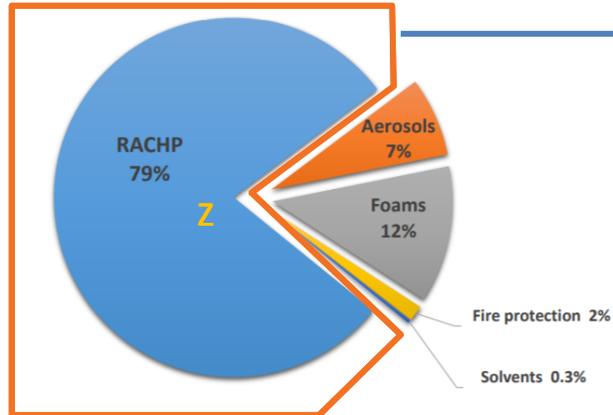
GWP

Global Warming Potential of Refrigerants



HFC Consumption

Figure 3 Markets using HFCs, % of total metric tonnes, 2012



Main RACHP Refrigerants

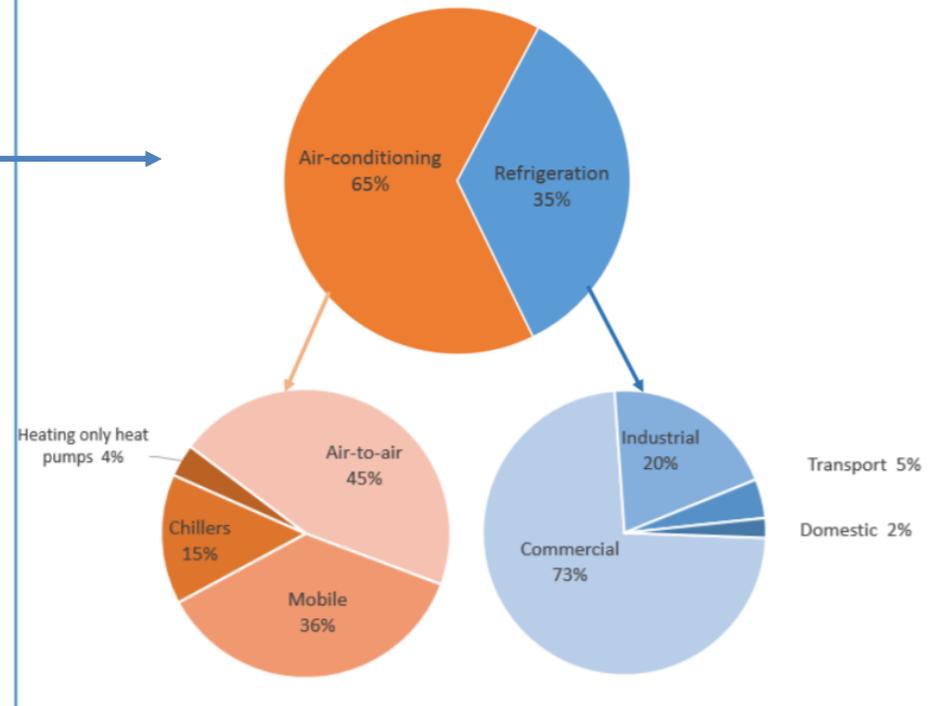
R-404A → GWP = 3922

R-410A → GWP = 2088

R-407C → GWP = 1774

HFC-134a → GWP = 1430

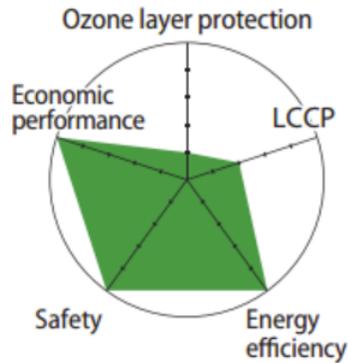
Figure 5: HFC use in RACHP sectors (GWP-weighted), 2012



Refrigerant Impacts

Refrigerants currently used in developing countries

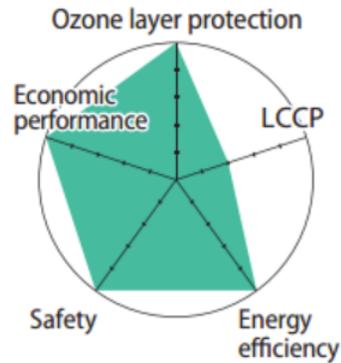
R22
(HCFC)



Global warming potential (GWP) 1,810

Refrigerants currently used in industrialized countries

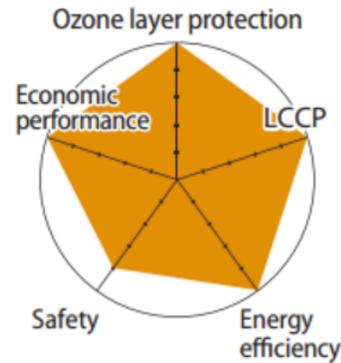
R410A
(HFC)



2,090

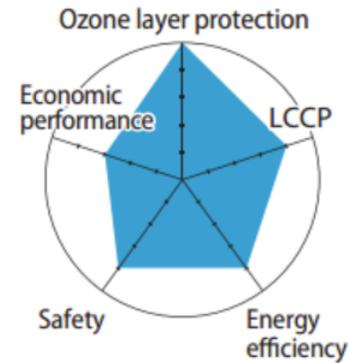
Next-generation refrigerants

R32
(HFC)



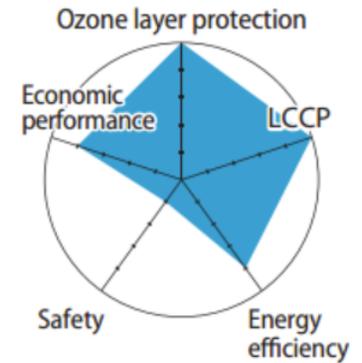
675

R1234yf
(HFO)



4

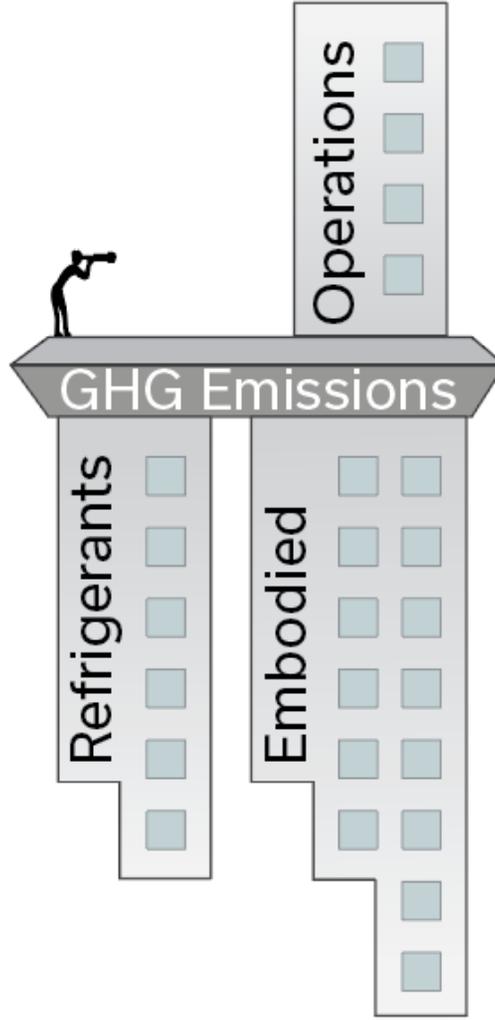
R290
(Propane)

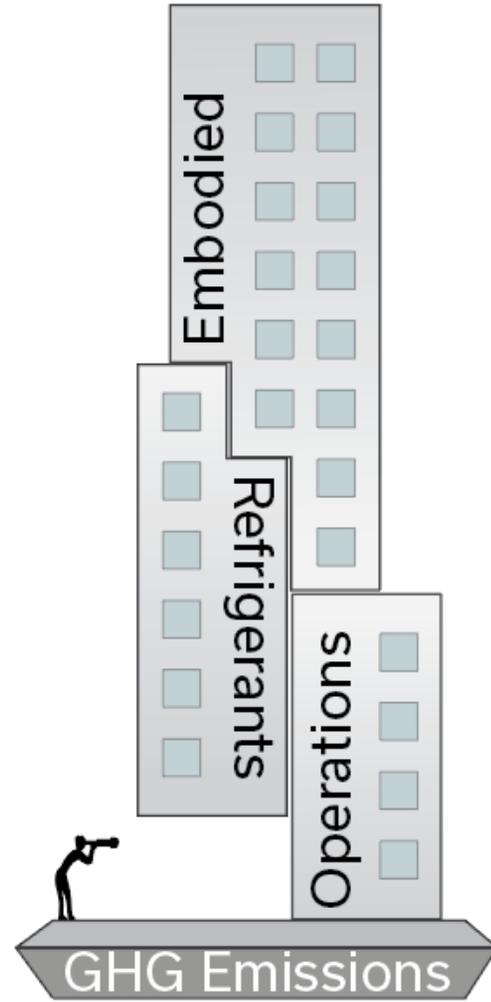


3.3



Refrigerants Matter





Holistic Emissions Analysis

Operations

Refrigerants

Embodied

NEW YORK TIMES BESTSELLER

DRAWDOWN

THE MOST COMPREHENSIVE
PLAN EVER PROPOSED TO
REVERSE GLOBAL WARMING
EDITED BY PAUL HAWKEN

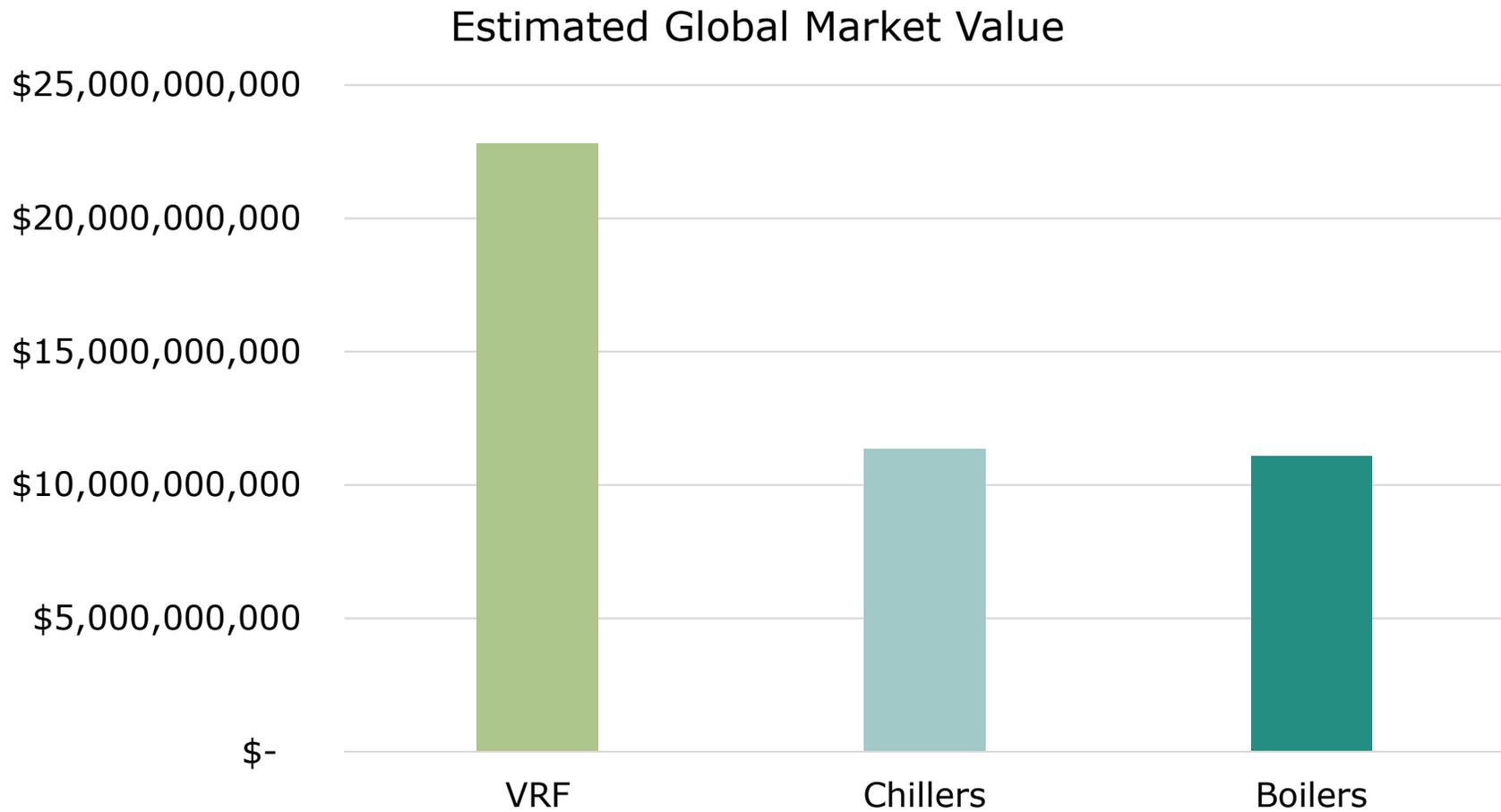


IMPACT!

Rank	Solution	Sector	TOTAL ATMOSPHERIC CO2-EQ REDUCTION (GT)	NET COST (BILLIONS US \$)	SAVINGS (BILLIONS US \$)
1	Refrigerant Management	Materials	89.74	N/A	\$-902.77
2	Wind Turbines (Onshore)	Electricity Generation	84.60	\$1,225.37	\$7,425.00
3	Reduced Food Waste	Food	70.53	N/A	N/A
4	Plant-Rich Diet	Food	66.11	N/A	N/A
5	Tropical Forests	Land Use	61.23	N/A	N/A
6	Educating Girls	Women and Girls	59.60	N/A	N/A
7	Family Planning	Women and Girls	59.60	N/A	N/A
8	Solar Farms	Electricity Generation	36.90	\$-80.60	\$5,023.84
9	Silvopasture	Food	31.19	\$41.59	\$699.37
10	Rooftop Solar	Electricity Generation	24.60	\$453.14	\$3,457.63
11	Regenerative Agriculture	Food	23.15	\$57.22	\$1,928.10
12	Temperate Forests	Land Use	22.61	N/A	N/A
13	Peatlands	Land Use	21.57	N/A	N/A
14	Tropical Staple Trees	Food	20.19	\$120.07	\$626.97
15	Afforestation	Land Use	18.06	\$29.44	\$392.33



Refrigerant Management





The Rail Spur Today





The Rail Spur Tomorrow





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

Life Cycle Cost

First Cost

Water Efficiency

Maintenance

Aesthetics

Tenant
Flexibility

Energy Cost

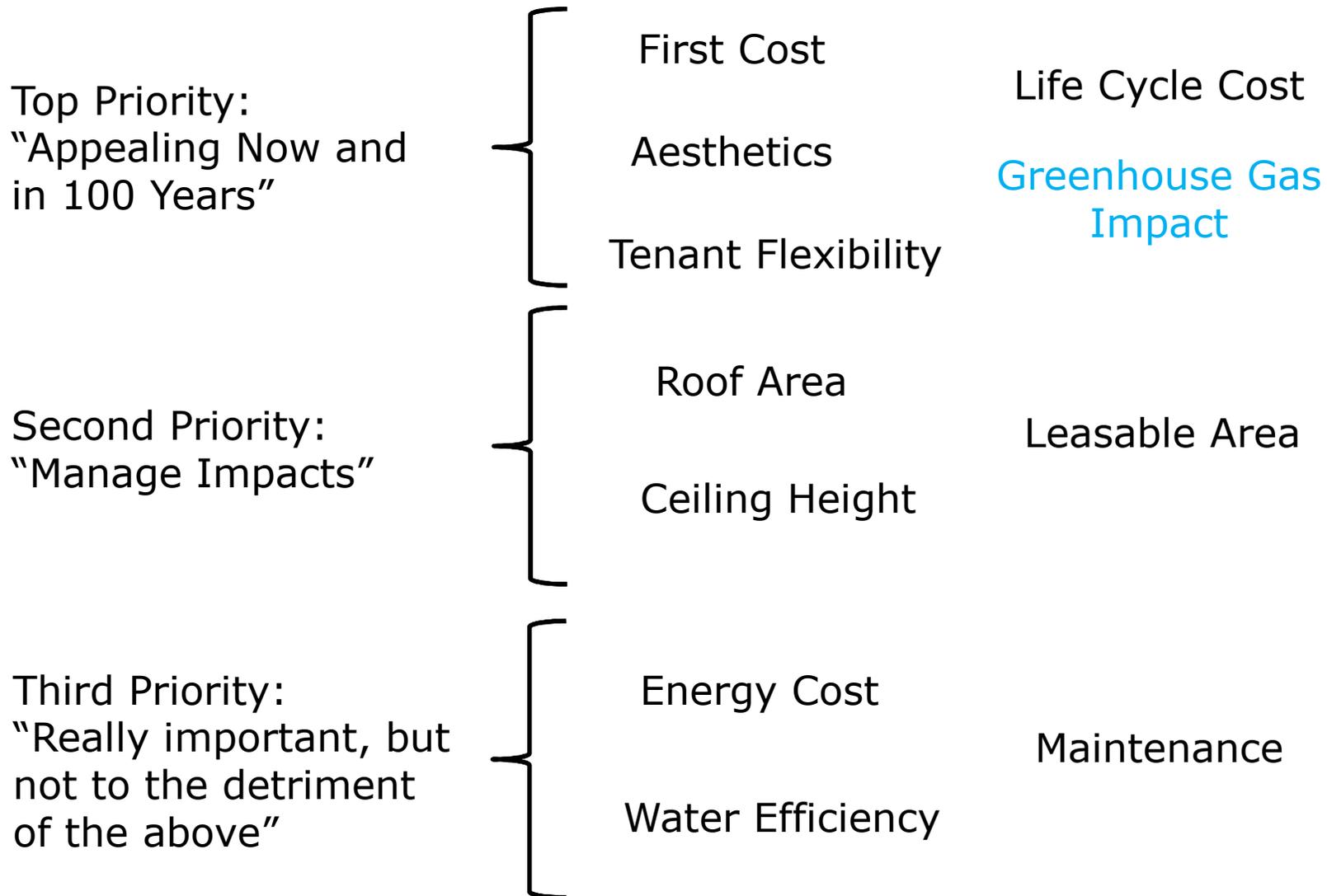
Roof Area

Greenhouse Gas
Impact

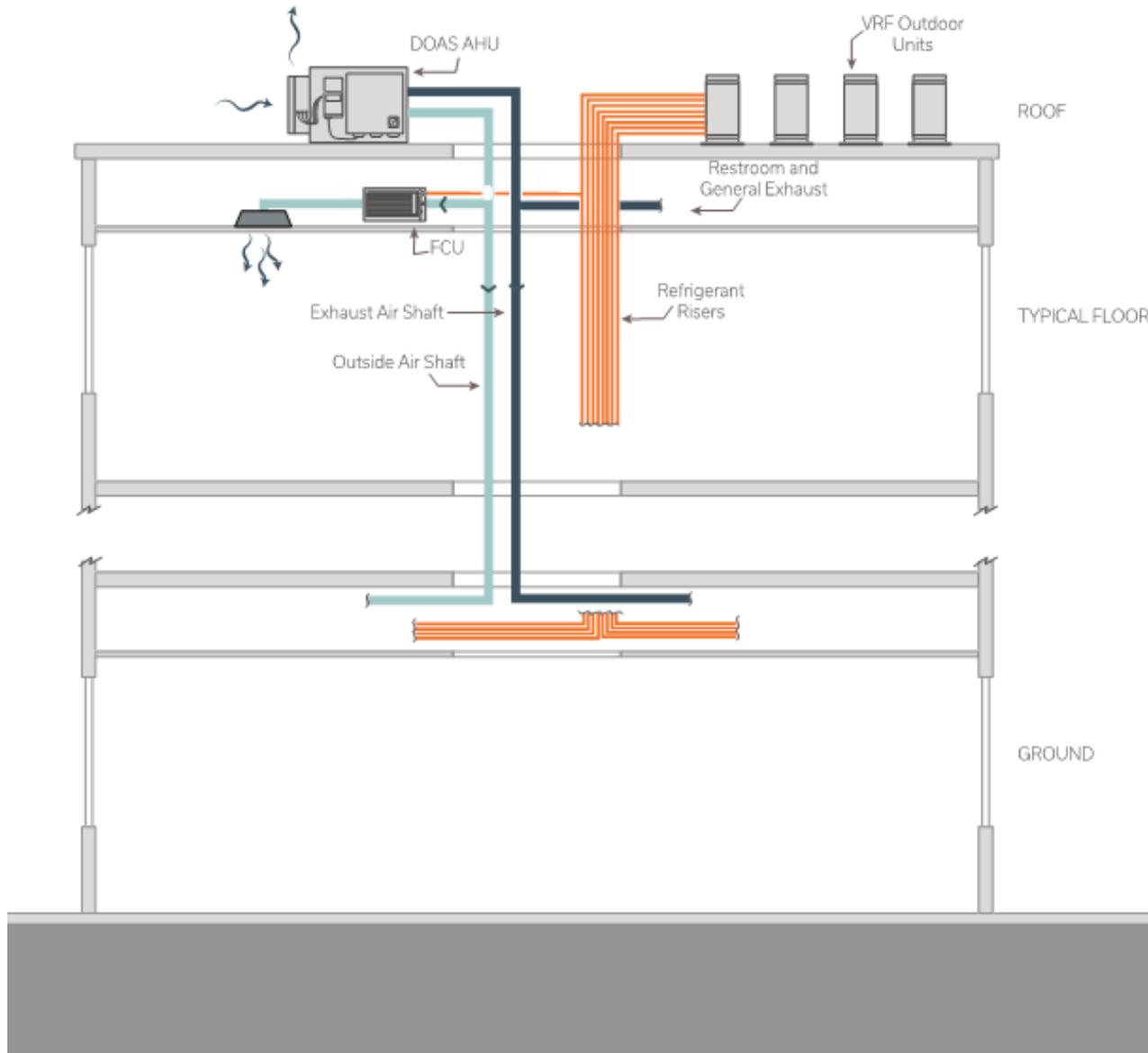
Leasable Area

Acoustics

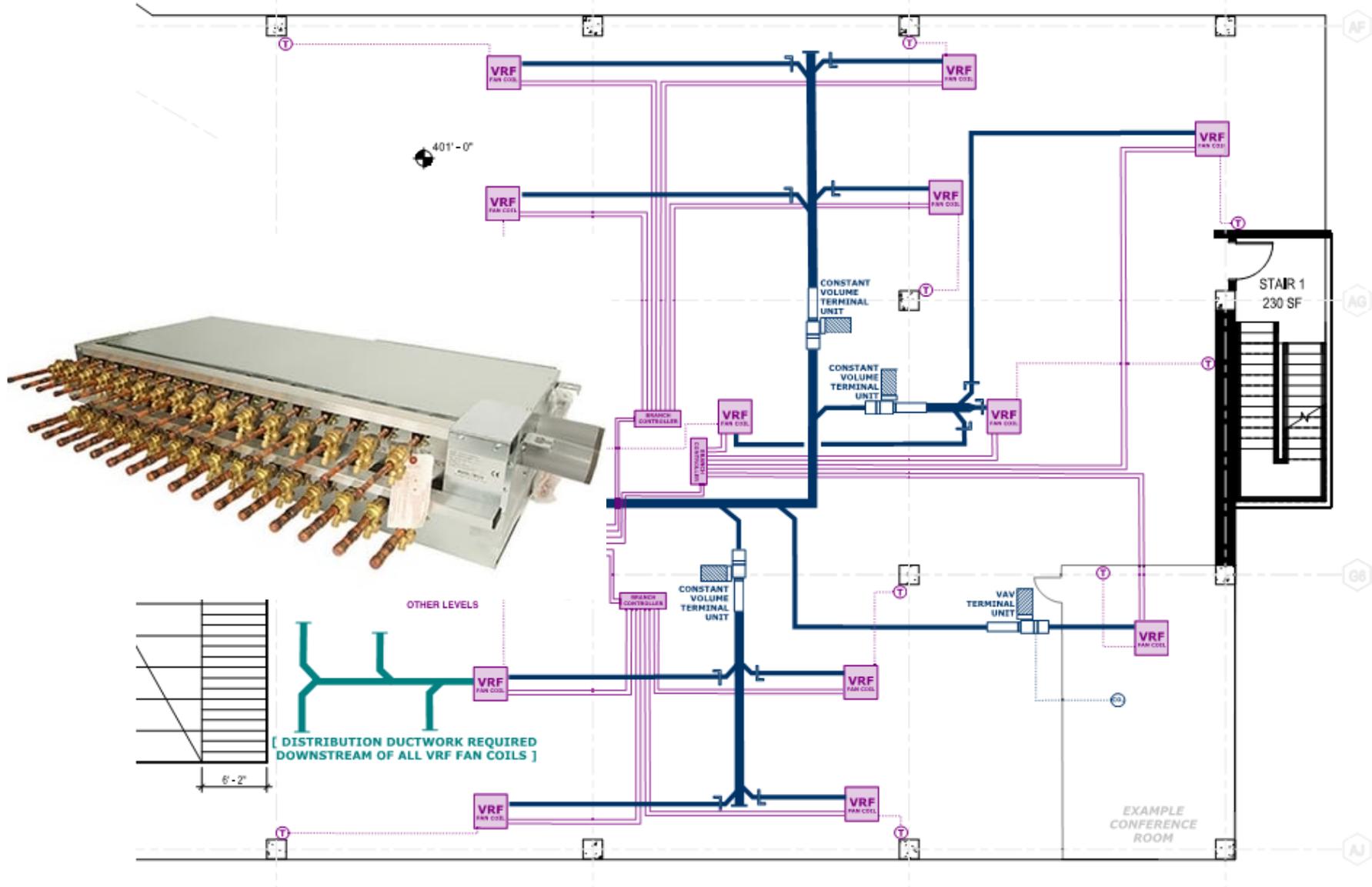
Selecting the Mechanical System



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



+



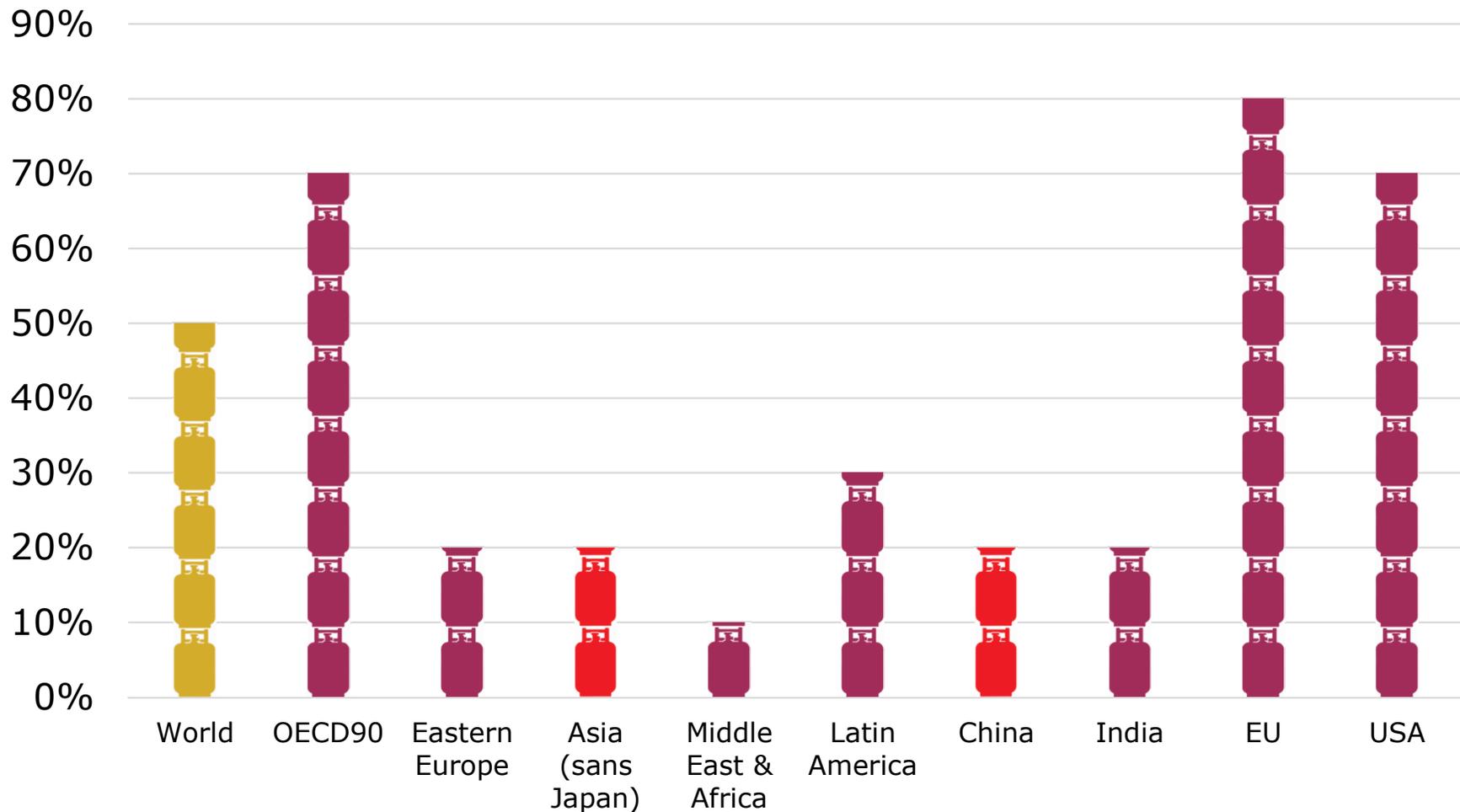
**Friendly
Refrigerants**



Leakage Issues & Refrigerant Management

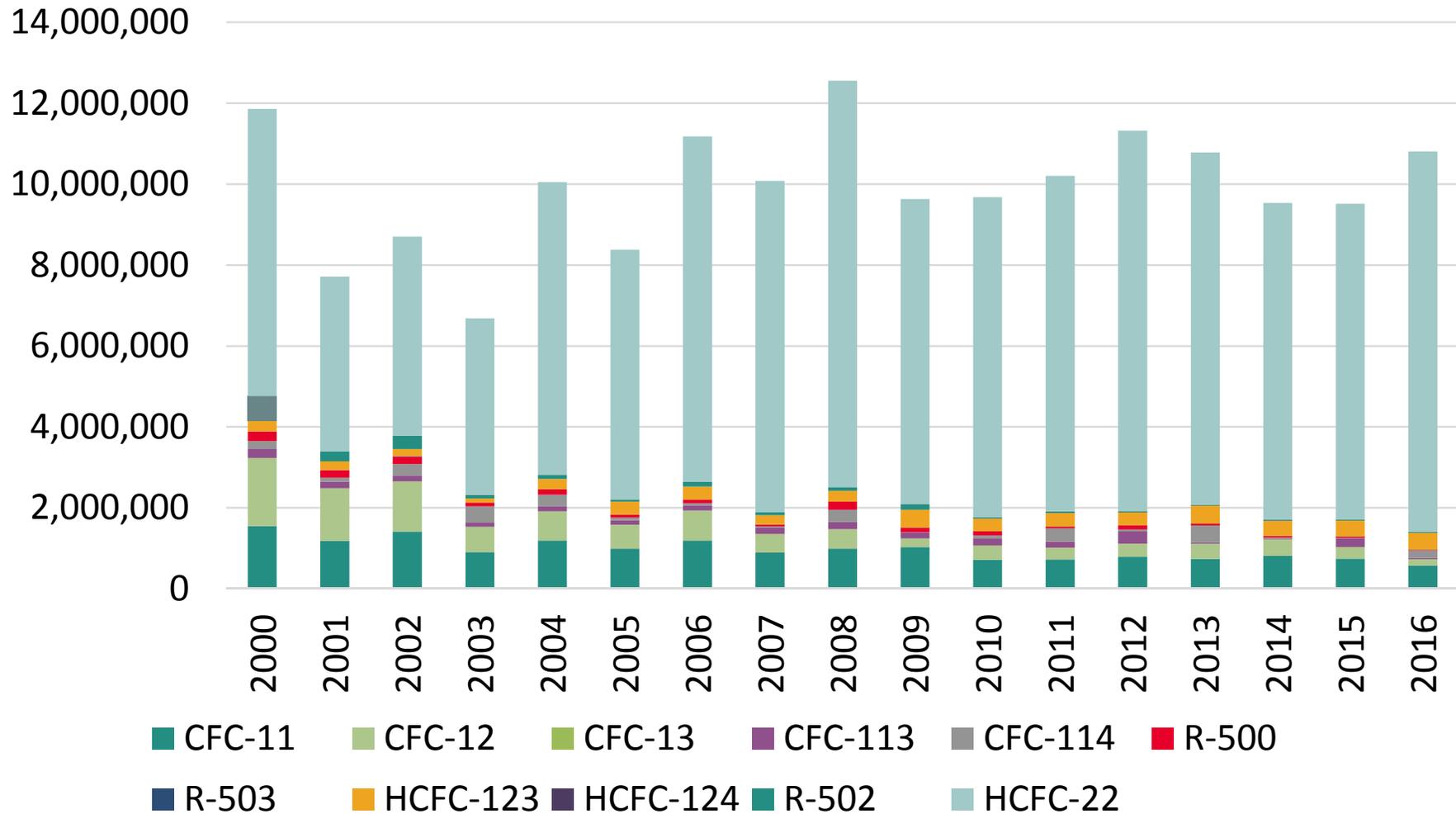
Refrigerant Management

Estimated Global CFC Refrigerant Recovery Rates



EPA - Refrigerant Reclamation

EPA Recovered Refrigerants 2000-2016



R410a



Honeywell

R410a Refrigerant - 25 lb cylinder - New factory sealed tank

★★★★★ [122 customer reviews](#) | [39 answered questions](#)

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

Brand Name	Honeywell
EAN	0783583693233
Part Number	4333078147
UNSPSC Code	52141501
UPC	783583693233

Reviews....



"I can top off my AC as necessary...for much less than the cost of one visit by the AC guy - at least unit the leak gets much worse."

- Verified Purchaser

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 month 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.

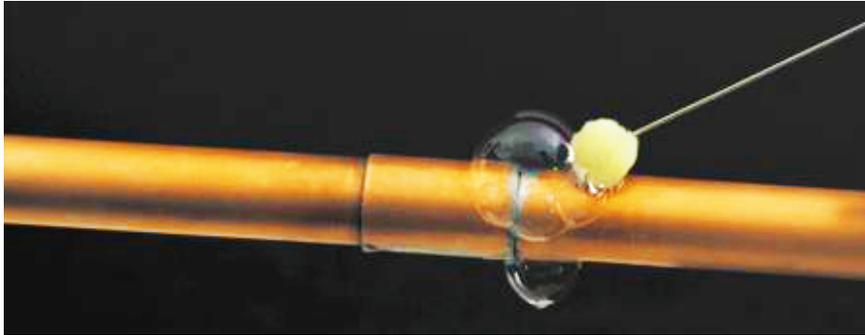
★★★★★ It's a great deal, you save money

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%

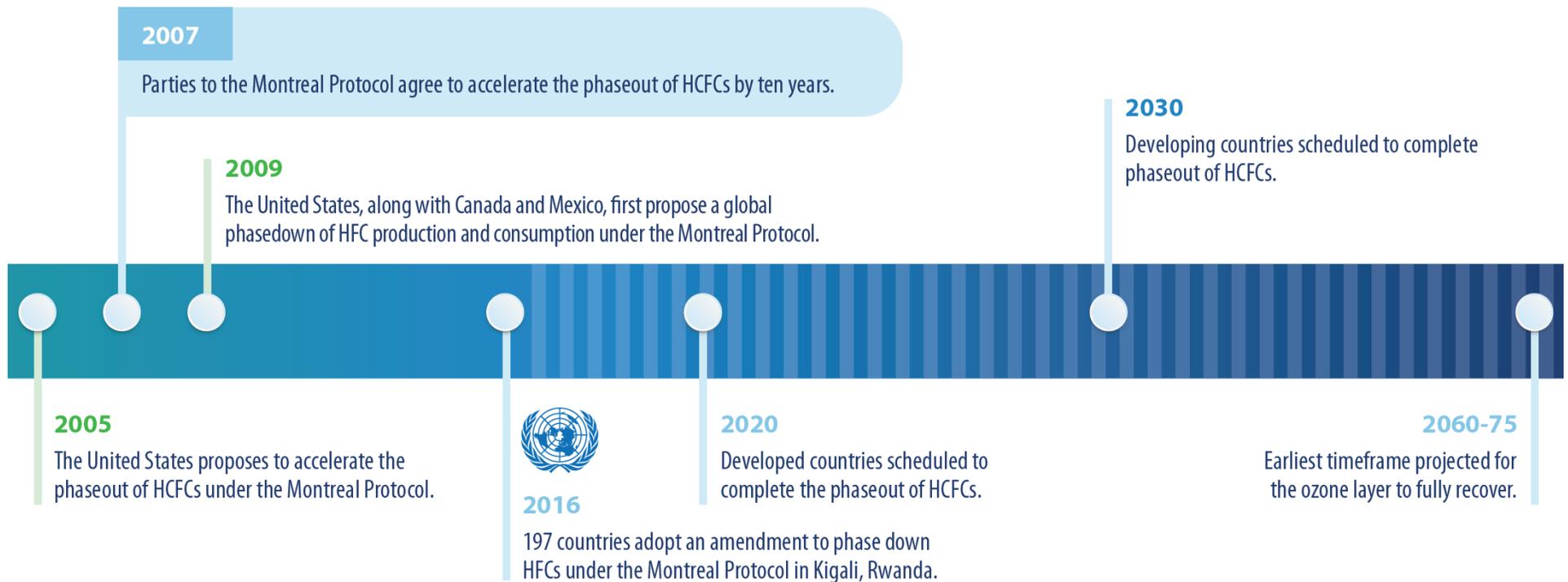


10%



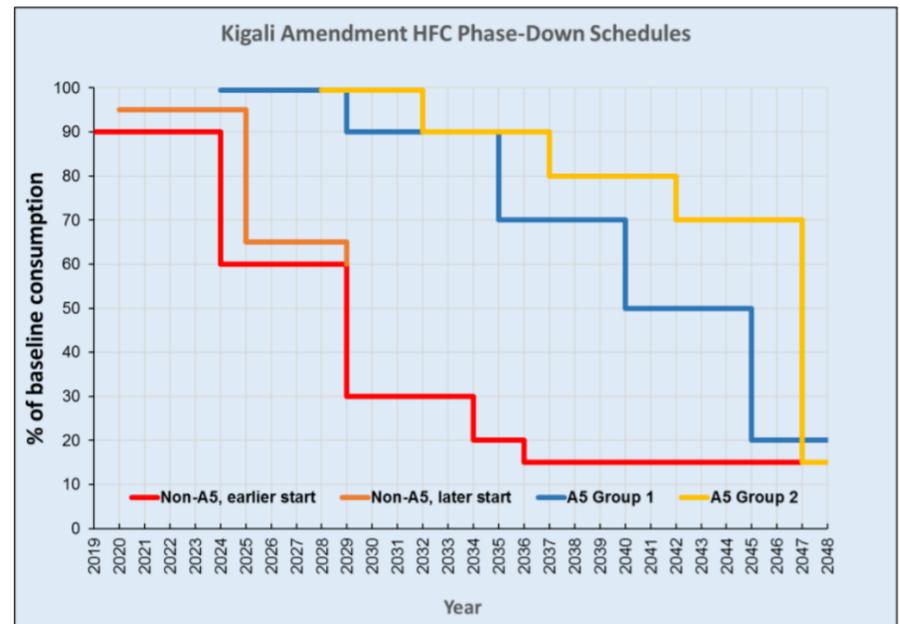
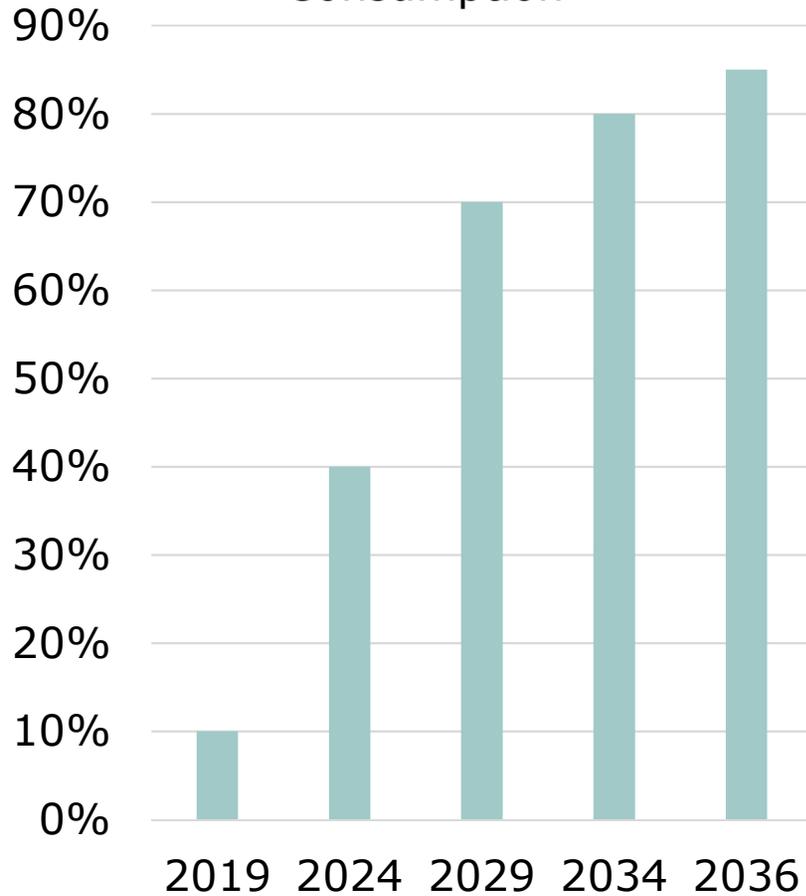
Agreements & Regulations

Meeting the Montreal Protocol HCFC Phaseout



Kigali Agreement – HFC Phasedown

National Reduction in Controlled Substances - HFC Consumption



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



The Alliance
for Responsible Atmospheric Policy

AN INDUSTRY COALITION AND LEADING VOICE
FOR VIABLE ENVIRONMENTAL POLICIES

**TELL WASHINGTON LAWMAKERS:
RATIFY THE KIGALI AMENDMENT**

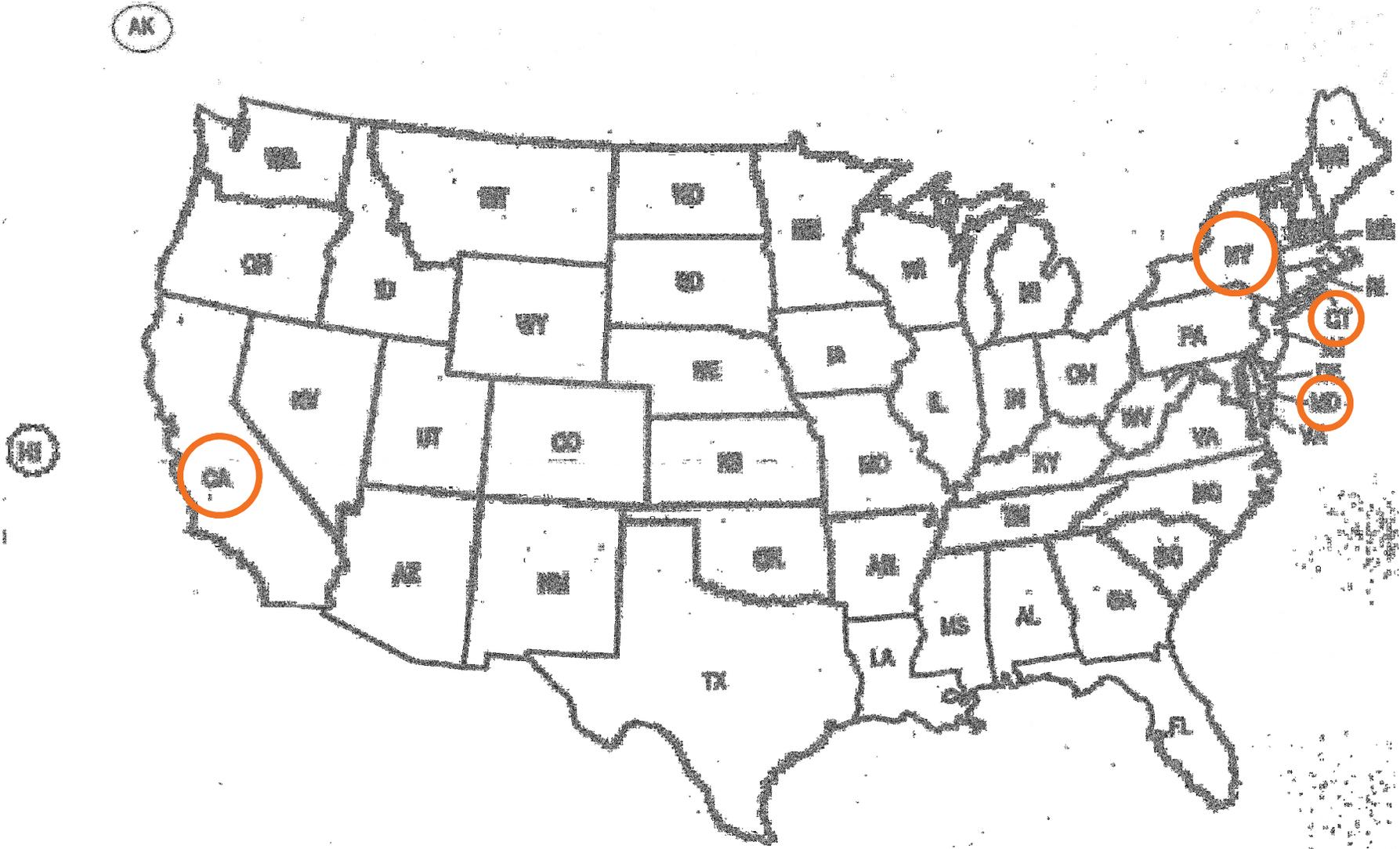


America Must Lead!

The Kigali Amendment will create American **jobs**,
boost our **economy**, and help American companies
capture global **market share**.



State Regulations



EPA – New Regulations

Changes to Section 608 of the Clean Air Act

Technicians must use certified recovery and/or recycling equipment when opening an HFC appliance (Starting 1/1/18)

Technicians must evacuate to the specified levels of vacuum when opening HFC appliances (Starting 1/1/18)

EPA – New Regulations

Changes to Section 608 of the Clean Air Act

Technicians must use certified recovery and/or recycling equipment when opening an HFC appliance (Starting 1/1/18)

Technicians must evacuate to the specified levels of vacuum when opening HFC appliances (Starting 1/1/18)

EPA (40 CFR Part 82, Subpart F)

Under Section 608 of the Clean Air Act



EPA - New Regulations

Changes to Section 608 of the Clean Air Act

	Current	New 608 Ruling
Refrigerants	CFC + HCFC	CFC, HCFC, HFC + HFO
Documenting	> 50 lbs	<ul style="list-style-type: none">• 5 lbs disposal• 50lbs service/repair
Allowable Leak Rates for Comfort Cooling (system with >50 lbs)	15%	10%
Leak Inspections	None Required	If allowable leak rate exceeded 50-500 lbs – annual >500 lbs – quarterly
Chronic Leaks	None Required	>=125% charge loss (in one year) detailed reports filled out – find and repair equipment

EPA – (40 CFR Part 82, Subpart F)

Under Section 608 of the Clean Air Act

LEAK INSPECTION MUST BE PERFORMED ACCORDING TO THE FOLLOWING SCHEDULE:

Equipment	Full Charge	Frequency of Leak Inspections
Commercial Refrigeration & IPR	≥ 500 pounds	Once every three months until the owner/operator can demonstrate that the leak rate has not exceeded the threshold for four quarters in a row.
	50 to 500 pounds	Once per calendar year until the owner/operator can demonstrate that the leak rate has not exceeded the threshold for one year.
Comfort Cooling	≥ 50 pounds	Once per calendar year until the owner/operator can demonstrate that the leak rate has not exceeded 10% for one year.



GHG Emission Impacts

Full Emissions Analysis

GGEA

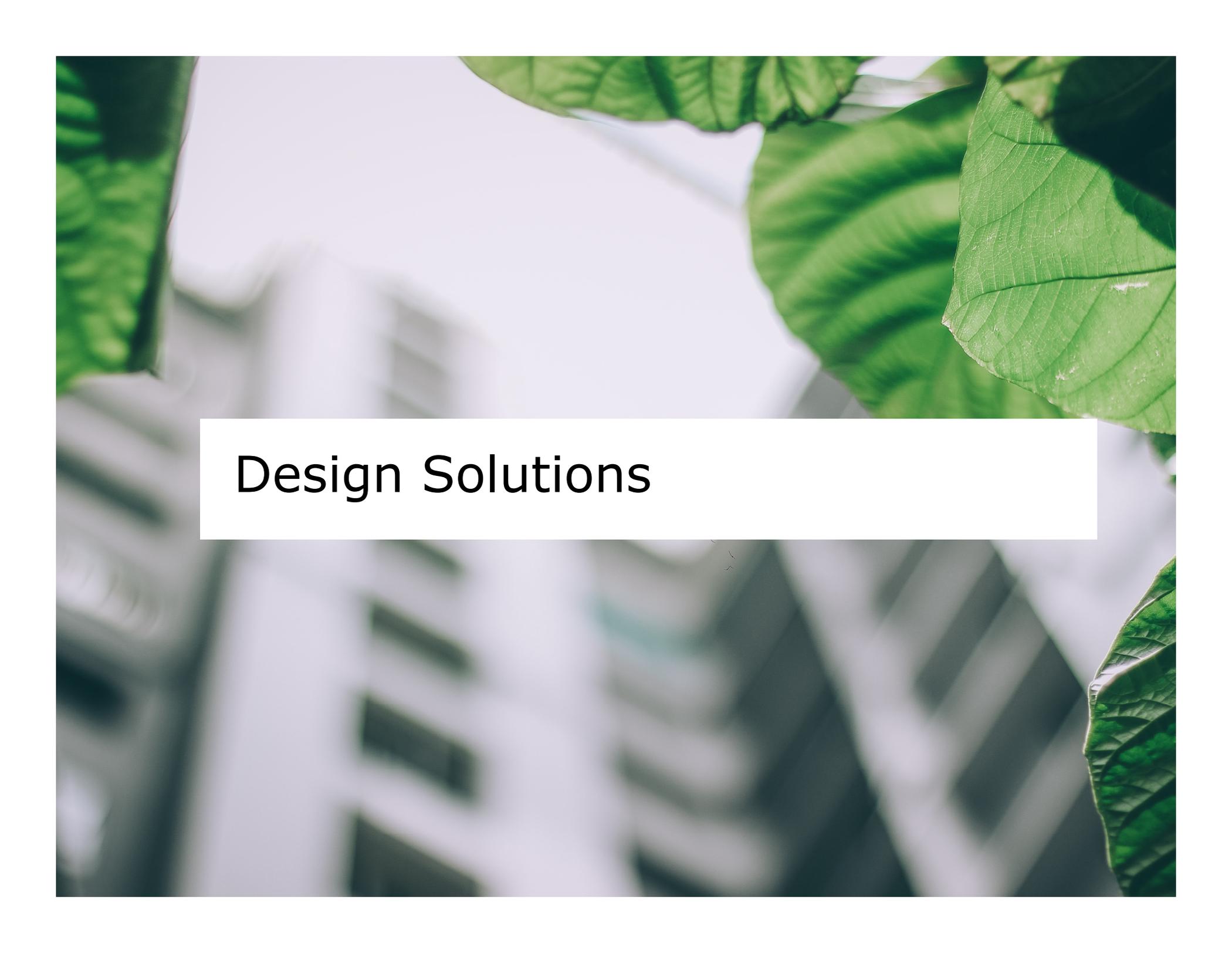
**Greenhouse Gas
Emissions Analysis**

REA

**Refrigerants
Emissions Analysis**

GGLCA

**Greenhouse Gas
Lifecycle Assessment**



Design Solutions

Solutions



Set Aggressive Goals



Choose Efficient Systems



Reduce Loads



Analyze the Climate



Opt for Renewables

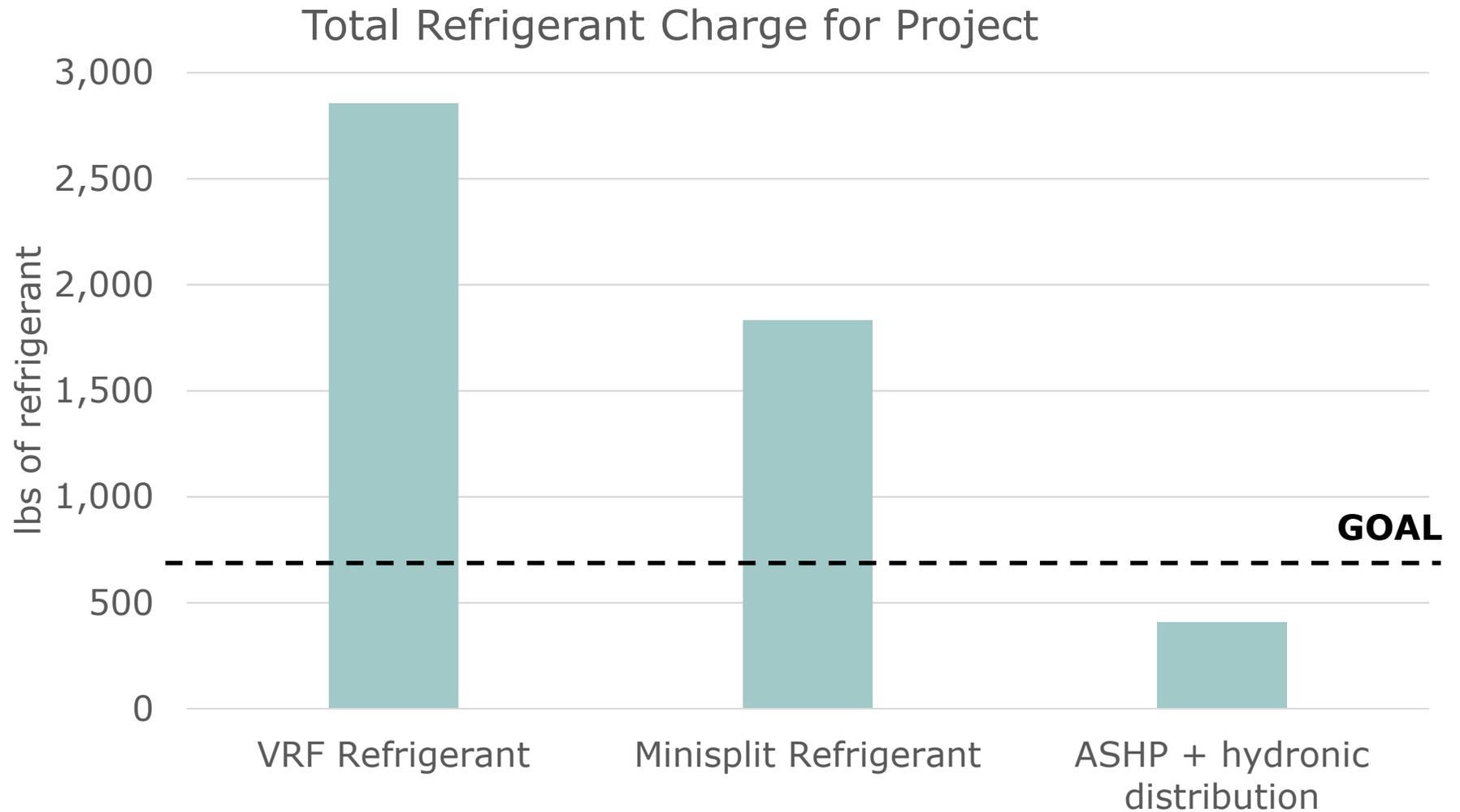


Verify Performance

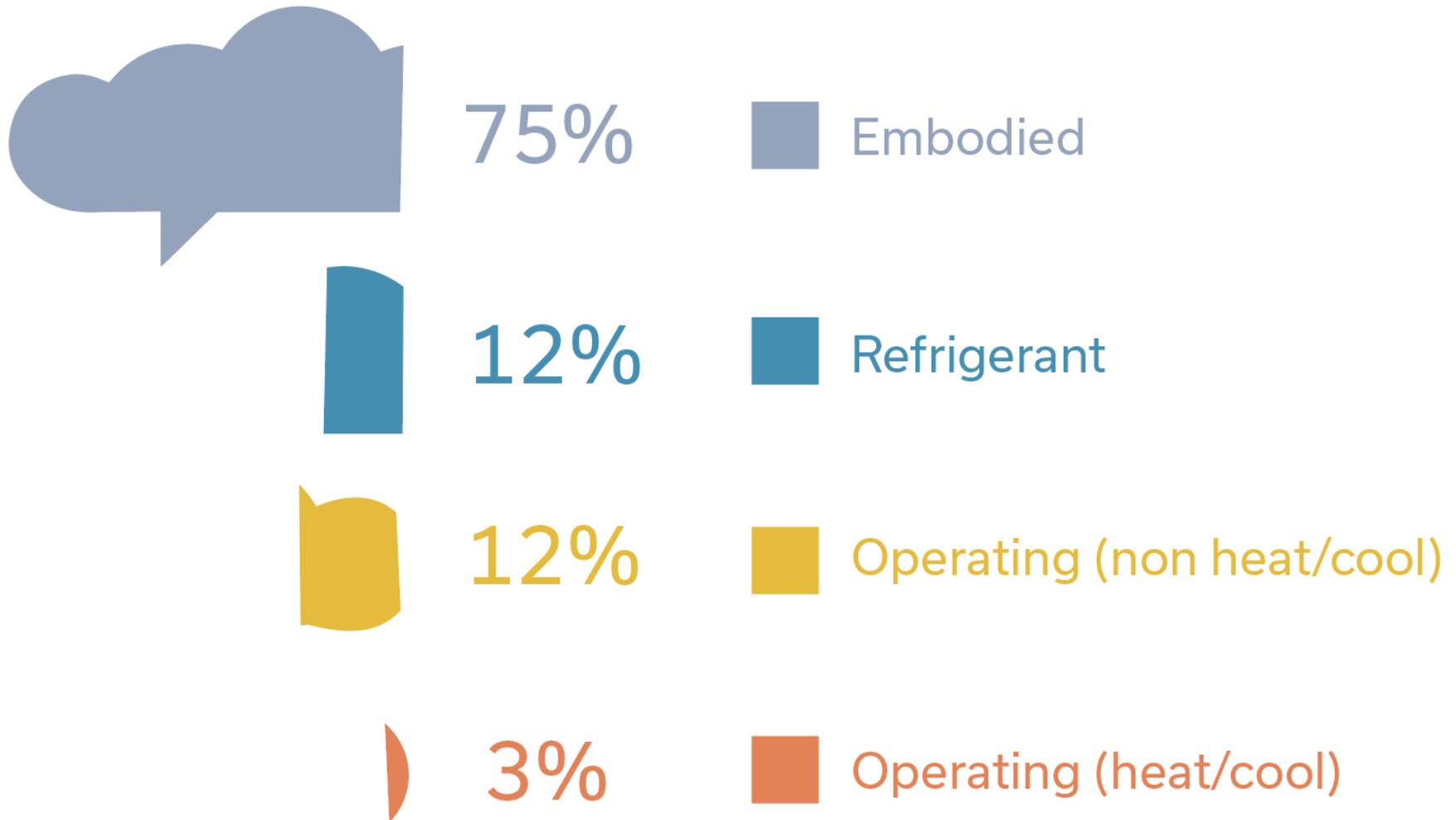


Low Refrigerant Charge

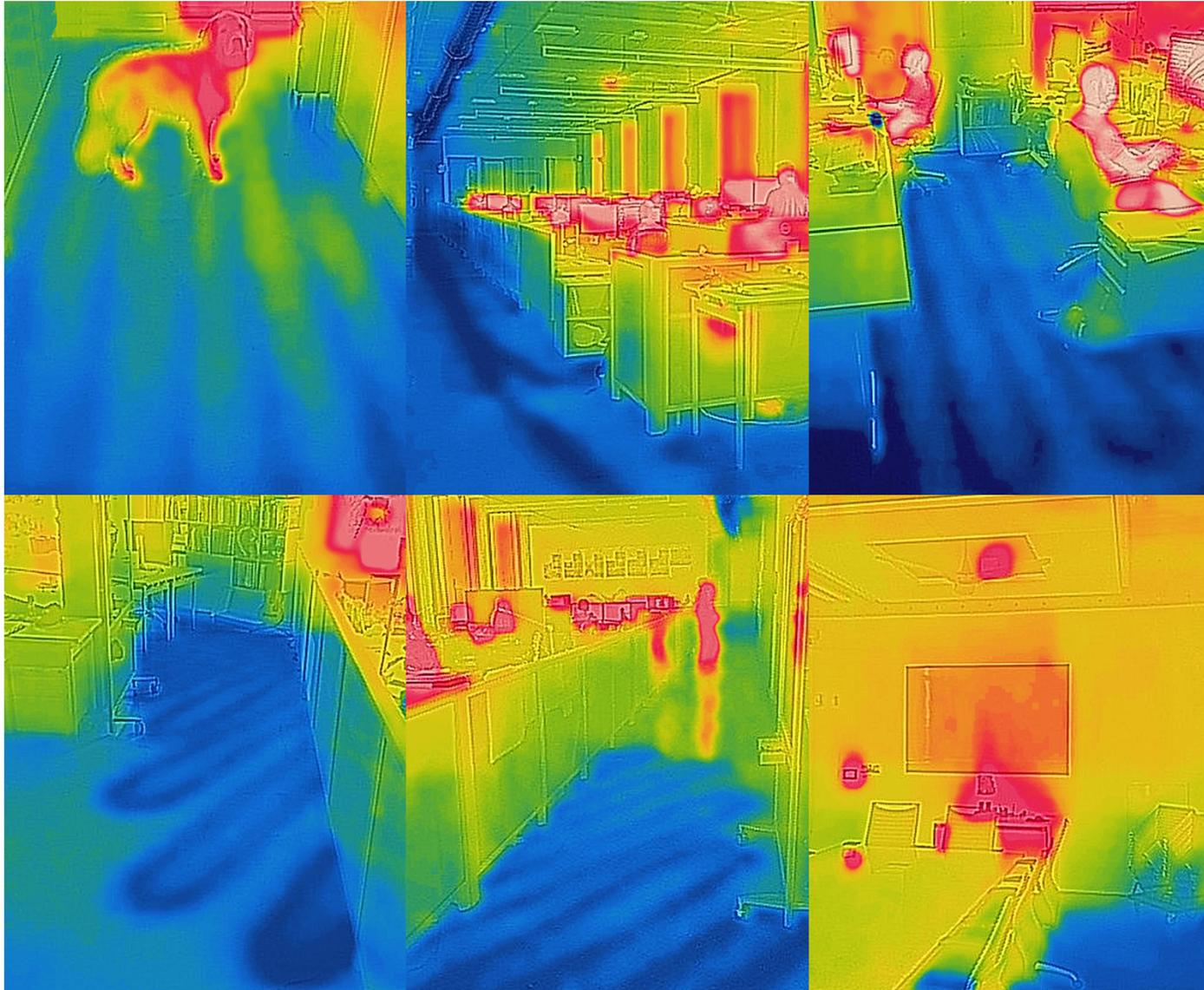
New Building Metric? **RUI** (refrigerant use intensity)

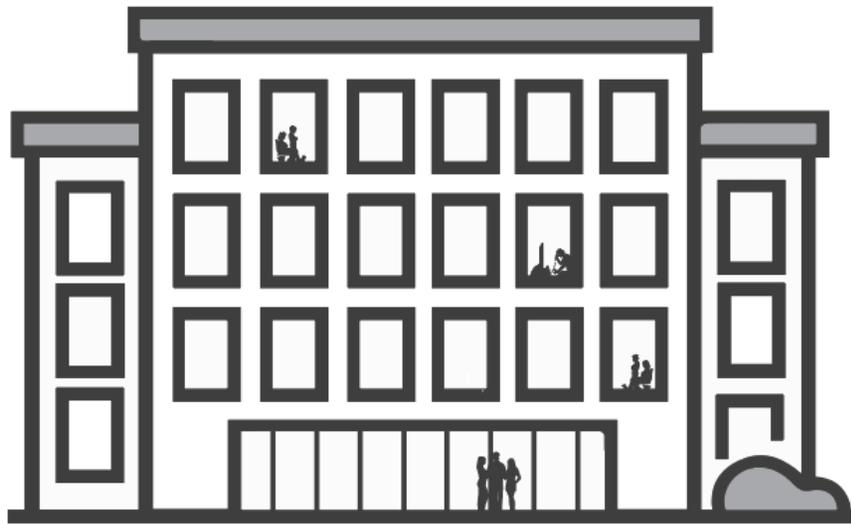


Seattle – VRF Impacts



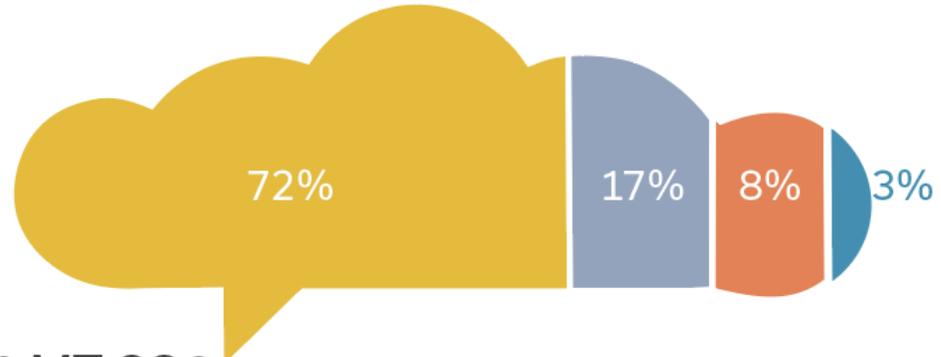
Hydronic Solutions





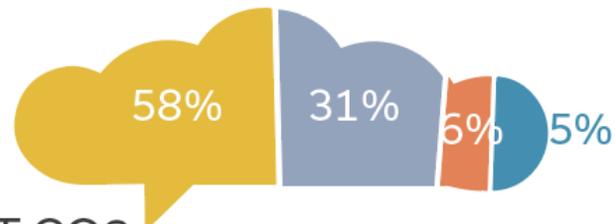
Portland

73,700 MT CO₂e



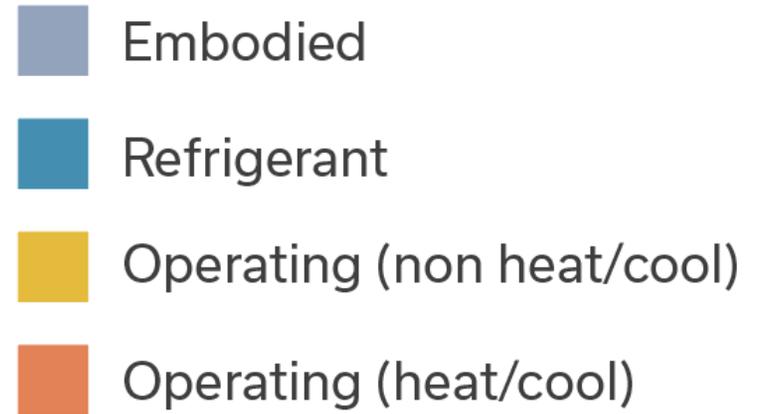
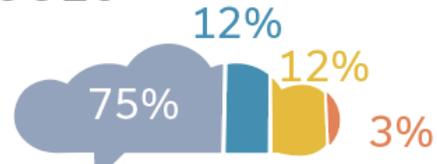
San Francisco

42,700 MT CO₂e



Seattle

17,300 MT CO₂e



A person wearing a blue and white plaid shirt is sitting at a desk, resting their head on their hands in a thoughtful or stressed pose. They are looking out a large window at a city skyline across a body of water. The scene is brightly lit, suggesting daytime. A white text box is overlaid on the image, containing the title and a short paragraph.

Future Buildings

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

New Refrigerants

Refrigerant Safety Groups



Higher Flammability	Class 3	A3 R-290 Propane	B3
Lower Flammability	Class 2	A2 R-152a	B2
Lower Burning Velocity	Class 2L	A2L R-32 R-1234yf R-1234ze	B2L R-717 Ammonia
No Flame Propagation	Class 1	A1 R-22 R-134a R-410A R-744 CO2	B2 R-123
		Lower Toxicity	Higher Toxicity

Future

Natural Refrigerants	HCs (hydrocarbons) Ammonia CO ₂ (Carbon dioxide)	e.g. R-290 (Propane), R-600a (Isobutane), R-1270 (propene) R-717 R-744
Synthetic HFCs	Saturated HFCs Unsaturated HFCs (known as “hydrofluoroolefins” or “HFOs”)	e.g., R-161, R-152a e.g. R-1234yf, R-1234ze

'Natural' Refrigerants

Potentials for Ammonia & CO2



Innovation

11.11.18 | INNOVATION AGENTS

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.



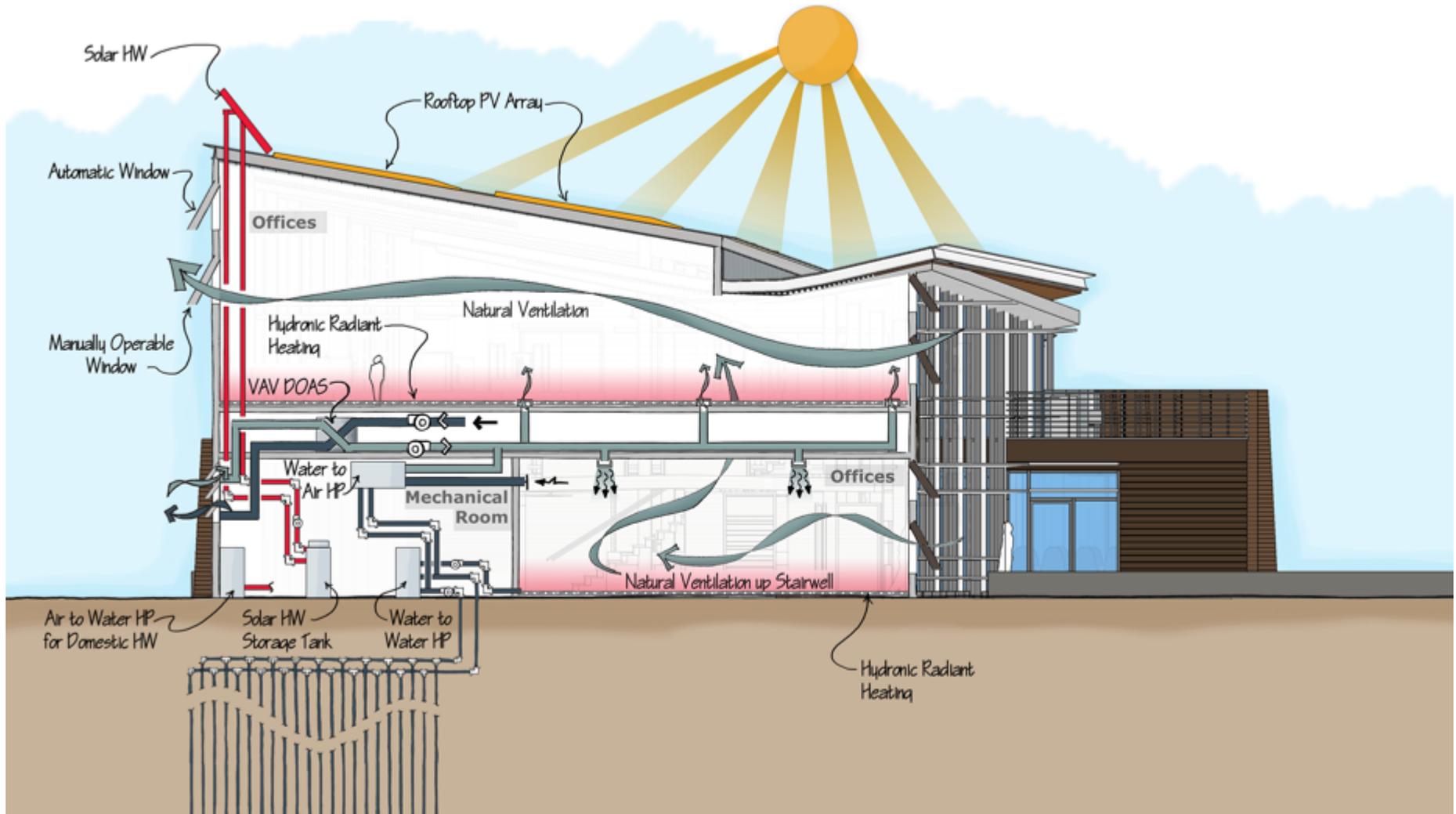
RMI – Innovation Center



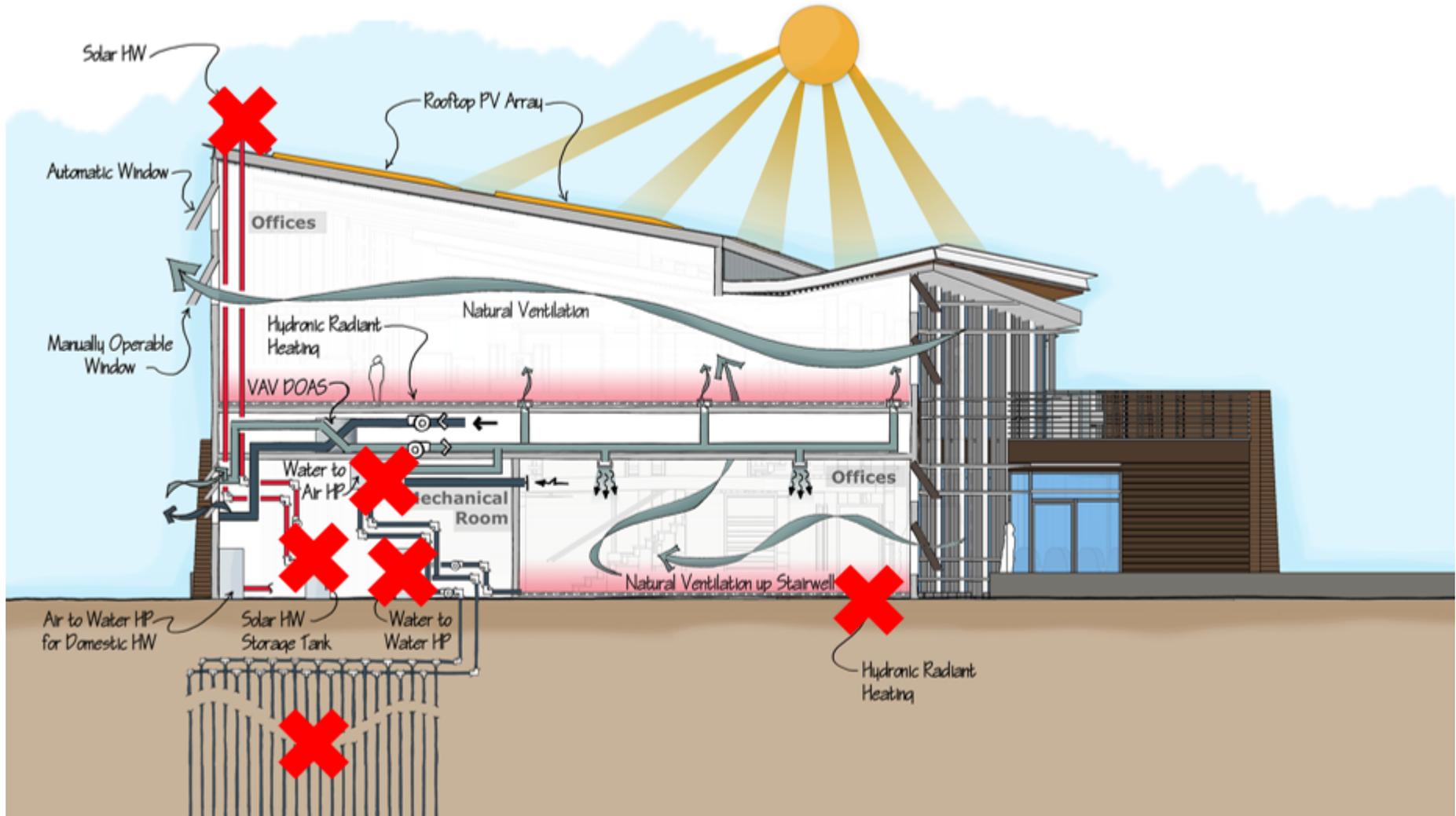
ZGF

ZIMMER GUNSUL FRASCA ARCHITECTS LLP

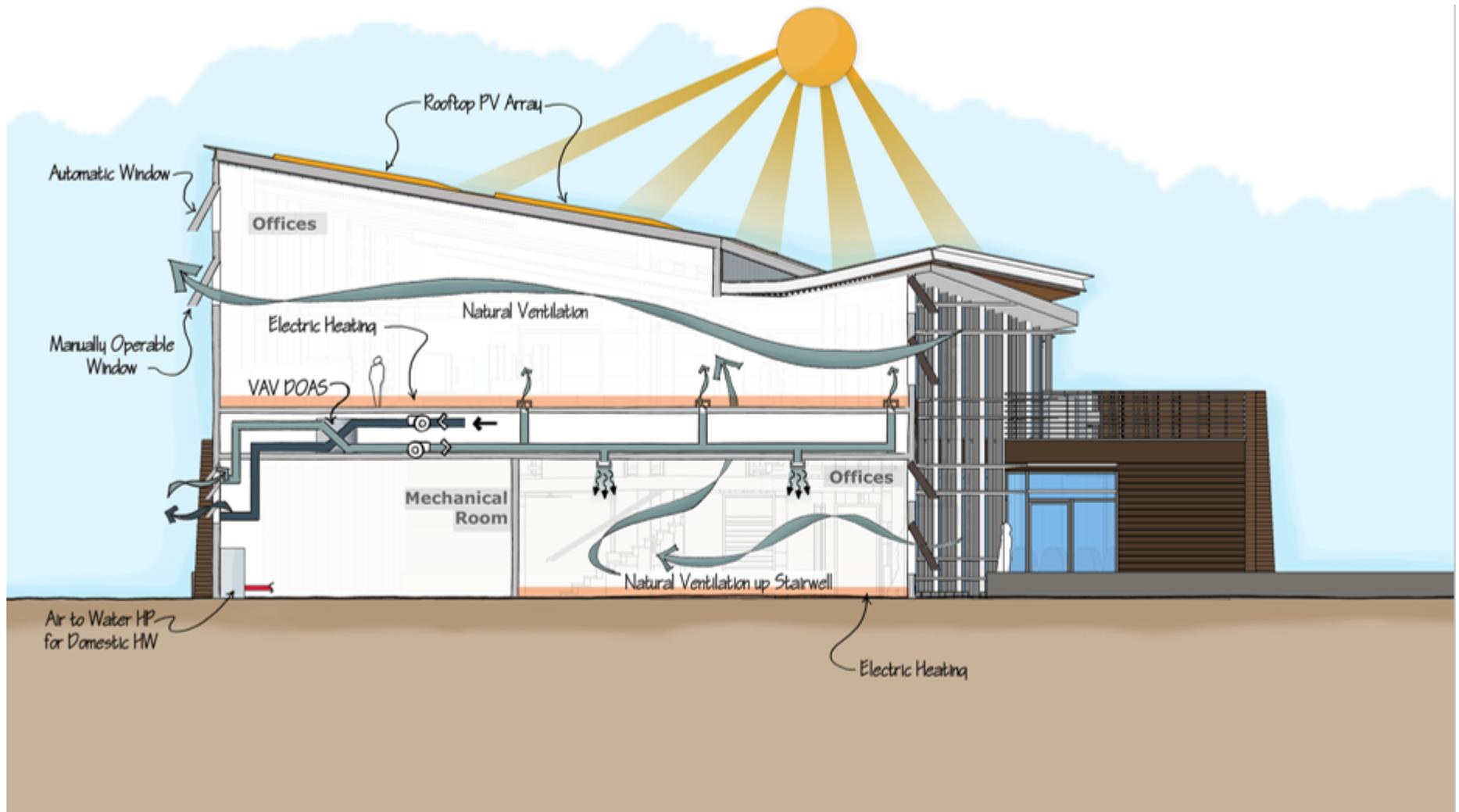
Refrigerant Based Systems



Refrigerant Based Systems



Almost No Refrigerants

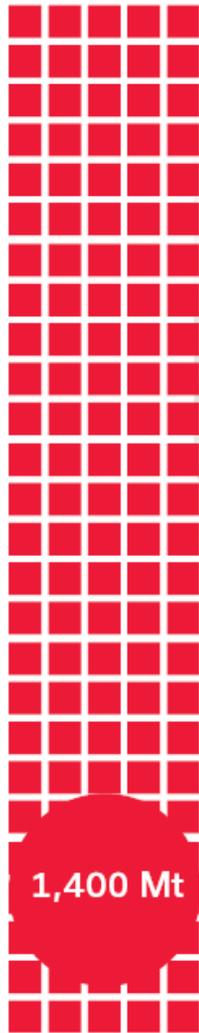


Key Design Elements – Glazing Design & Performance



RMI Emissions Analysis – 35 years

Operational
Emissions



Refrigerants
Emissions



Embodied
Emissions



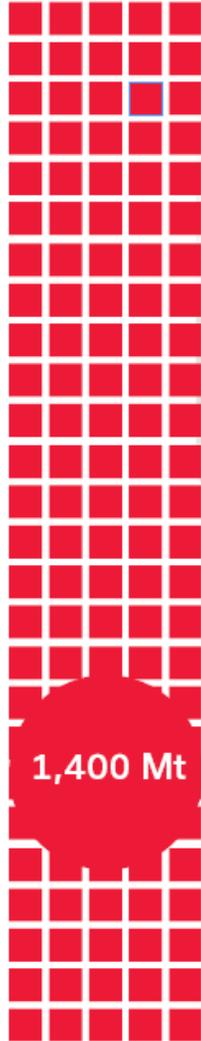
1,400 Mt

10 Mt

1,130 Mt

RMI Emissions Analysis – 35 years

Operational
Emissions



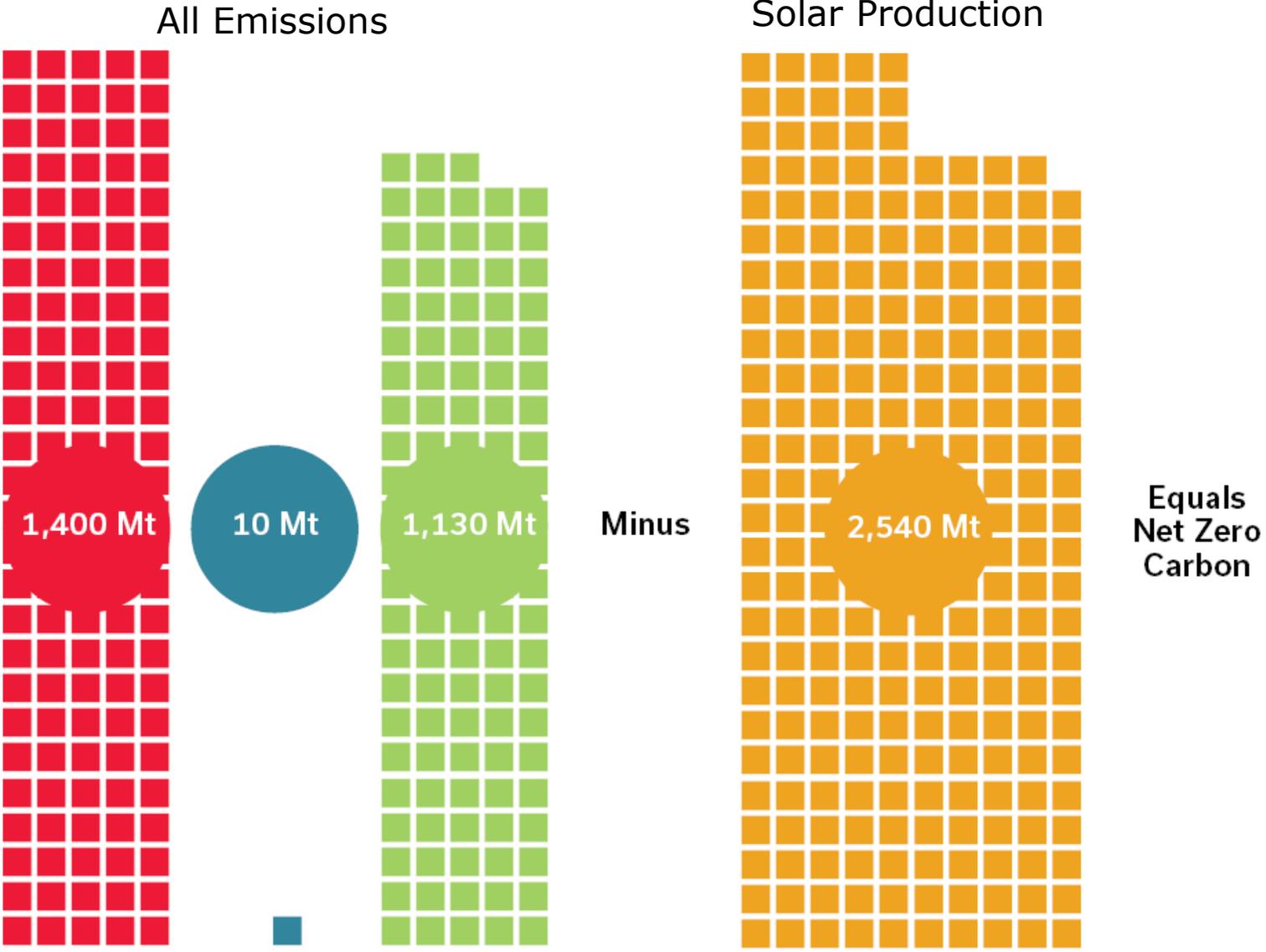
Refrigerants
Emissions



Embodied
Emissions



RMI Emissions Analysis – 35 years



Audience Questions





Creating a better environment

Katie Zabrocki, PE

Project Manager

Katie.Zabrocki@pae-engineers.com

503.542.0568

522 SW 5th Ave., Suite 1500
Portland, OR 97204