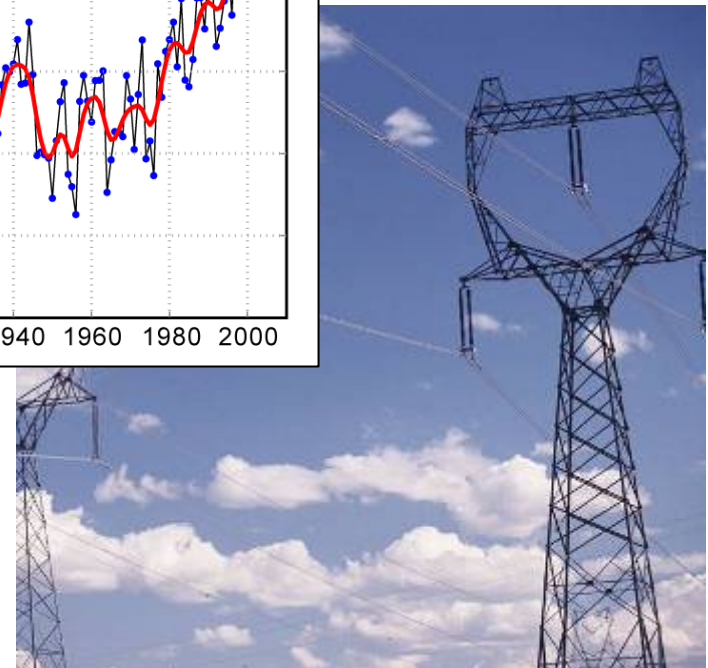
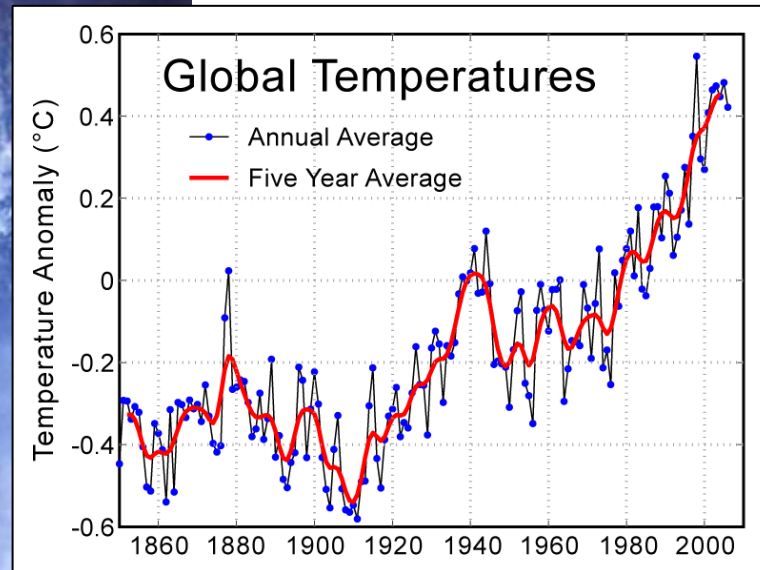
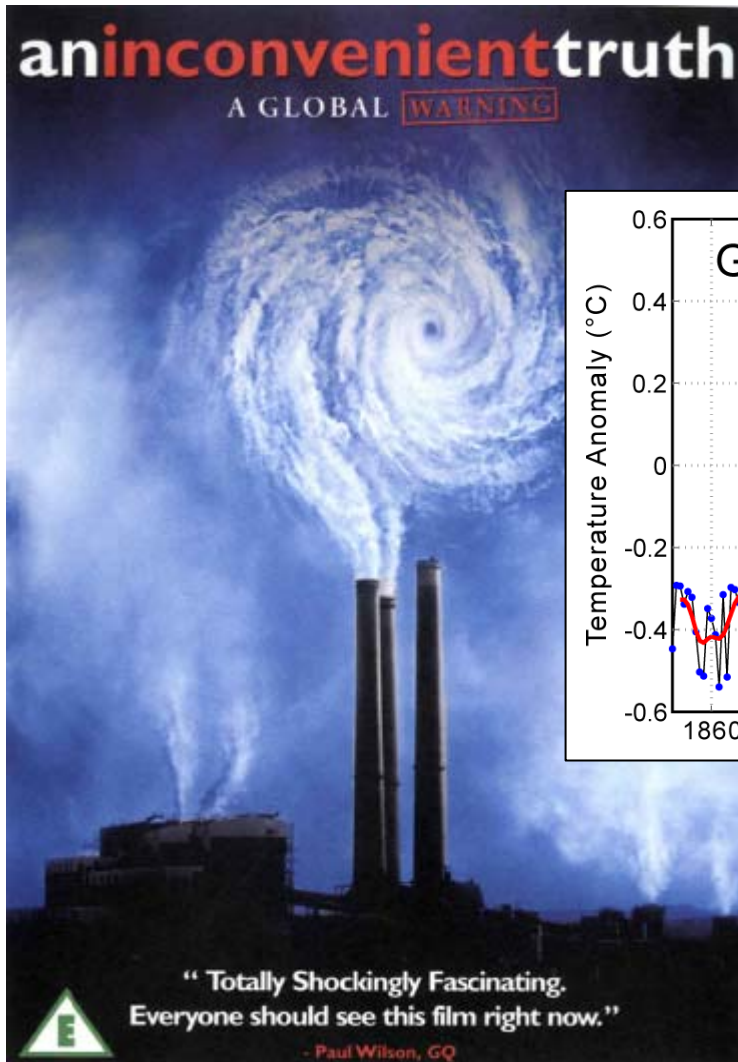




Greenhouse Gases, Climate Change and R22: What's the next phase?

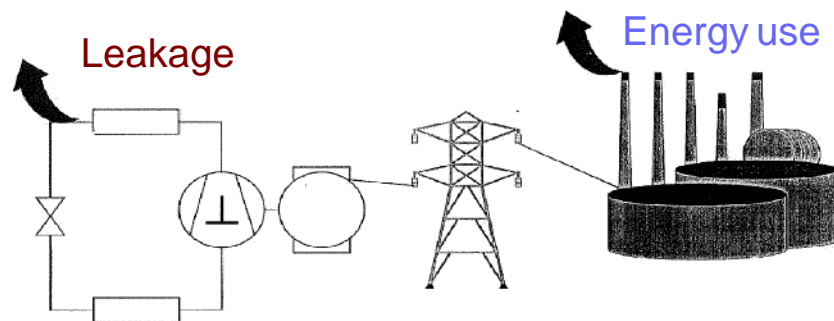
The Global Warming Focus...



GHG Emissions of HVAC&R Systems

Emission categories:

- **Energy use for system operation**
 - “Indirect Emissions”
- **Refrigerant leakage/release**
 - “Direct Emissions”

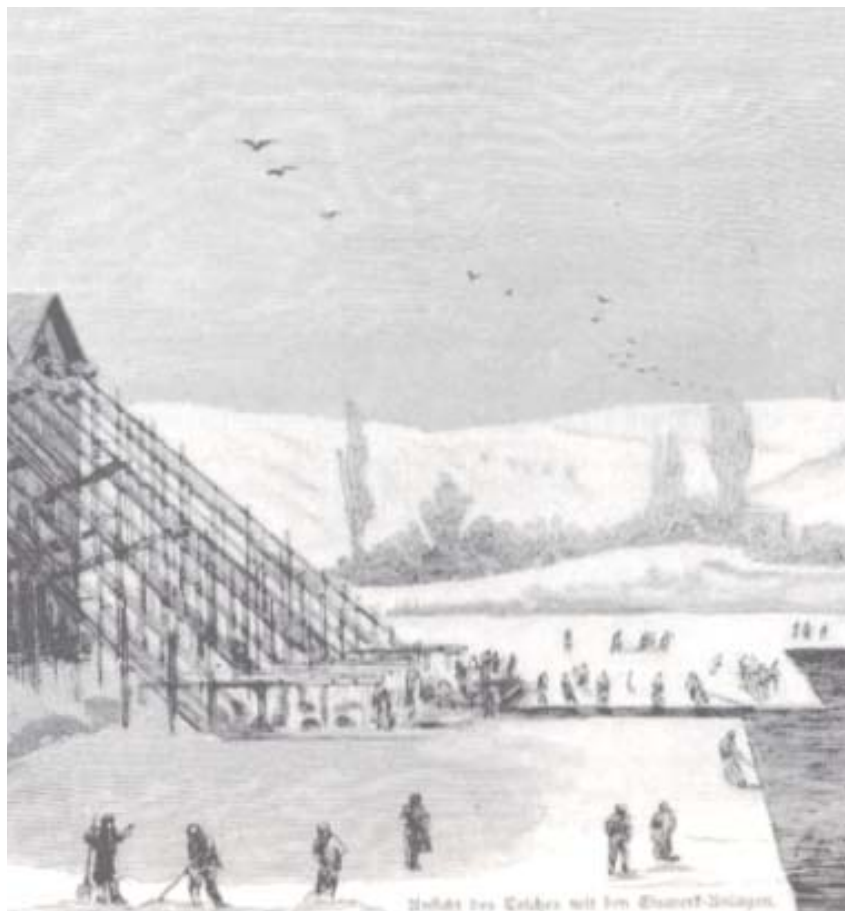


Applications

sorted by direct emissions:

1. Mobile Air Conditioning (HFC)
2. Supermarket Refrigeration (DX HFC)
3. Unitary A/C & Heat Pump (HFC)
4. Commercial Air Condition (HFC)
5. Light Commercial SME (HFC)
6. Water Chiller (HFC)
7. Domestic Refrigerator (HFC)
8. Domestic Refrigerator (HC)

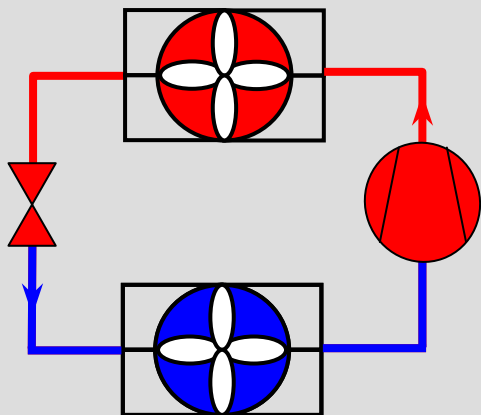
Different Ways of Cooling



Cooling technologies:

- Reverse Rankine
- Stirling
- Magneto caloric refrigeration
- Vortex tube
- Joule process
- Peltier
- Steam ejector
- Absorption
- Adsorption

Different Ways of Cooling



The traditional compression process offers the best value proposition for our industry

But which refrigerants and technologies should be used for greatest sustainability?

Cooling technologies:

- Reverse Rankine
- Stirling
- Magneto caloric refrigeration
- Vortex tube
- Joule process
- Peltier
- Steam ejector
- Absorption
- Adsorption

What refrigerants are made of...

more flammable

GROUP IA
↑
CORROSI
metalloid

Table of Selected Radioactive Isotopes

only 8 elements are really suitable for refrigerant molecules

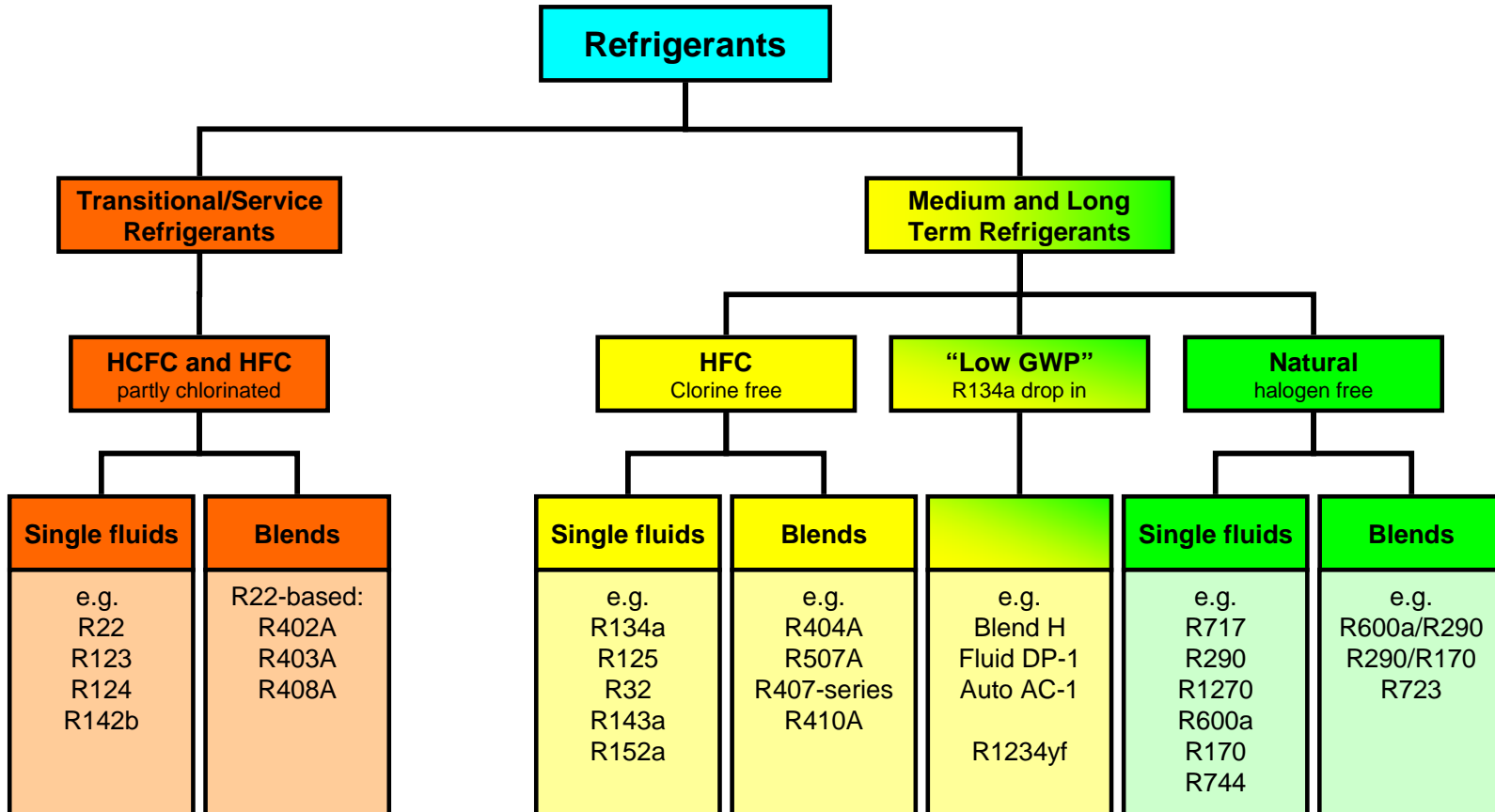
more toxic



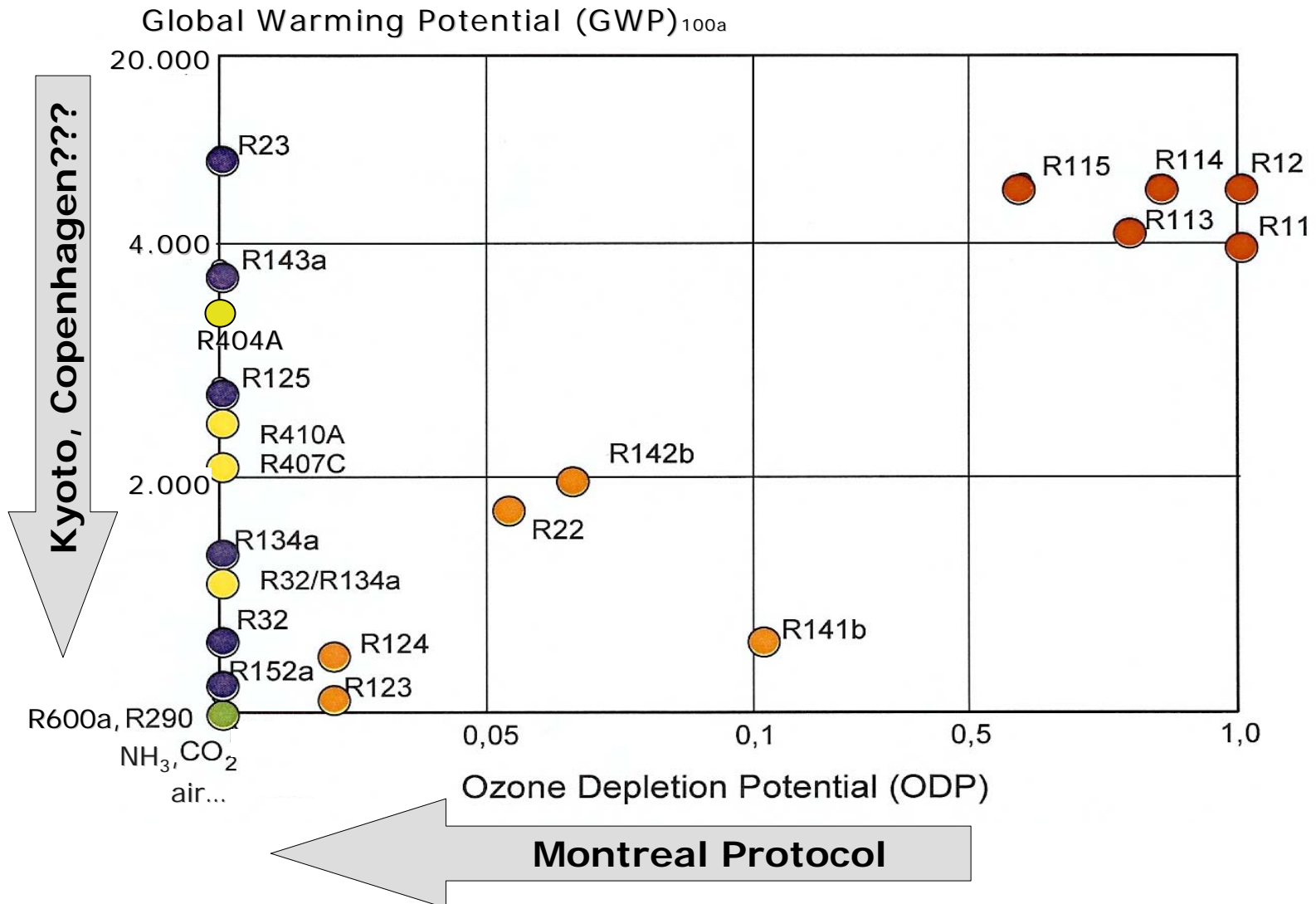
58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

NOTES:
 (1) Black — stable; red — gas; blue — liquid; white — solid.
 (2) Based upon carbon-12; (1) indicates most stable or least known isotope.
 (3) Extreme marked with asterisk refer to the gaseous state at 273 K and 1 atm and are synthetic.
 (4) Estimated values.

Refrigerant Options



Ozone Depletion and Global Warming



Minimizing GHG Emissions from the HVAC&R Industry

1. Apply latest appropriate technologies and components
2. Service the systems to ensure optimal operation
3. Enhance and ensure energy efficient system operation by adding intelligence to components
4. Avoid refrigerant emissions
(component design, system layout, tightness & handling practices)
5. Minimize refrigerant charge
6. Enhance system configuration (layout)
7. Enhance component efficiency
8. Apply refrigerants with low GWP

Danfoss's Ways to Reduce GHG Emissions

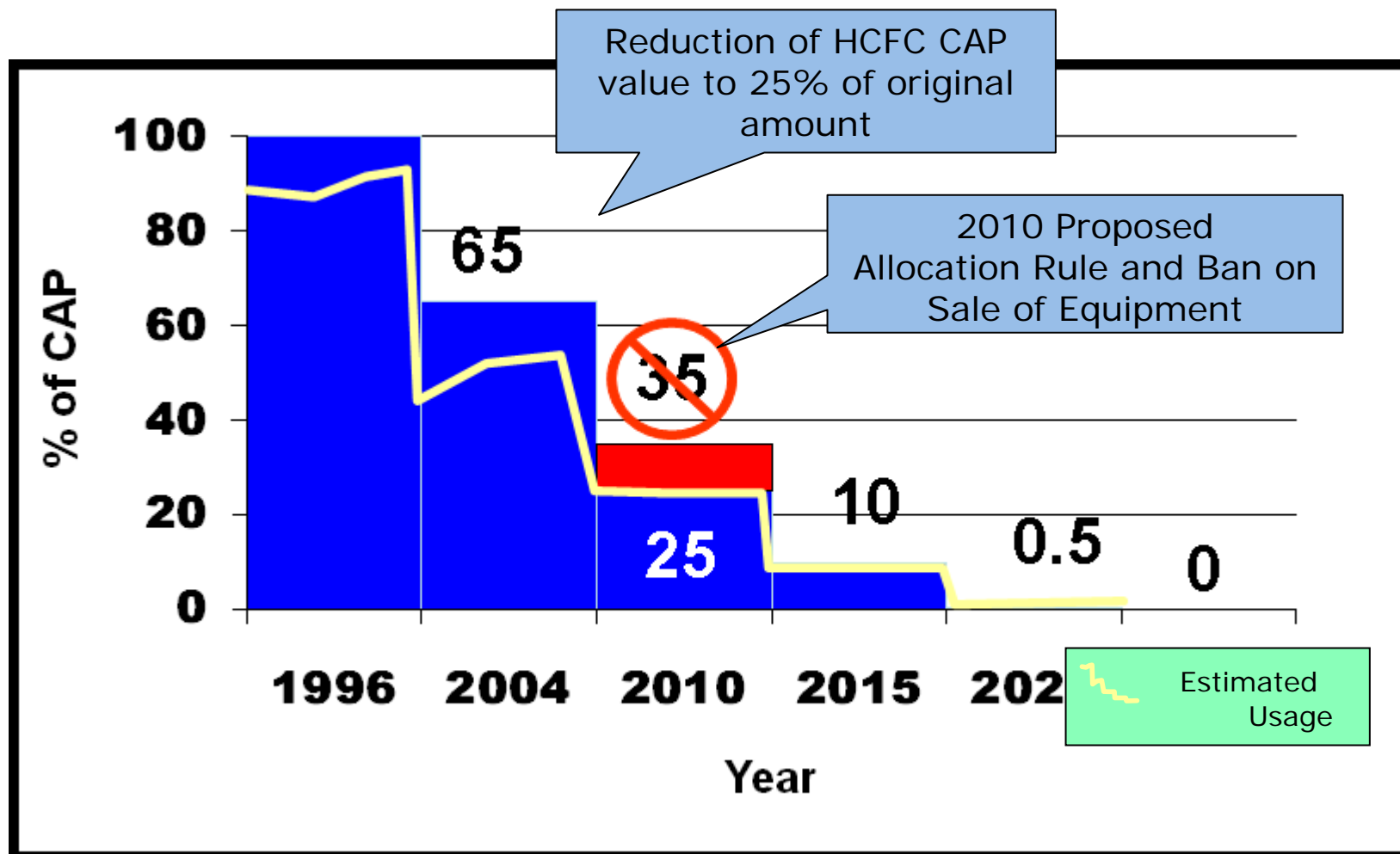


- Develop low charge and low leakage solutions
- Enhance significantly the system's energy efficiency e.g. by applying variable speed and increased component intelligence as well as Ease of Use concepts etc.
- Support the application of low GWP (natural) refrigerants where commercially viable and technical feasible



R-22 Alternatives for 2010: Options and Opportunities

Clean Air Act: 2010 Reduction



HCFCs - Clean Air Act

- ***FACT:*** HCFCs manufactured or imported as of January 1, 2010:
 - Used only to service equipment manufactured before 2010
 - This is NOT a ban on the manufacture of equipment!



2 New Proposed Rules

- Allocation Rule: Says who is allowed to make/import NEW HCFC refrigerant to meet CAP
 - Also: Definition of 'manufacture'
- Pre-Charged Appliance Rule: Proposes limits on the sale and distribution of pre-charged products
 - Appliances versus Components

Definitions in Proposed Rules

- Manufactured
 - Refrigerant loop is completed and unit functions
 - Holds complete and proper charge
 - Ready for its intended purpose
- Appliance: any device which contains and uses a refrigerant...for household or commercial purposes
 - (air conditioner, refrigerator, chiller, freezer)
- Components: condensing units, line sets, expansion valves
 - Not considered appliances



Proposed Pre-Charged Appliance Rule

- Sale and Distribution allowed after 1/1/2010
 - Self contained pre-charged appliances manufactured before 1/1/2010
 - Pre-charged components manufactured before 1/1/2010 used to service equipment manufactured before 1/1/2010
- Sale and Distribution not allowed after 1/1/2010
 - Any pre-charged appliance manufactured after 1/1/2010 using new refrigerant
 - Pre-charged components manufactured after 1/1/2010 using new refrigerant



AREP Study: 1992 – 1997

- evolution of refrigerants

<u>Refrigerant</u>	<u>Components</u>	<u>Glide</u>	Pressure Match				
			<u>-20</u>	<u>10</u>	<u>40</u>	<u>110</u>	<u>130</u>
R-22	22	0	10	33	68	226	297
<u>Look-Alike Blends</u>							
R-407C	32 / 125 / 134a	10	10	34	71	245	324
Others in Future	??	?	Lower / Similar / Higher?				
<u>New Equipment Only</u>							
R-410A	32 / 125	0.2	27	62	118	365	476



Retrofit Property Match: PT

<u>Refrigerant</u>	<u>Components</u>	<u>Glide</u>	<u>Pressure Match</u>				
			<u>-20</u>	<u>10</u>	<u>40</u>	<u>110</u>	<u>130</u>
R-22	22	0	10	33	68	226	297
<u>Look-Alike Blends</u>							
R-417A	125 / 134a / 600	6.5	6	26	59	206	274
R-424A	125/134a/600a/600/601a	7	6	27	60	210	278
R-421A	125 / 134a	8	8	29	63	220	291
R-422B	125 / 134a / 600a	6	8	30	65	221	292
R-427A	32 / 125 / 143a / 134a	13	9	32	69	235	311
R-422D	125 / 134a / 600a	6	10	34	71	238	313
R-407C	32 / 125 / 134a	10	10	34	71	245	324
R-407A	32 / 125 / 134a	11	12	37	78	259	345
R-434A	125/143a/134a/600a	4	14	40	80	268	340
R-421B	125 / 134a	8	14	41	83	268	352
R-404A (R-507)	125 / 143a / 134a	1.5	16	44	86	271	356
R-422A / C	125 / 134a / 600a	4.5	16	43	86	274	358
Others in Future	??	?	Lower / Similar / Higher?				
<u>New Equipment Only</u>							
R-410A	32 / 125	0.2	27	62	118	365	476



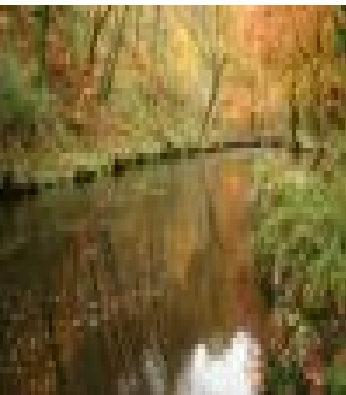
Short List of R-22 Retrofit Blends

<u>Refrigerant</u>	<u>Components</u>	<u>Glide</u>	Pressure Match				
			<u>-20</u>	<u>10</u>	<u>40</u>	<u>110</u>	<u>130</u>
R-22	22	0	10	33	68	226	297
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R-407A	32 / 125 / 134a	11	12	37	78	259	345
R-404A (R-507)	125 / 143a / 134a	1.5	16	44	86	271	356

Issues with Systems

- Refrigeration or Air Conditioning?
 - Evaporator Temperature
 - Complexity of System
- Storage / Cycling or Full Capacity?
 - Cycling systems can tolerate loss of capacity (longer run times)
 - Systems running full time need to match capacity
- Small or Large?
 - Small, self-contained systems = Ease of Retrofit
 - Larger systems: standard practice to change or adjust parts, change oil, other maintenance items
- Planned Retrofit or Change Refrigerant during Service Call for Something Else?
 - If replacing a compressor, can install POE and retrofit easily

Retrofit Considerations for Blends



Environmental Properties

- Zero Ozone Depletion Potential (ODP)
- Low Global Warming Potential (GWP)
 - “Hot” topic at Food Marketing Institute Energy Conference
 - California regulations directed at Global Warming



Performance Properties

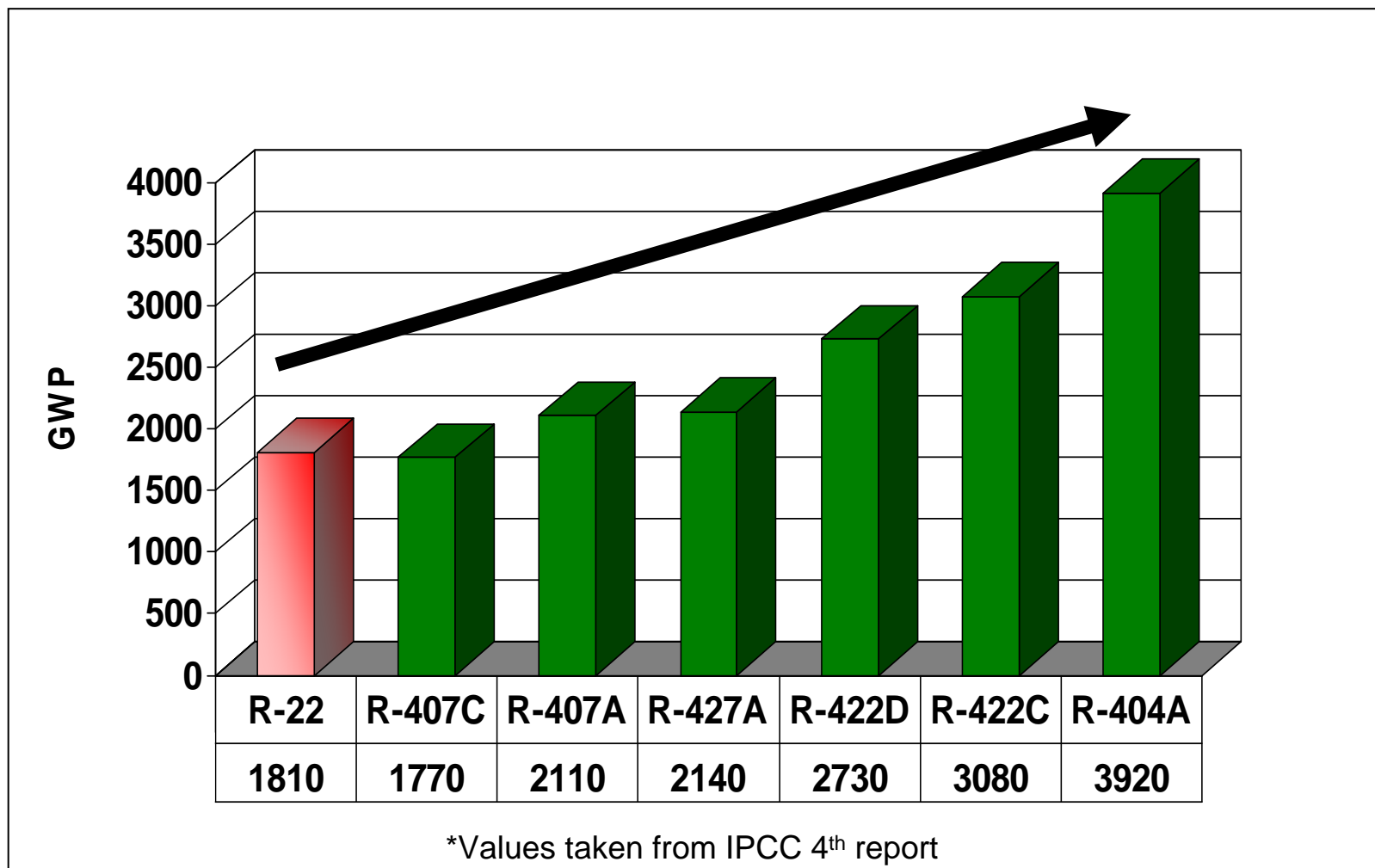
- Refrigeration Capacity – match R22 or lower?
- Efficiency - \$\$ and indirect GWP contribution
- Pressure Drop / Component Sizing (TXV, distributor)



Ease of Retrofit

- Change system components?
- Change oil? How much?
- Adjustment of controls?

Global Warming Potential



Existing Systems Can Be Retrofitted

- Hermetic compressors and controls can be retrofitted to run on R-22 substitutes, following a series of modifications and checks to ensure system reliability:
 - overall system performance and capacity drop
 - refrigerant and oil miscibility – Oil Circulation / capacity drop
 - heat exchanger compatibility and temperature glide
 - operating pressure compatibility with existing components
 - specification compliance and warranty requirements