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The Environmental Impact of Refrigerants: Past, Present, and Future

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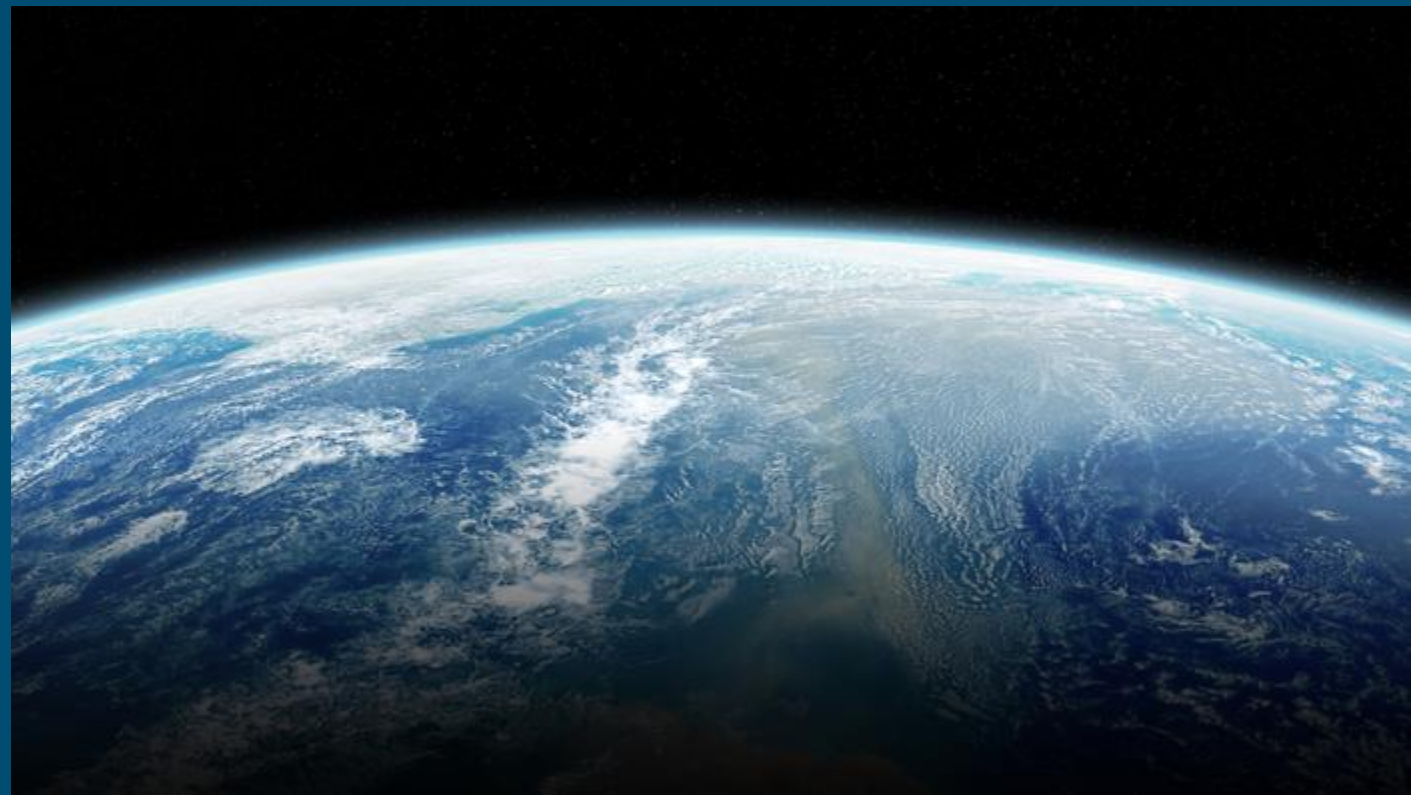
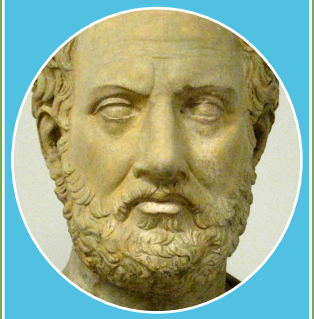


Today's Topics

What are Refrigerants

Where We Find Them



Brief History of Refrigerants

Refrigerant Management

Future of Refrigerants

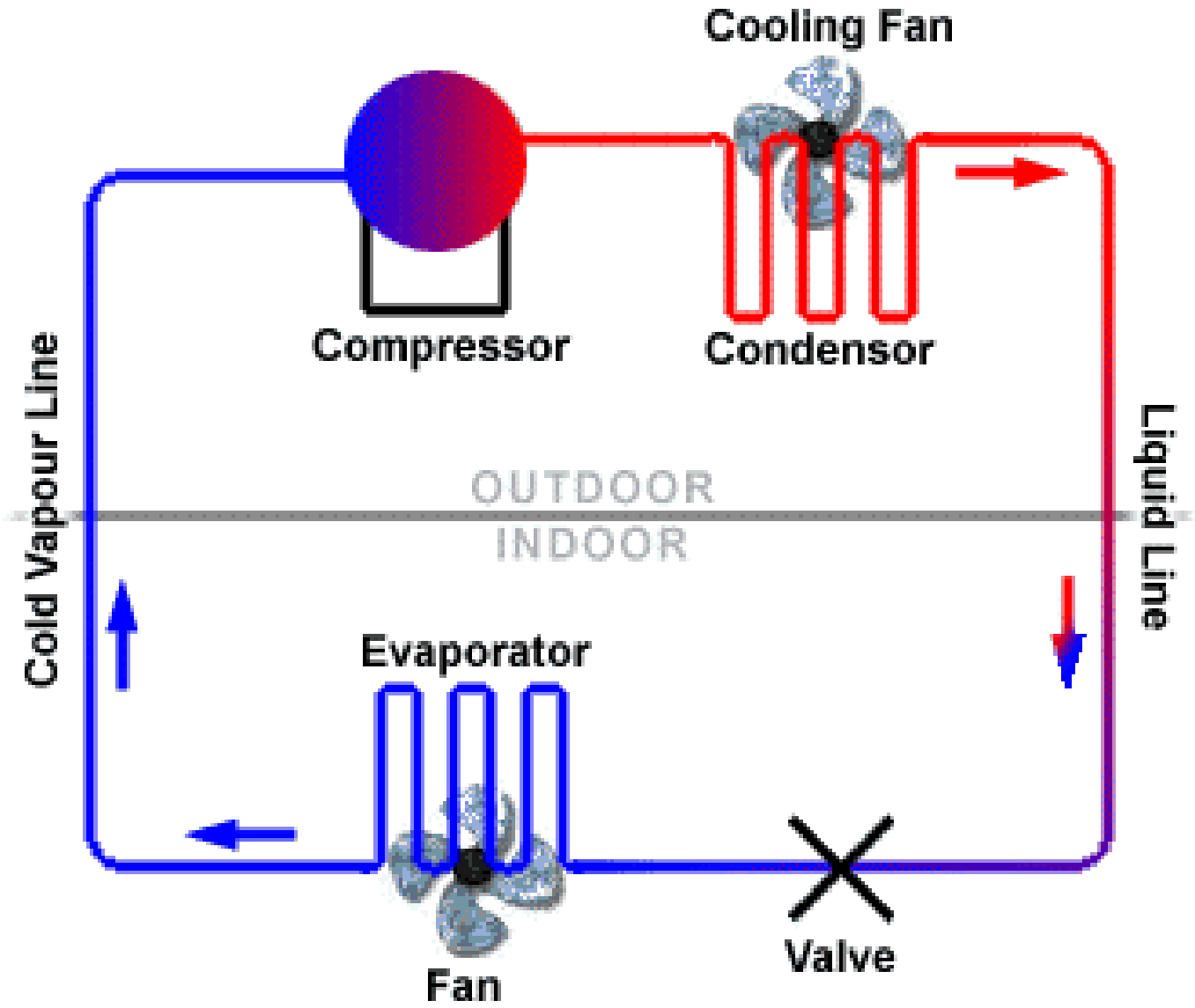
Market Trends

Tying it All Together

What are Refrigerants?

What They’re NOT - Coolant

What are Refrigerants – Refrigeration Cycle



What They're NOT – Freon (at least not *usually*)

GWP

Global Warming Potential

The relative impact of a substance as a greenhouse gas.

CO2 = 1

...So a GWP of 1,000, means that 1 kg of that substance is equivalent to 1 metric ton of CO2

ODP

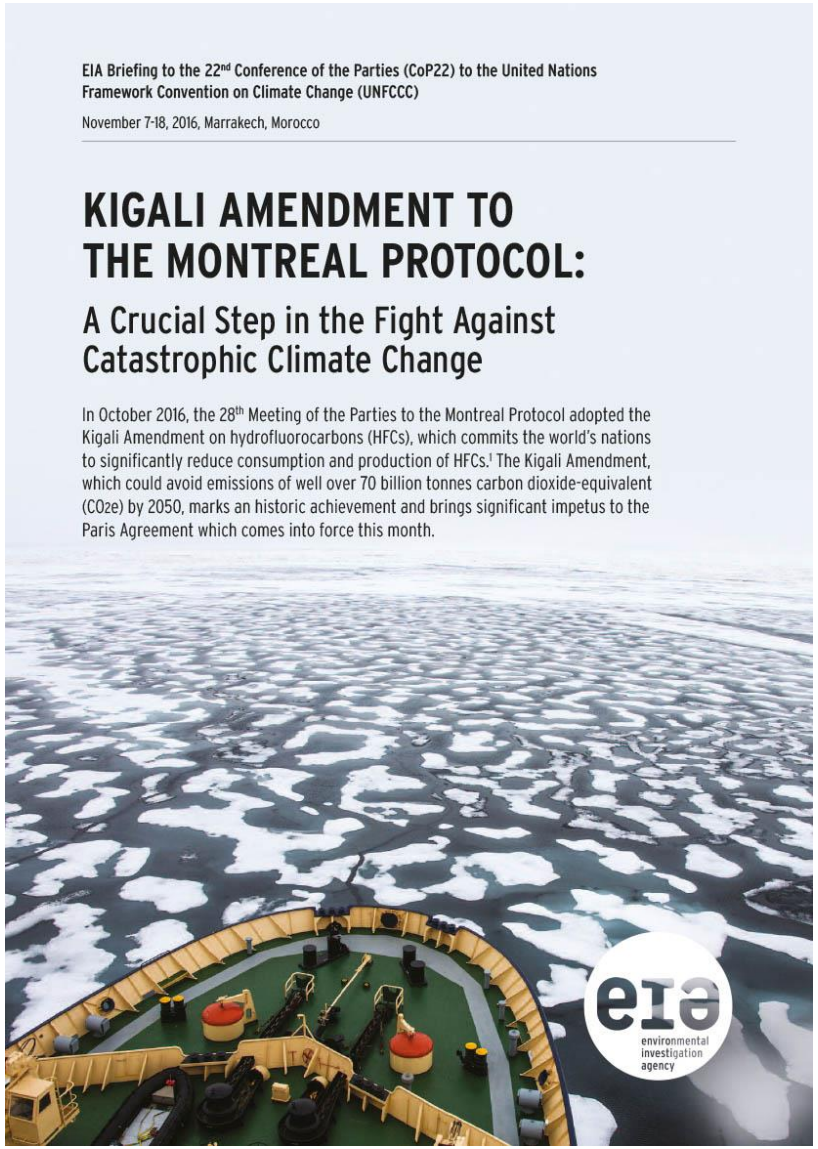
Ozone Depletion Potential

The relative impact of a substance as a depletion of the Earth's Ozone Layer.

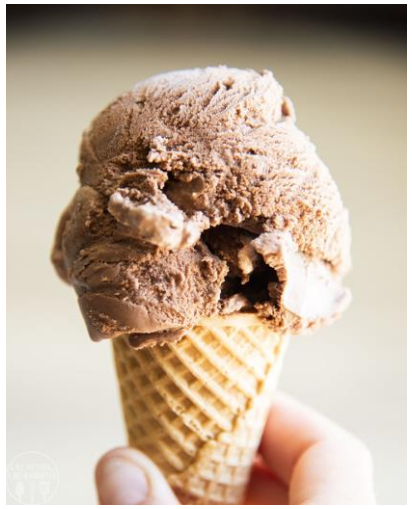
ODP > 0 = BAD

...So substances with ODP's >0 have been regulated out of use through the Montreal Protocol

What they ARE – Regulated Substances



What they ARE – Responsible for the Miracles of Modern Life



Where Refrigerants are Found - Commercial

Where Refrigerants are Found - Residential

Where Refrigerants are Found - Transportation

Where Refrigerants are Found - Insulation

History of Refrigerants

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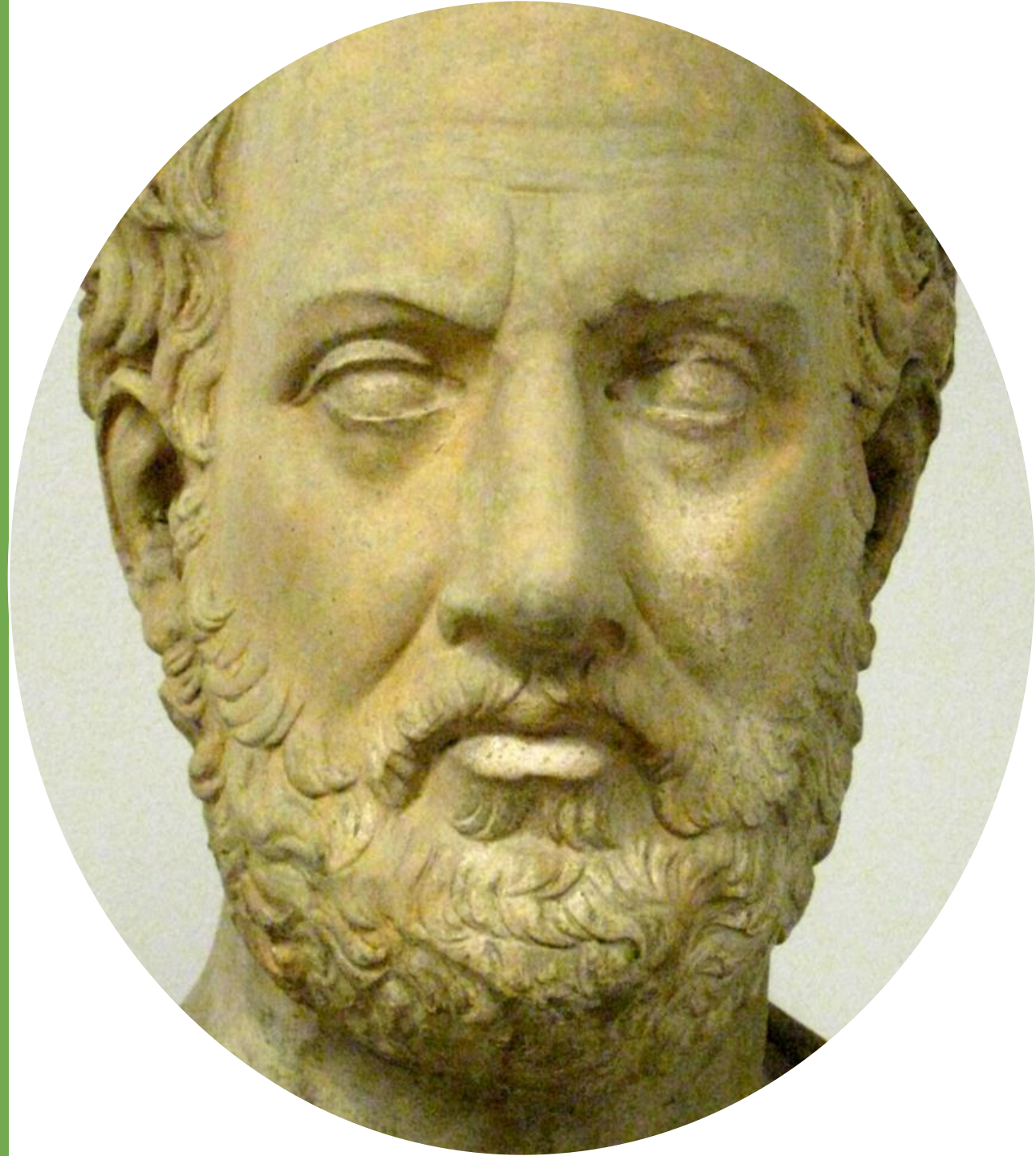
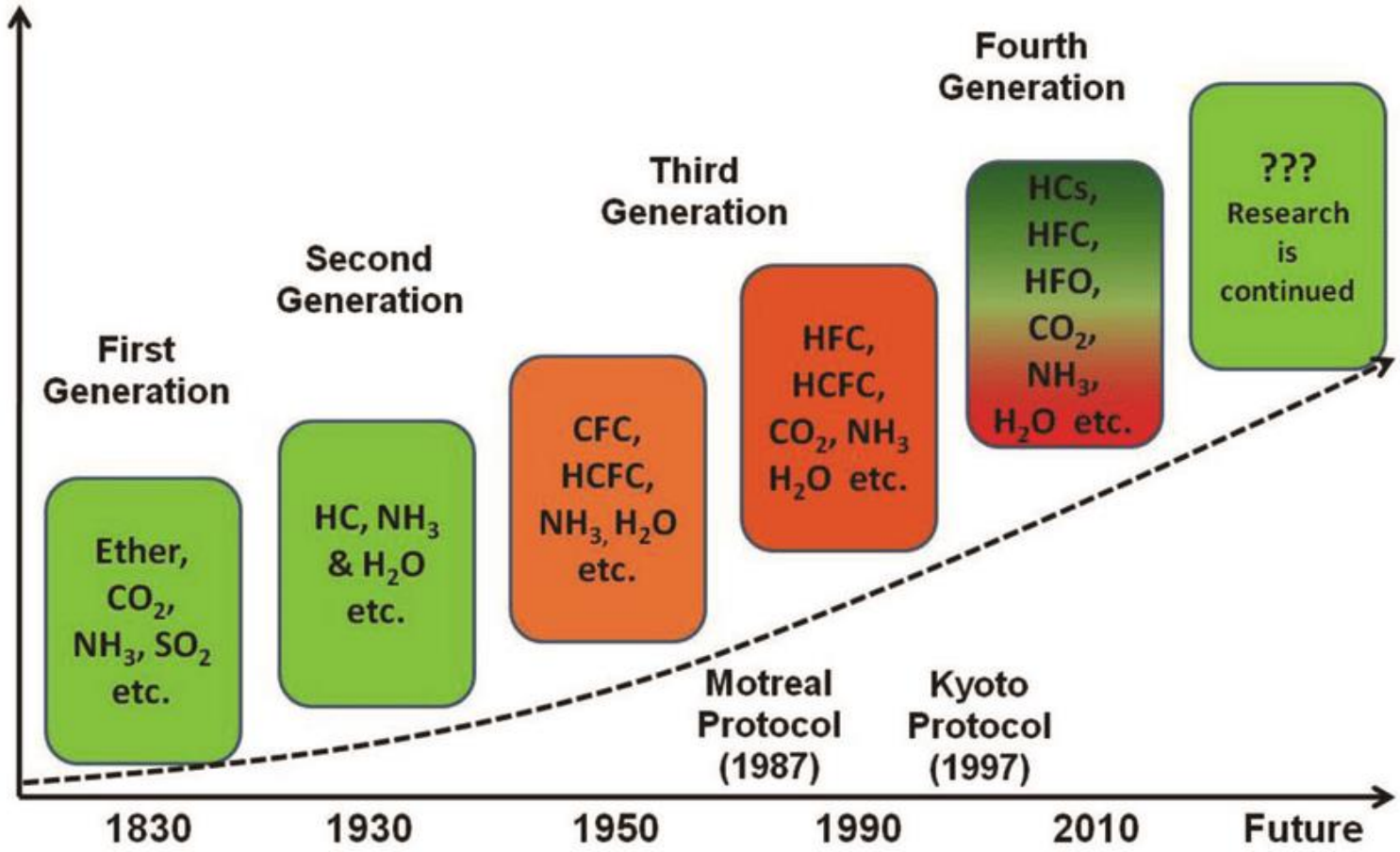


1st Refrigerant

1st Refrigerator

Vapor Compression Refrigeration History



https://www.researchgate.net/figure/History-of-refrigerants_fig1_328494214

CFC's

- Extremely high Global Warming Potential (GWP)
  - R12- 10,200
  - R13- 13,900
- Very high Ozone Depletion Potential (ODP)

HFC's

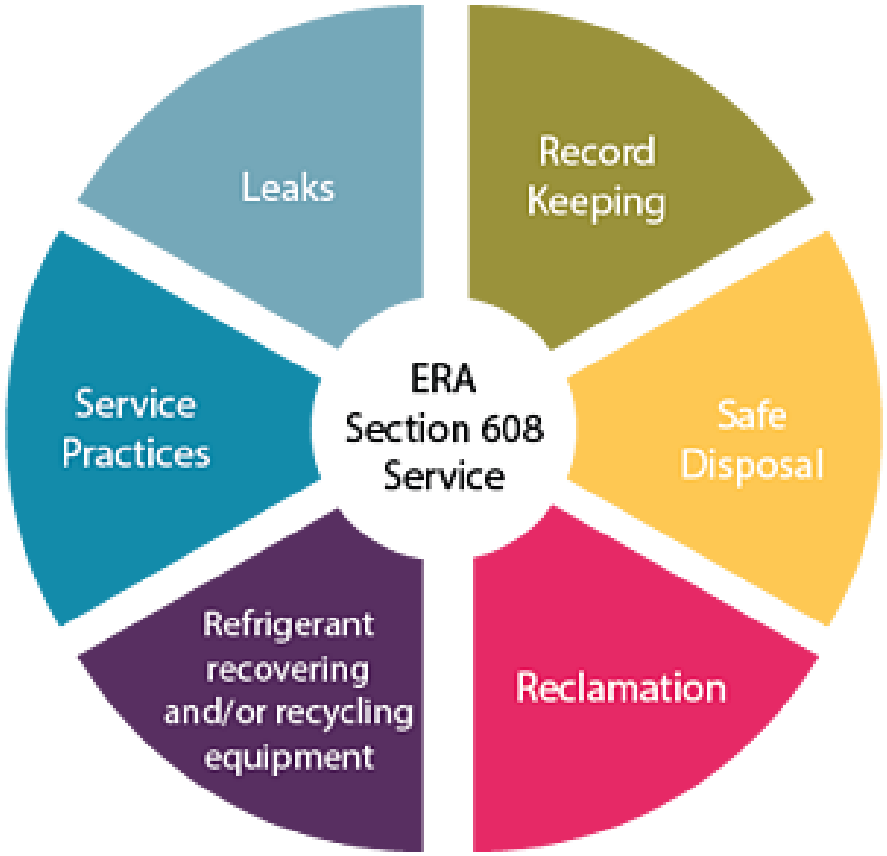
- Very high Global Warming Potential (GWP)
  - R404a- 3,900
  - R507c- 3,800
- Zero Ozone depletion
- Easy to work with
- Cheap

Natural Refrigerants

- Dramatically lower GWPs
  - Ammonia – 0
  - Propane – 4
  - CO2 – 1
- Cost-effective refrigerant prices
- Maintenance and energy savings*

*When designed properly!

Refrigerant Management



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Why Refrigerant Management?

Global warming potential (**GWP**) is a measure of how much heat a greenhouse gas traps in the atmosphere up to a specific time horizon, relative to carbon dioxide

Greenhouse Gas (GHG)	Atmospheric Lifetime (yrs)	Global Warming Potental (GWP)	Primary Current Sources
Carbon dioxide (CO_2)	50-200	1	Fossil fuel use, land use, cement
Methane (CH_4)	12±3	21	Fossil fuel use, agriculture
Nitrous oxide (N_2O)	120	310	Mostly agriculture, ~1/3 are anthropogenic
Hydrofluorocarbons (HFCs)	1.5 to 209	150 to 11,700	Alternative to ozone depleting substances
Perfluorocarbons (PFCs)	2,600 to 50,000	6,500 to 9,200	Primary aluminum production; semiconductor manufacturing
Sulfur Hexafluoride (SF_6)	3,200	23,900	Used in electric power transmission, magnesium and semiconductor industries

High GWP gases

Why Refrigerant Management?

- IPCC Special Report: To remain below Global Warming of 1.5° C, we must reduce HFC emissions by 70-80% by 2050
- HFCs are part of “short-lived climate pollutants” category

Why Refrigerant Management?

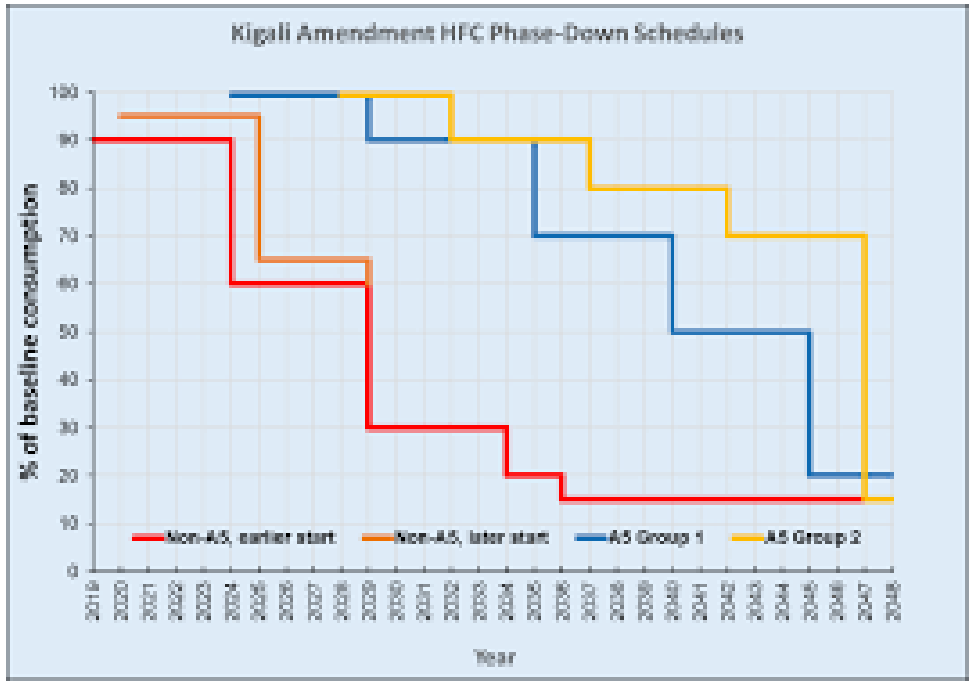
Rank	Solution	Sector	TOTAL ATMOSPHERIC CO2-EQ REDUCTION (GT)	NET COST (BILLIONS US $)	SAVINGS (BILLIONS US $)
1	Refrigerant Management	Materials	89.74	N/A	$-902.77
2	Wind Turbines (Onshore)	Electricity Generation	84.60	$1,225.37	$7,425.00
3	Reduced Food Waste	Food	70.53	N/A	N/A
4	Plant-Rich Diet	Food	66.11	N/A	N/A
5	Tropical Forests	Land Use	61.23	N/A	N/A
6	Educating Girls	Women and Girls	51.48	N/A	N/A
7	Family Planning	Women and Girls	51.48	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

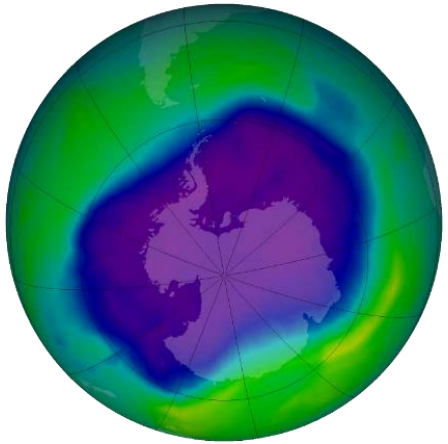
Typical Grocery Store Leakage

- Average Refrigerant Charge: 3,000 pounds
- Average Industry annual leakage rate: 24%
- GWP = 2500
- 1,800,000 lbs CO2e/year
  - 970 acres deforested

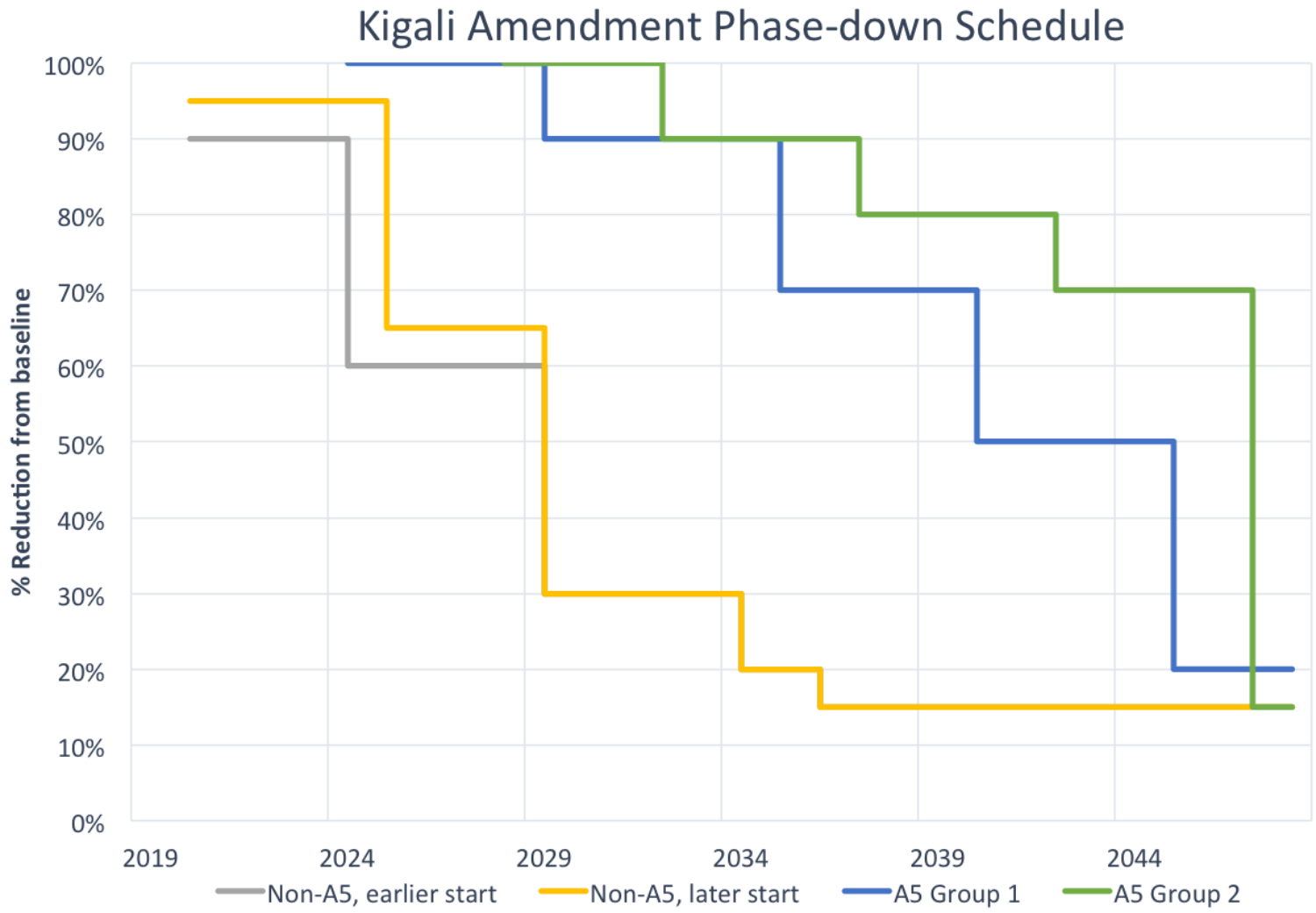
Montreal Protocol / Kigali Amendment

- September 16th 1987, agreed to phase out CFC's
- Newest iteration is Kigali Amendment (2016) which phases down HFC's by 85%
- US will follow this amendment
- Next jump is in 2025





Montreal Protocol / Kigali Amendment



What is Refrigerant Management?

CFC's	HFC/HCFC's	HFO's	HC's
• High ODP • High GWP	• No ODP • High GWP	• No ODP • Lower GWP	• No ODP • No GWP

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Three-pronged approach

1. Proactive leak repair
2. Switching to low-GWP refrigerants
3. Installing natural refrigerant systems

Future of Refrigerants

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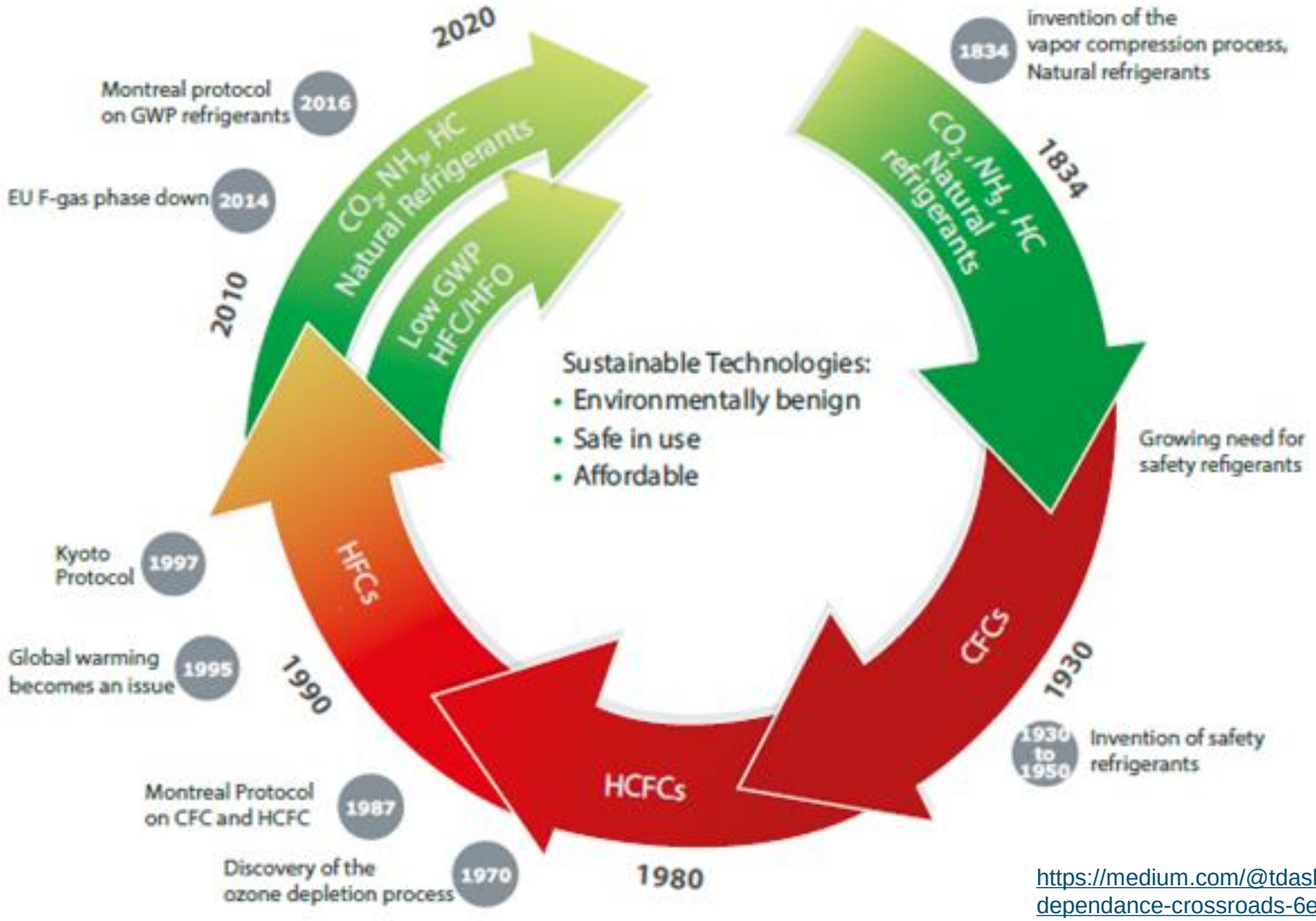
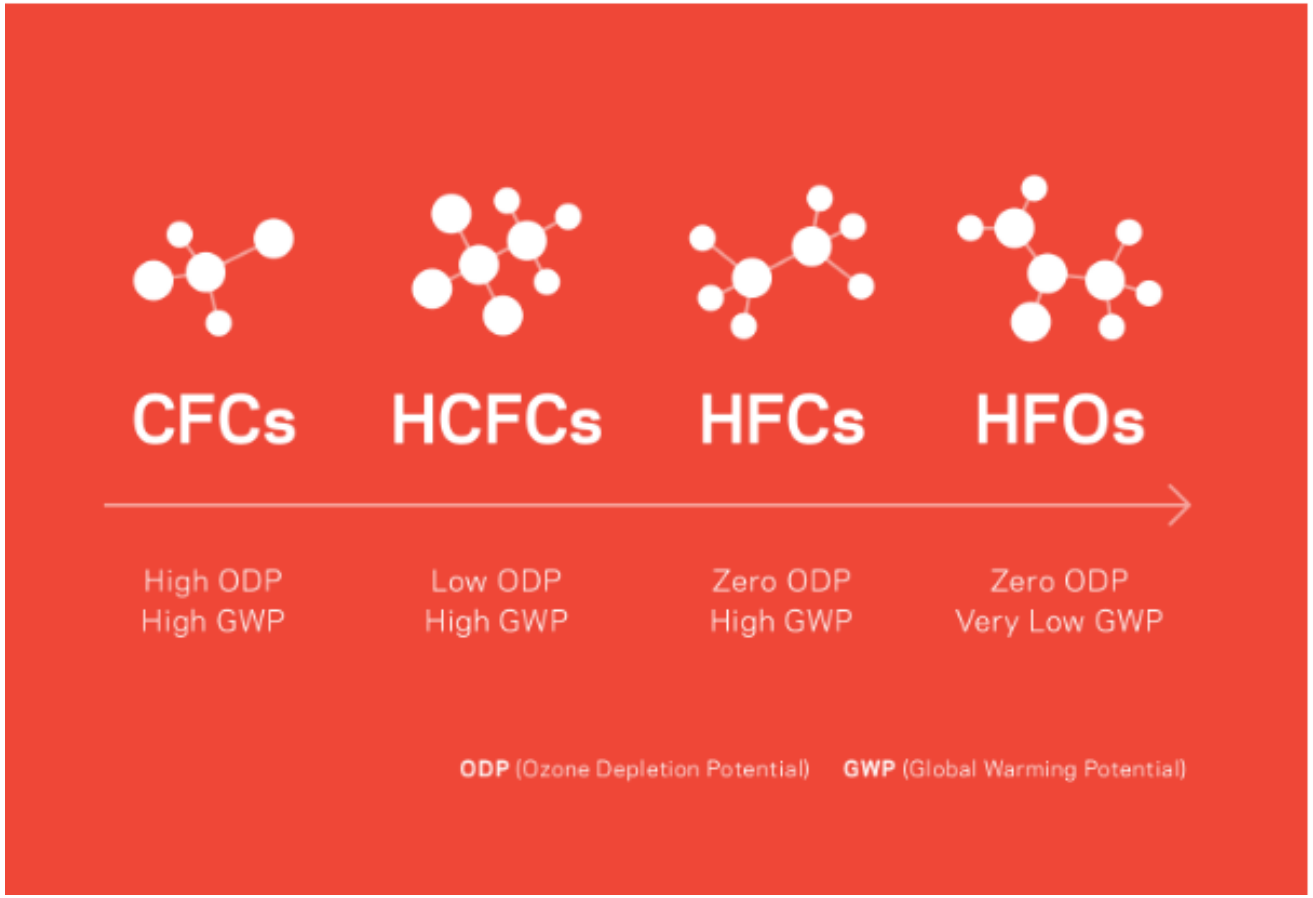
Future of Refrigerants



https://medium.com/@tdaskalopoulos/refrigerant-dependance-crossroads-6ed4033bfb5a

HFO’s (Hydrofluoroolefins)

- Not saturated. (Short climate lifespan)
- Low GWP around 0.1% of most HFC’s
- Downsides
  - Mildly flammable, so charge constraints
  - During Atmosphere breakdown TFA is produced
  - When they burn they produce hydrogen fluoride.



HFOs and HFO Blends

- **Current HFO's we are seeing**
  - **R1234YF, 1st HFO in all new cars, 10 million vehicles and growing**
  - **R448,R449, Refrigeration System HFC,HFO blend. 27-30% HFO, still A1 refrigerant**
  - **Retrofit option for Grocery stores**
  - **Chiller applications have HFO options today.**

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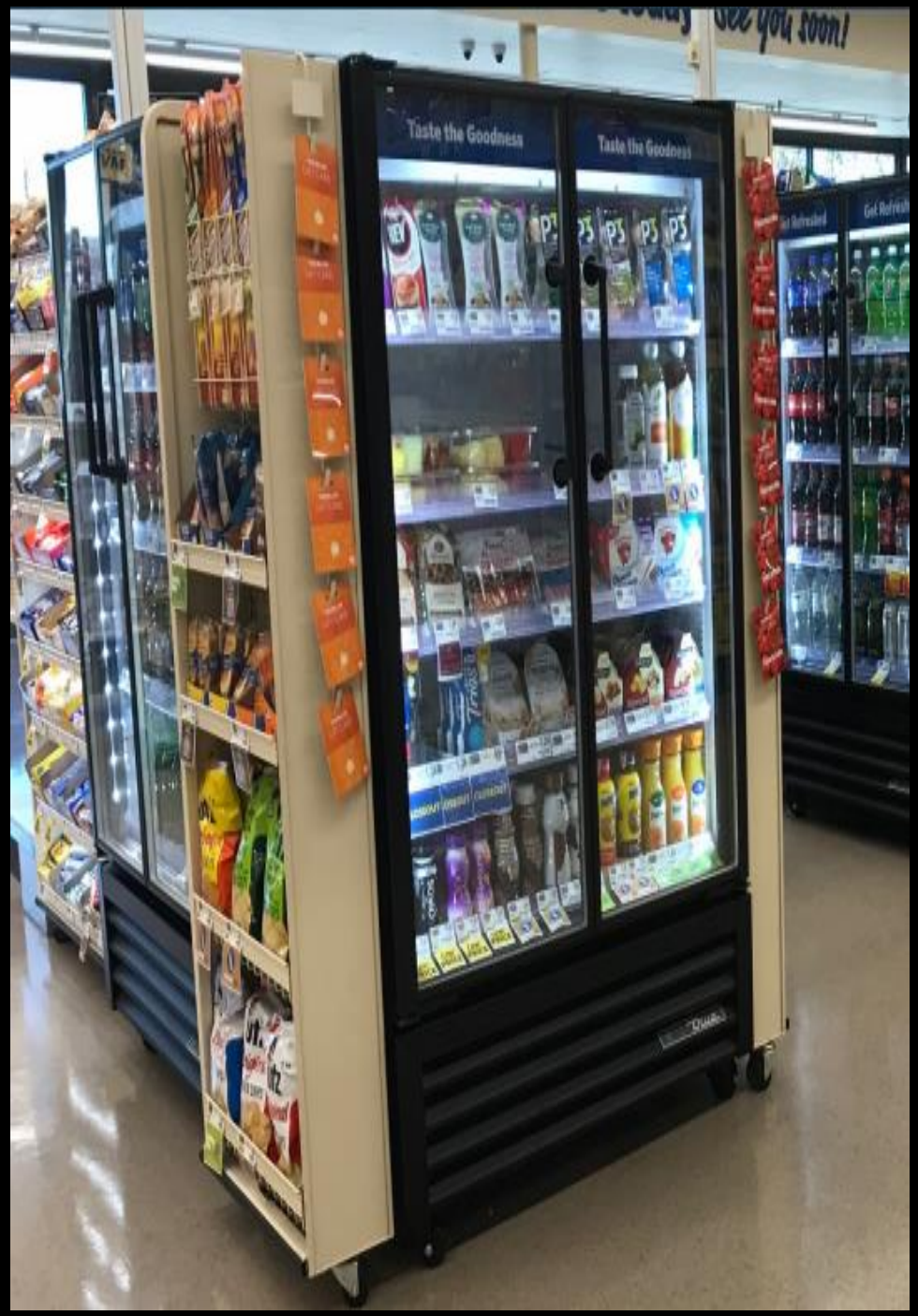
Natural Refrigerants

Transcritical CO2 System

- No toxicity or flammability (A1)
- Higher operating pressures
- Indoor or Outdoor Installation
- Sensitive to ambient temp
  - Great for Vermont!



Self-contained Propane Cases

- New or existing stores
- Significant Energy Savings
  - 30-50%
- Placement Flexibility
- Ease of Use
- Capital Costs – Self contained vs. Rack

R290 Heat pumps

- Vaillant producing R290 air to water heat pumps in Germany
- aroTHERM
- ¾ ton to 3 ton capacity
- Many other European manufacturers are jumping in

CO2 Heat Pumps

- Seasonal COP’s greater than 3
- Water temperatures up to 170 degrees
- $600 Efficiency Vermont Rebate

Market Trends in Refrigeration

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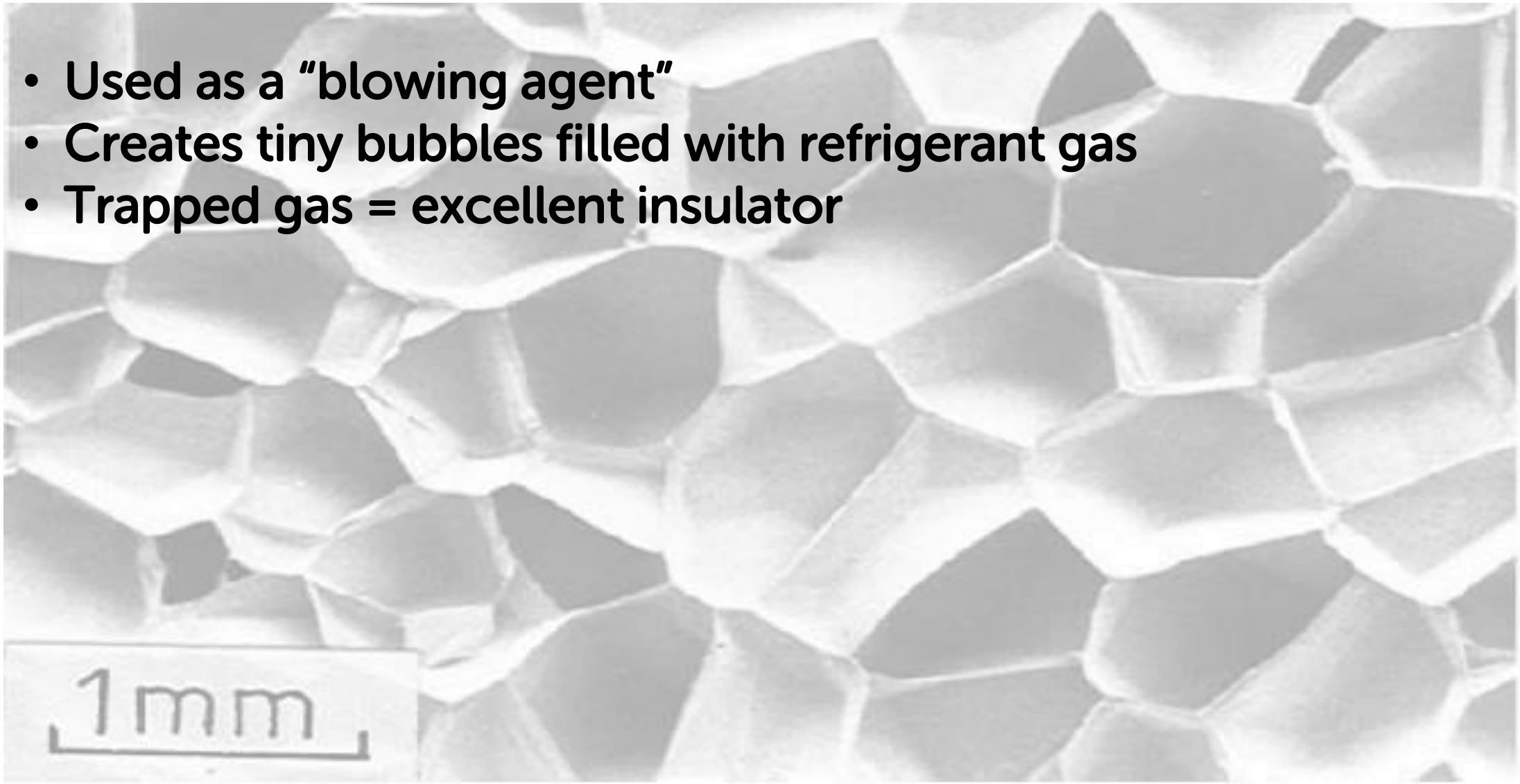
Refrigerants and Polyurethane Foam

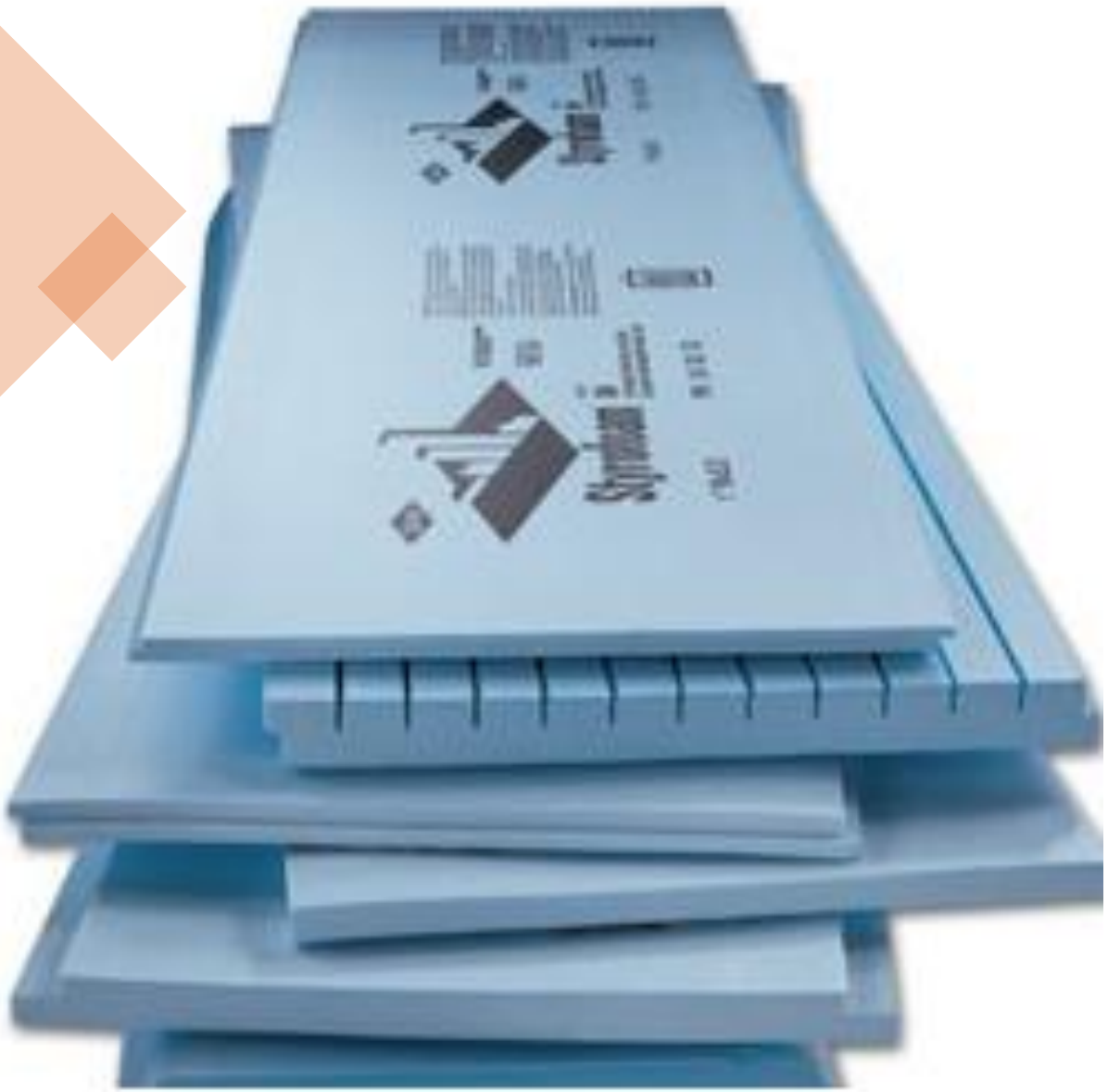


- Used as a “blowing agent”
- Creates tiny bubbles filled with refrigerant gas
- Trapped gas = excellent insulator

Refrigerants Used in Foam

Trends in Spray Foam

- **HFO**, the new stuff, since 2017
  - **Honeywell Solstice** GWP <5
  - Several products available
  - R 7.4/inch
  - 10-15% price premium
  - Single “lift” 6.5”



Trends in Foam Board

- **XPS, “blue/pink board”**
  - **Still manufactured using HFCs**
  - **Despite HFO proof of concept (2012)**

Natural Refrigerants

Store Type and Surface Area (ft^2)	Trend Architecture and Refrigerant Toward 2020
Warehouses and Large Supermarkets >40k ft^2	Centralized Architecture: CO_2 Booster, NH_3 / CO_2 Cascade HFO Blend / CO2 
Medium-Size Supermarkets 10k to 40k ft^2	Centralized: HFO/CO_2 or Booster CO_2  Semi-Centralized/Distributed HFO or CO_2 
Small Supermarkets and Hard Discounts 6k to 10k ft^2	Centralized: HFO or CO_2  Distributed HFO or CO_2  Integrated Display Cases R-290 
C-Stores 1.2k to 6k ft^2	Distributed HFC/HFO/CO_2  Integrated Display Cases R-290/Plug-Ins 
Restaurants <1.2k ft^2	Distributed HFC/HFO  Multiple Units  Integrated Display Cases R-290 

Residential

Market Trends in HVAC

Refrigerant Showdown… who will come out on top?

- 410a replacement
- A1 vs A2L vs A3
- Not many HVAC OEM's are focused on refrigerant evolutions
  - **Ingersoll Rand (Trane) Leaders**
  - **Heavily focused on HFO blends**
- CA After 2022
  - AC equipment must have a GWP <750
  - Be ready for different refrigerants that have glide

Tying it All Together

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Conclusions

1. We need refrigeration
2. Refrigeration is having a huge impact on our environment
3. Change/regulation is coming
4. We have market ready solutions
5. ….for most industries
6. We’re here to help

How to Get Involved

Refrigerant **Leak Repair**

- 80% project cost reimbursement

Purchase **Natural Refrigerant** equipment

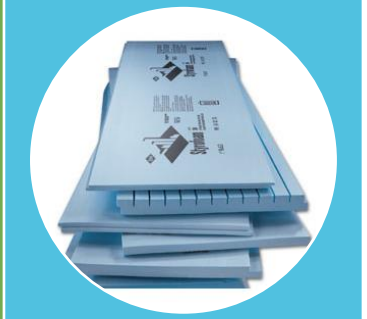
Refrigerant Connections

- “press fit” is least likely to leak
- Pressure test systems

Refrigerant Charge

- Low charge systems = GOOD
- High charge = BAD

Request HFO blown spray foam



Avoid XPS foam

Discussion and Questions

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