AMERICA

ATMOsphere Business Case for Natural Refrigerants

June 5-7, 2017 / San Diego

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The Energy Efficiency in Washington DC Office Buildings and Hospitals when Using Total Energy CO_2 Systems for Heating and Cooling

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ISSUES

- Energy Consumption
- Global Warming Resulting from Energy Consumption
- Global Warming Resulting from HFC/HCFC Fugitive Gases
- Cooling Water Consumption
- Legionella Disease
- How can CO_2 Improve the Energy Performance?

Benefits of CO_2 Refrigeration and Hybrid Evaporative Condenser/Gas Coolers.

- Reduces Electrical Energy Consumption.
- Virtually Eliminates Gas Consumption for Building Heating and Domestic Hot Water.
- Reduces Global Warming Emissions Due to Reduction in Energy Consumption and Fugitive HFC Refrigerant Gases.
- Reduces Cooling Water Consumption.
- Virtually Eliminates the Danger of Legionella Disease.

Figure 1:- Total HVAC Primary Energy Use by Building Type in the USA.

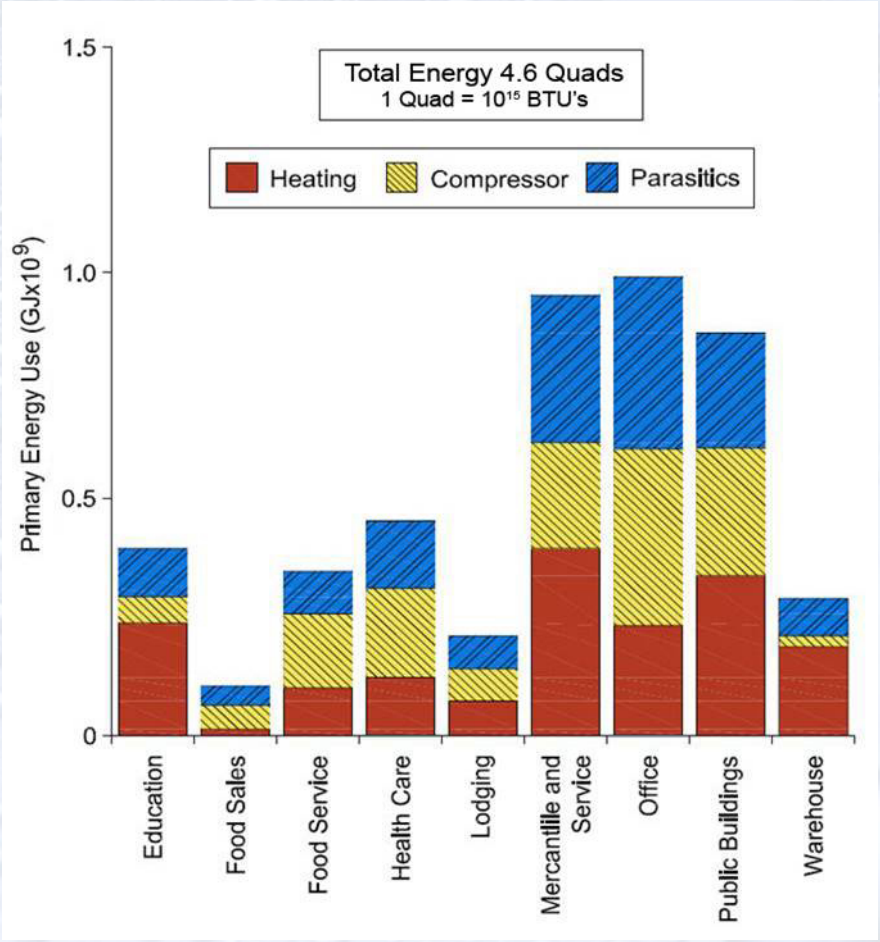

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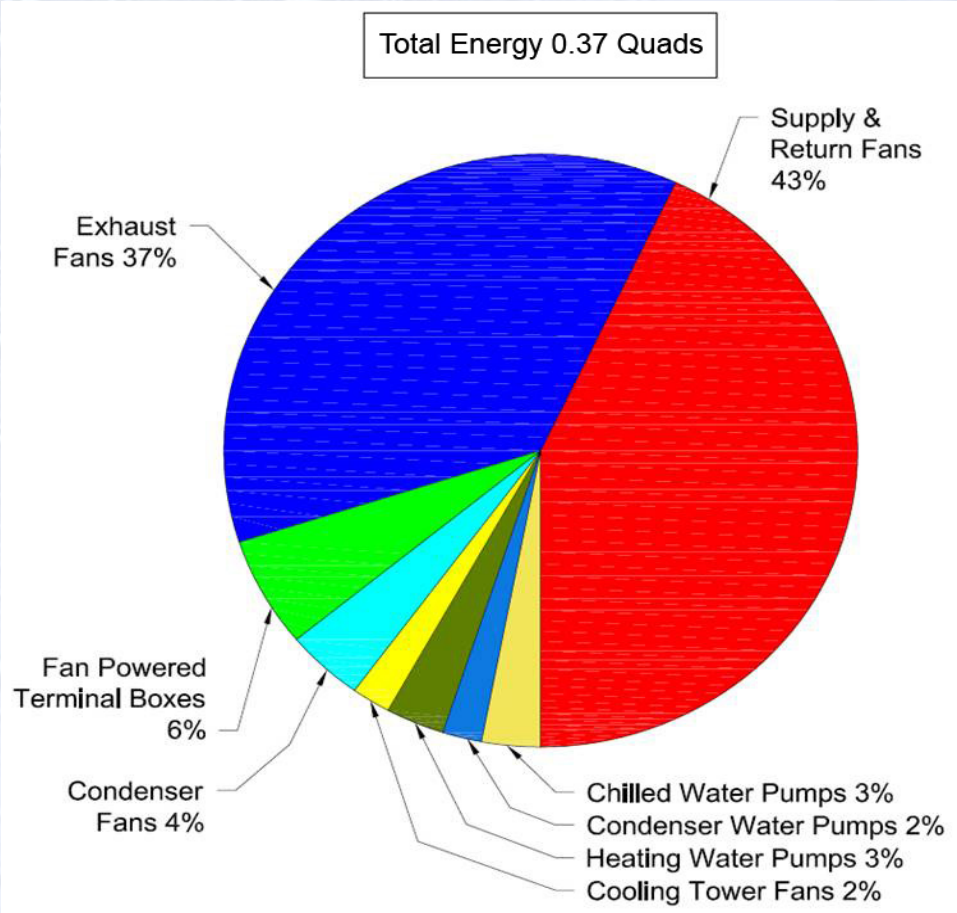
Figure 2:- Parasitic Primary Energy use by Type of Equipment.



The Energy Efficiency in Washington DC Office Buildings and Hospitals when Using Total Energy CO_2 Systems for Heating and Cooling

Table 1:- Development of Seasonally Weighted Coefficient of Performance (COP) for USA Office Buildings.

Equipment Type	COP [1]	COP Correction Factor for Fans	COP Corrected	Office Area Applied to [2]		Weighted Contribution to Mean COP
				$Ft^2 \times 10^6$	%	
Centrifugal Chiller	4.4	1	4.4	1,453	15	0.66
Water Cooled Screw Chiller	4.14	1	4.14	194	2	0.083
Water Cooled Recip Chiller	3.91	1	3.91	291	3	0.117
Air Cooled Screw Chiller	3.17 [3]	1.1 [5]	3.49	388	4	0.140
Air Cooled Recip Chiller	2.71 [3]	1.1 [5]	2.98	1,550	16	0.477
PTAC. PTHP	2.49 [4]	1.3 [6]	3.24	635	7	0.227
Room AC	2.34 [4]	1.3 [6]	3.04	624	6	0.182
Packaged AC	2.13 [4]	1.3 [6]	2.9	3,778	39	1.13
Heat Pump	2.13 [4]	1.3 [6]	2.9	667	7	0.203
Absorption Chiller	0.98	1.0	0.98	97	1	0.001
TOTAL				**9,677**	**100**	**3.22**

(1) Westphalen et al (1999)
(2) Westphalen et al (1999)
(3) Includes condenser fans
(4) Includes condenser and evaporator fans
(5) Adjustment factor for condenser fans
(6) Adjustment factor for condenser and evaporator fans

Table 2:- Development of Seasonally Weighted Coefficient of Performance (COP) for USA Health Care Buildings.

Equipment Type	COP [1]	COP Correction Factor for Fans	COP Corrected	Hospital Area Applied to [2]		Weighted Contribution to Mean COP
				$Ft^2 \times 10^6$	%	
Centrifugal Chiller	4.4	1	4.4	490	22.4	0.97
Water Cooled Screw Chiller	4.14	1	4.14	67	3.1	0.12
Water Cooled Recip Chiller	3.91	1	3.91	36	1.6	0.16
Air Cooled Screw Chiller	3.17 [3]	1.1 [5]	3.49	229	10.5	0.353
Air Cooled Recip Chiller	2.71 [3]	1.1 [5]	2.98	624	28.6	0.84
Room AC	2.34 [4]	1.3 [6]	3.04	134	6.1	0.18
Packaged AC	2.13 [4]	1.3 [6]	2.9	478	21.9	0.62
Heat Pump	2.13 [4]	1.3 [6]	2.9	81	3.7	0.11
Absorption Chiller	0.98	1.0	0.98	45	2.1	0.02
TOTAL				**2,184**	**100**	**3.35**

(1) Westphalen et al (1999)
(2) Westphalen et al (1999)
(3) Includes condenser fans
(4) Includes condenser and evaporator fans
(5) Adjustment factor for condenser fans
(6) Adjustment factor for condenser and evaporator fans

Figure 3: Heat Rejection Profile for a Commercial Compressor at 5°C Satd. Suction, 5 K Useful Suction Superheat and 5°C CO_2 Liquid Temp.

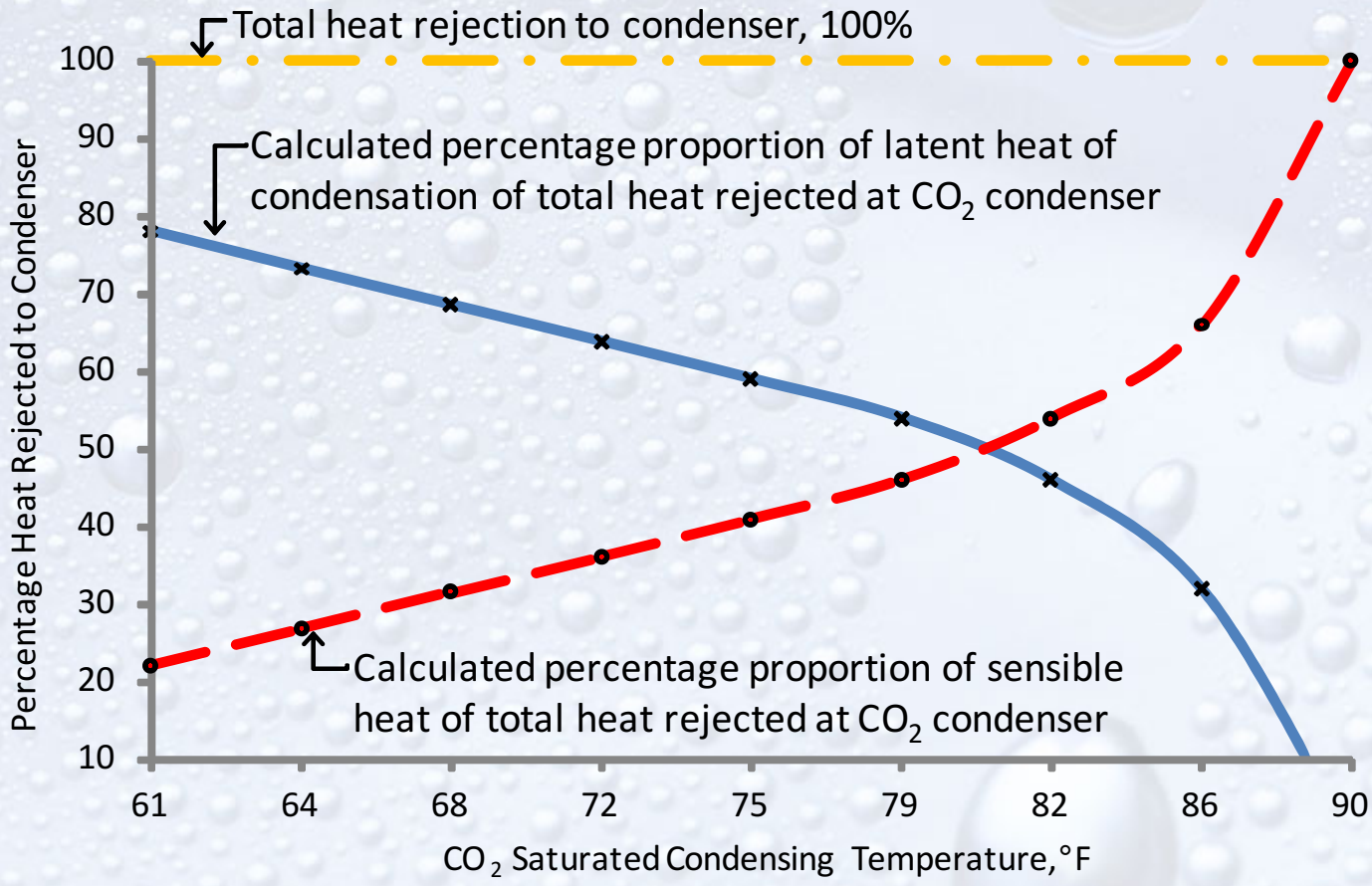


Figure 4: Performance of a Commercially Available Transcritical CO_2 Compressor at 50HZ. 40HP/16CFM.

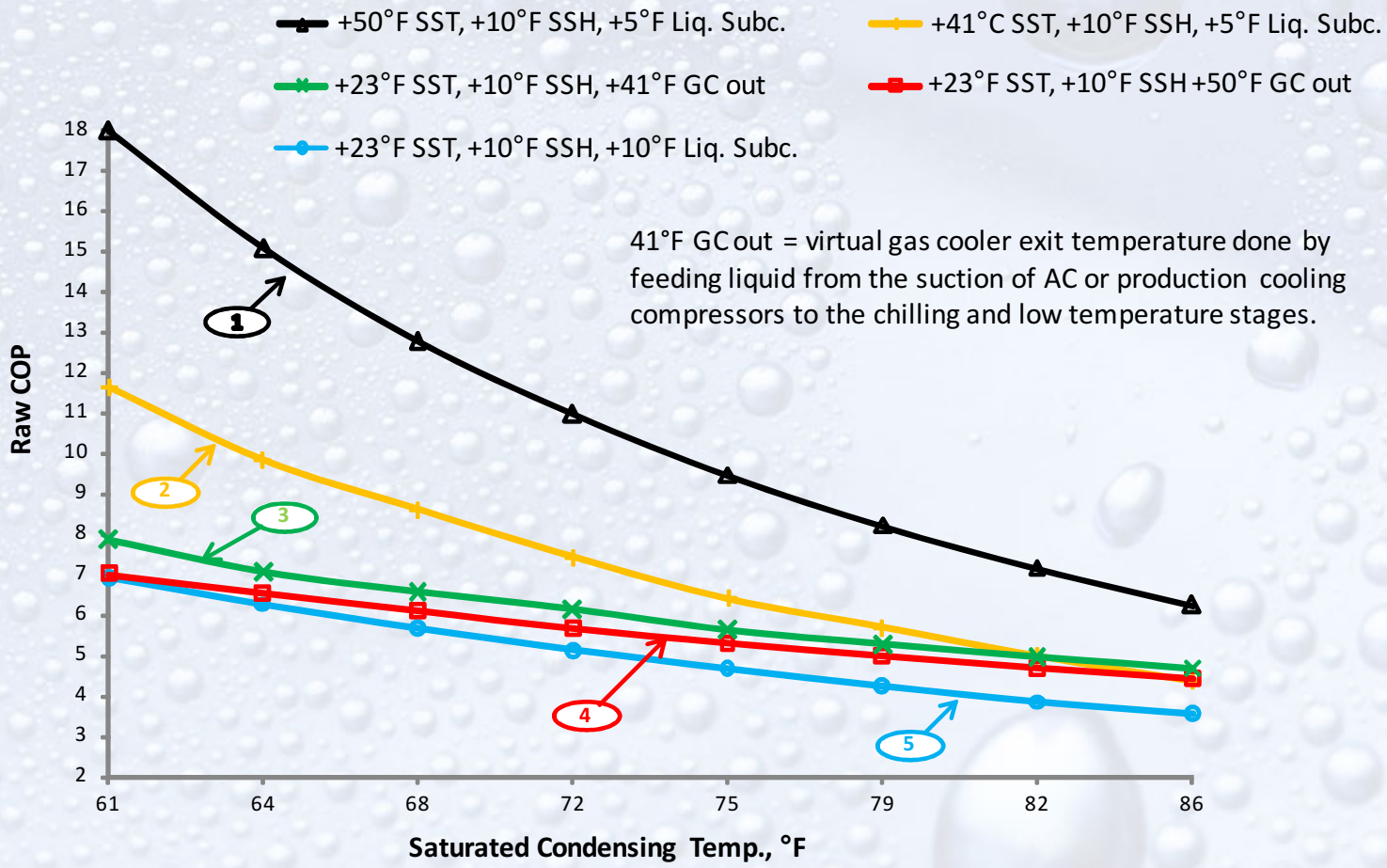
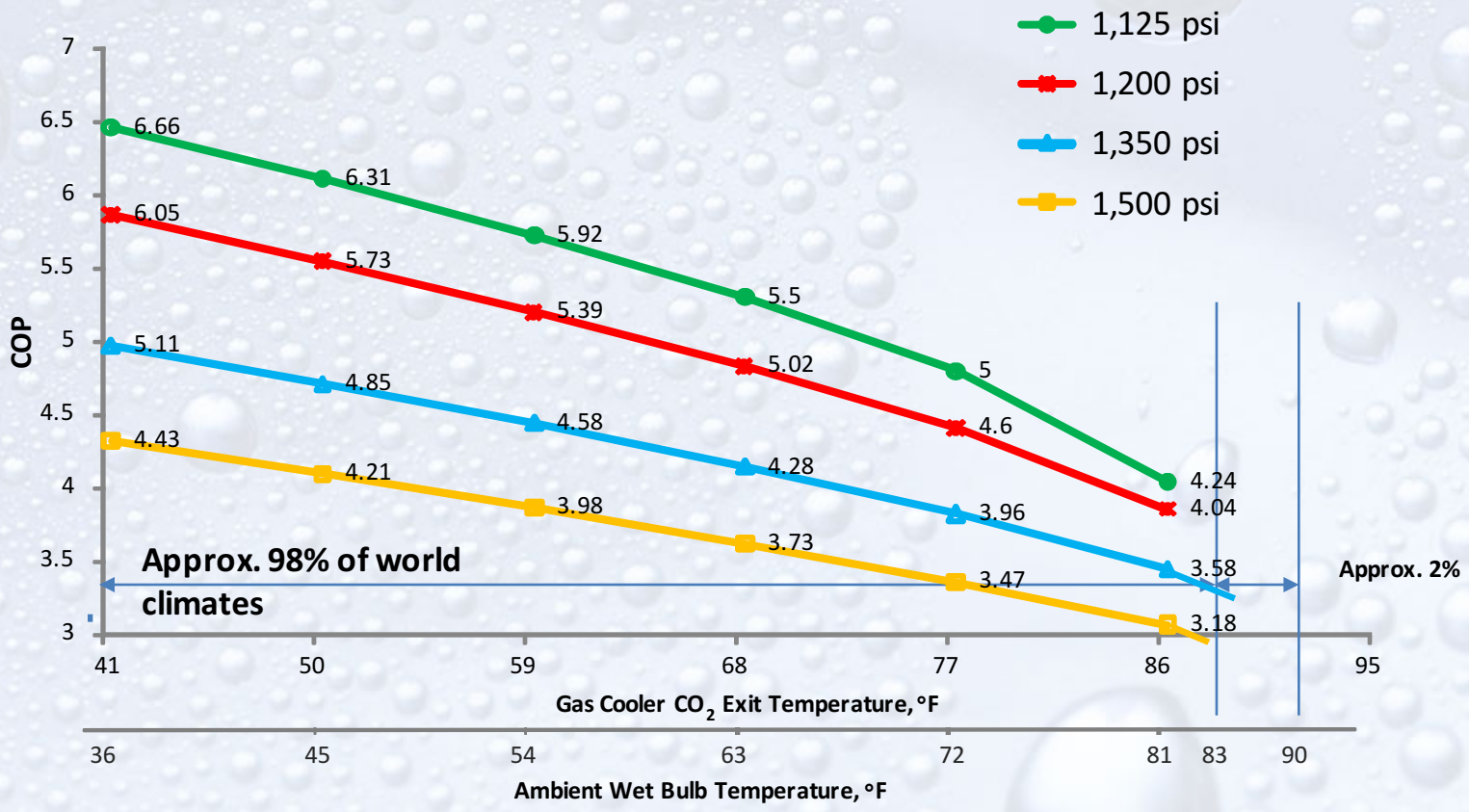


Figure 5: COP vs Supercritical CO_2 Cooler Exit Temperature at +5°C SST, 5 K SSH.



Source – Bock VAP10 Software

Figure 6: COP vs Supercritical CO_2 Cooler Exit Temperature at +10°C SST, 5 K SSH.

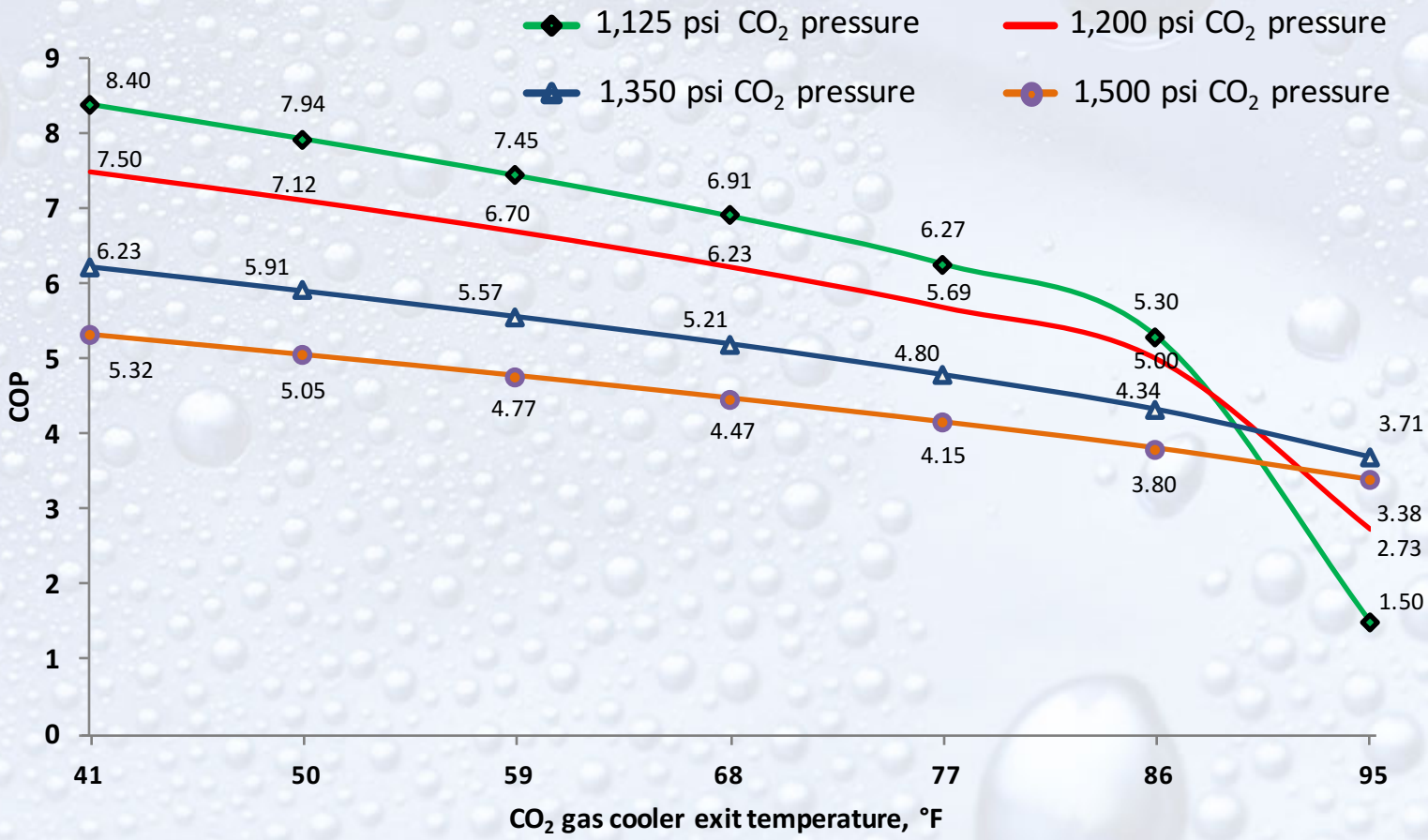


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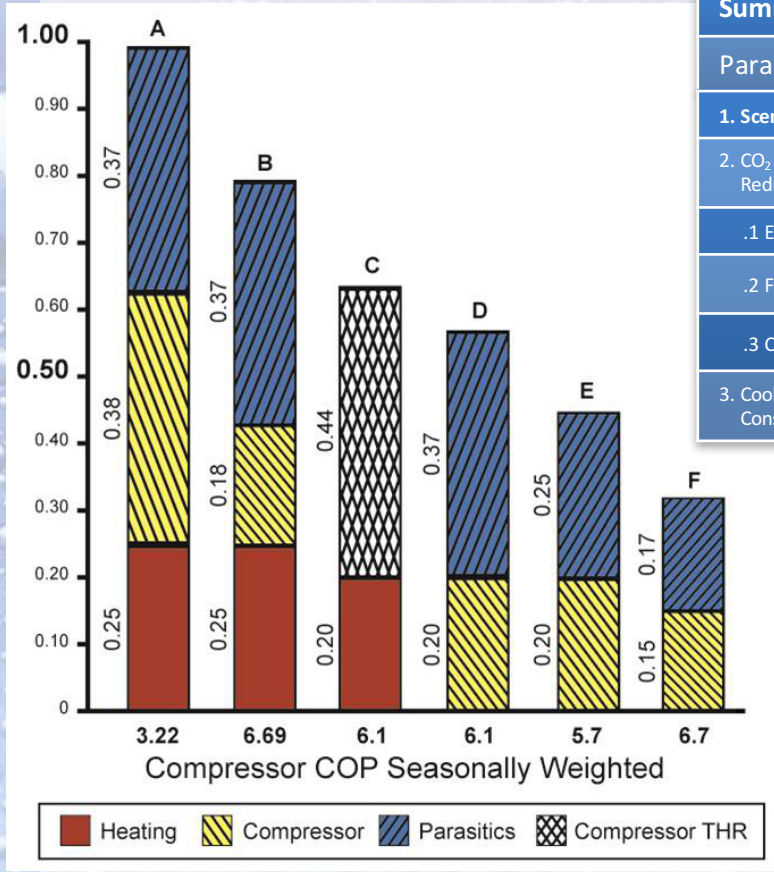
Figure 7:- Using CO_2 Refrigeration Systems for the Efficient Cooling & Heating of USA Office Buildings.



Summary of Benefits:					
Parameter	% Reduction				
1. Scenario	A	B	D	E	F
2. CO_2 Emissions Reduction due to:					
.1 Electrical Energy	0	27	24	40	57
.2 Fuel	0	0	100	100	100
.3 Chemical Refrigerants	0	100	100	100	100
3. Cooling Water Consumption	0	68	65	67	68

Legend:

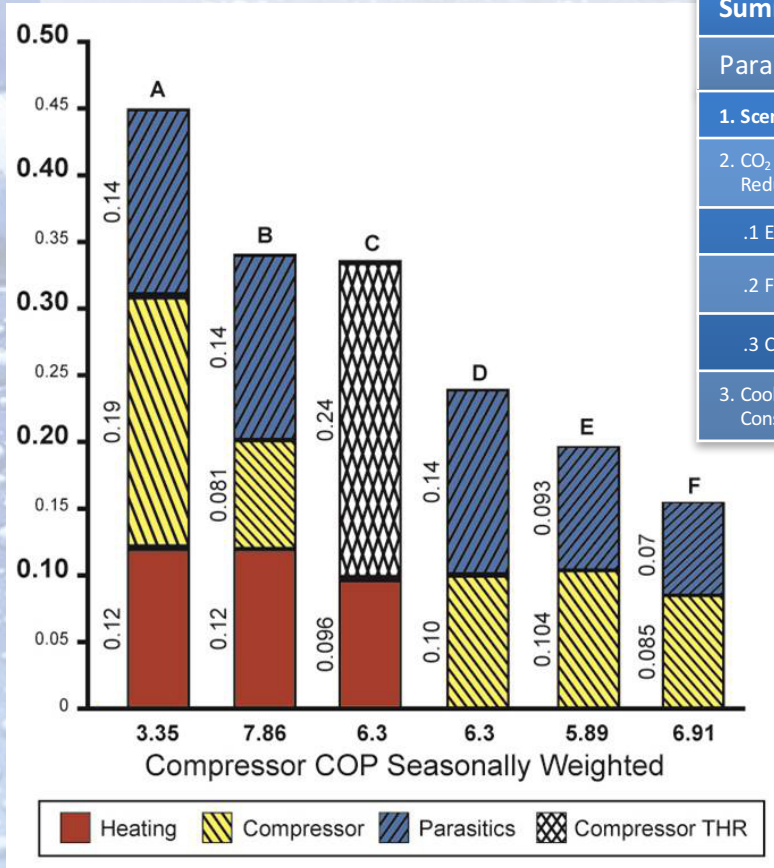
- A = Existing USA Situation in Office Buildings (2)
- B = Retrofit CO_2 Compressor
- C = Total Heat Rejection Compared with Heat Required
- D = Retrofit CO_2 Heat Recovery
- E = Slow Down Fans by 25%
- F = New Building with Pumped CO_2 and Reduced Air Flow

Energy Consumer	A	B	D	E	F	C
Parasitics	0.37	0.37	0.37	0.25	0.17	0.44 Quad Total Comp Heat Rejection
Compressor	0.38	0.18	0.20	0.20	0.15	
Heating	0.25	0.25	-	-	-	0.2 Quad Heat Required
Total	1.00	0.80	0.57	0.45	0.32	
Reduction Quad	-	0.20	0.43	0.55	0.68	
Reduction %	-	20	43	55	68	

Notes: (1) 1 Quad = 10^{15} BTU's
1 Quad = 1.0551×10^{9}

(2) Westphalen, D. And Koszalinski S., (October 1999) *"Energy Consumption Characteristics of Commercial Building HVAC GJ Systems Volume II: Thermal Distribution, Auxiliary Equipment and Ventilation."* Arthur D. Little Inc (ADLI) 20 Acorn Park, Cambridge, MA 02140-2390 ADLI Ref No 33745-00 for US Department of Energy Contract No DE-AC01-96CE23798

Figure 8:- Using CO_2 Refrigeration Systems for the Efficient Cooling & Heating of USA Hospitals.



Summary of Benefits:					
Parameter	% Reduction				
1. Scenario	A	B	D	E	F
2. CO_2 Emissions Reduction due to:					
.1 Electrical Energy	0	33	27	40	53
.2 Fuel	0	0	100	100	100
.3 Chemical Refrigerants	0	100	100	100	100
3. Cooling Water Consumption	0	57	64	66	70

Legend:
A = Existing USA Situation in Office Buildings (2)
B = Retrofit CO_2 Compressor
C = Total Heat Rejection Compared with Heat Required
D = Retrofit CO_2 Heat Recovery
E = Slow Down Fans by 25%
F = New Building with Pumped CO_2 and Reduced Air Flow

Energy Consumer	A	B	D	E	F	C
Parasitics	0.140	0.140	0.140	0.093	0.070	0.240 Quad Total Comp Heat Rejection
Compressor	0.190	0.081	0.100	0.104	0.085	
Heating	0.120	0.120	-	-	-	0.096 Quad Heat Required
Total	0.450	0.341	0.240	0.197	0.155	
Reduction Quad	-	0.109	0.210	0.253	0.295	
Reduction %	-	24.2	46.7	56.2	65.5	

Notes: (1) 1 Quad = 10^{15} BTU's
1 Quad = 1.0551×10^{9} GJ

(2) Westphalen, D. And Koszalinski S., (October 1999) *"Energy Consumption Characteristics of Commercial Building HVAC Systems Volume II: Thermal Distribution, Auxiliary Equipment and Ventilation."* Arthur D. Little Inc (ADLI) 20 Acorn Park, Cambridge, MA 02140-2390 ADLI Ref No 33745-00 for US Department of Energy Contract No DE-AC01-96CE23798

Figure 9:- Schematic of a Conventional Central System with Water Chiller & Cooling Tower.

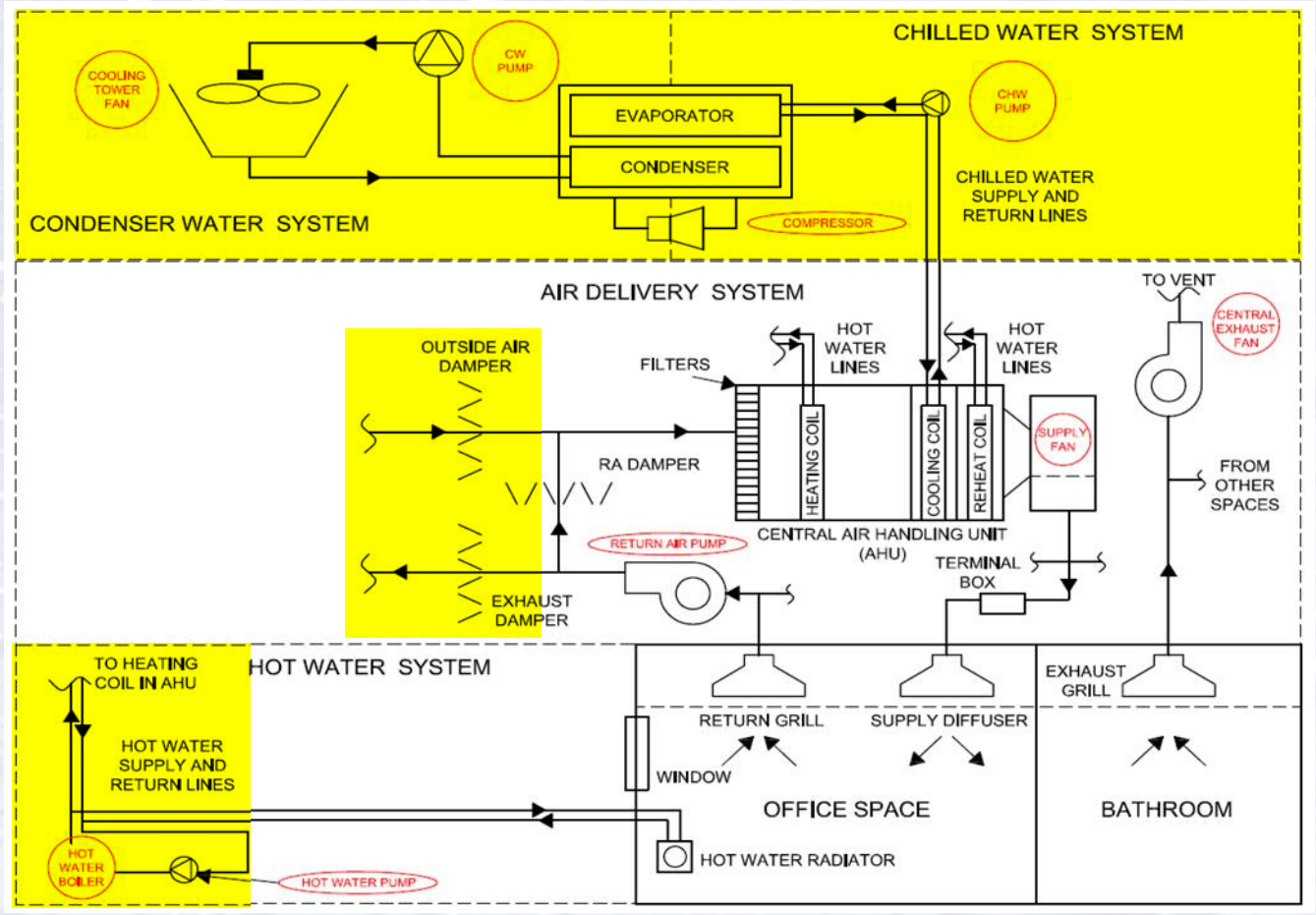


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Figure 10:- Schematic of a Central System with CO_2 Cooled Water Chiller, Exhaust Air Energy Recovery and Water Heating.

NB: Evaporative Condenser/Gas Cooler in Lieu of Cooling Tower.

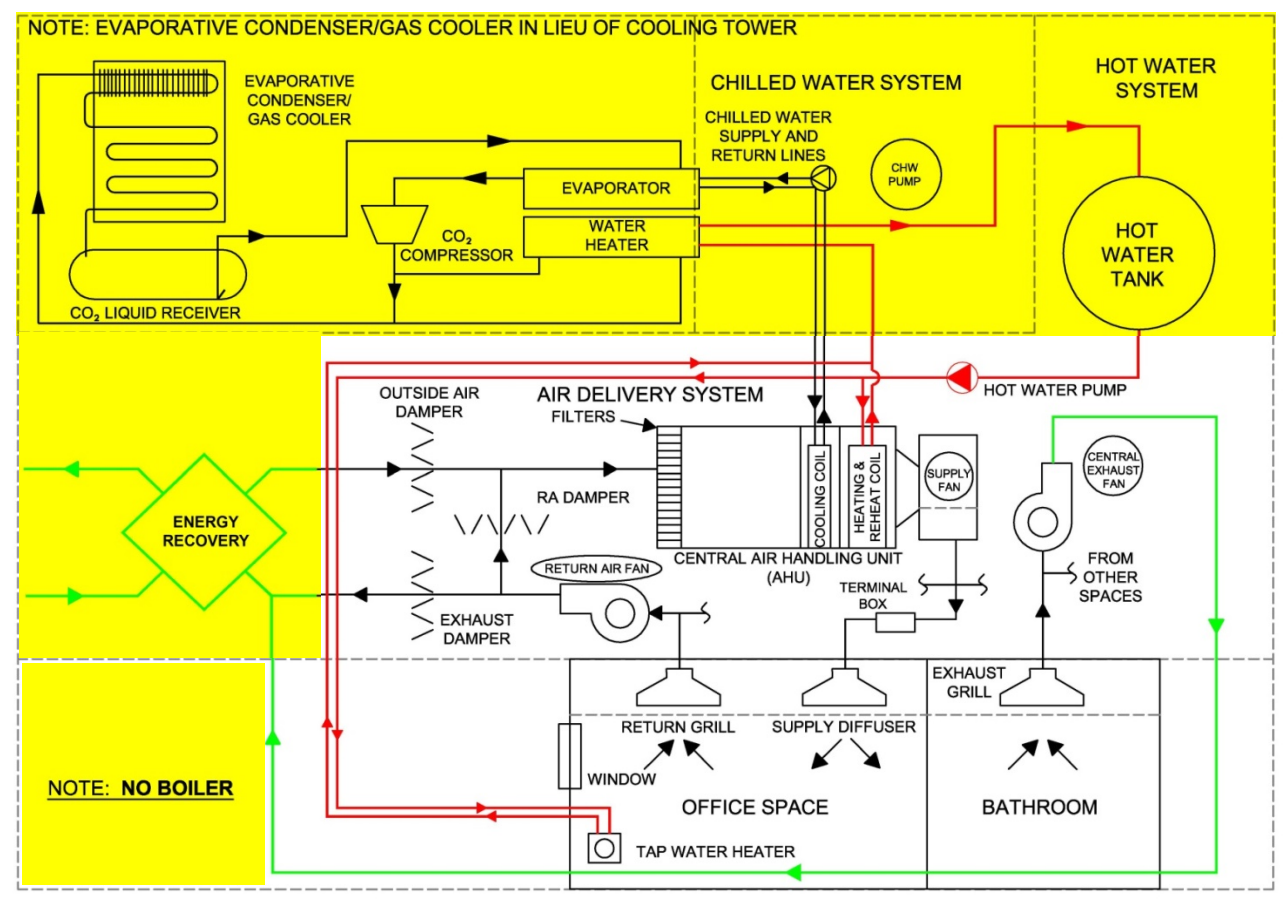


Figure 11:- Schematic of a Central System with CO_2 Liquid Recirculation, Exhaust Air Energy Recovery and Water Heating.

NB: Evaporative Condenser/Gas Cooler in Lieu of Cooling Tower.

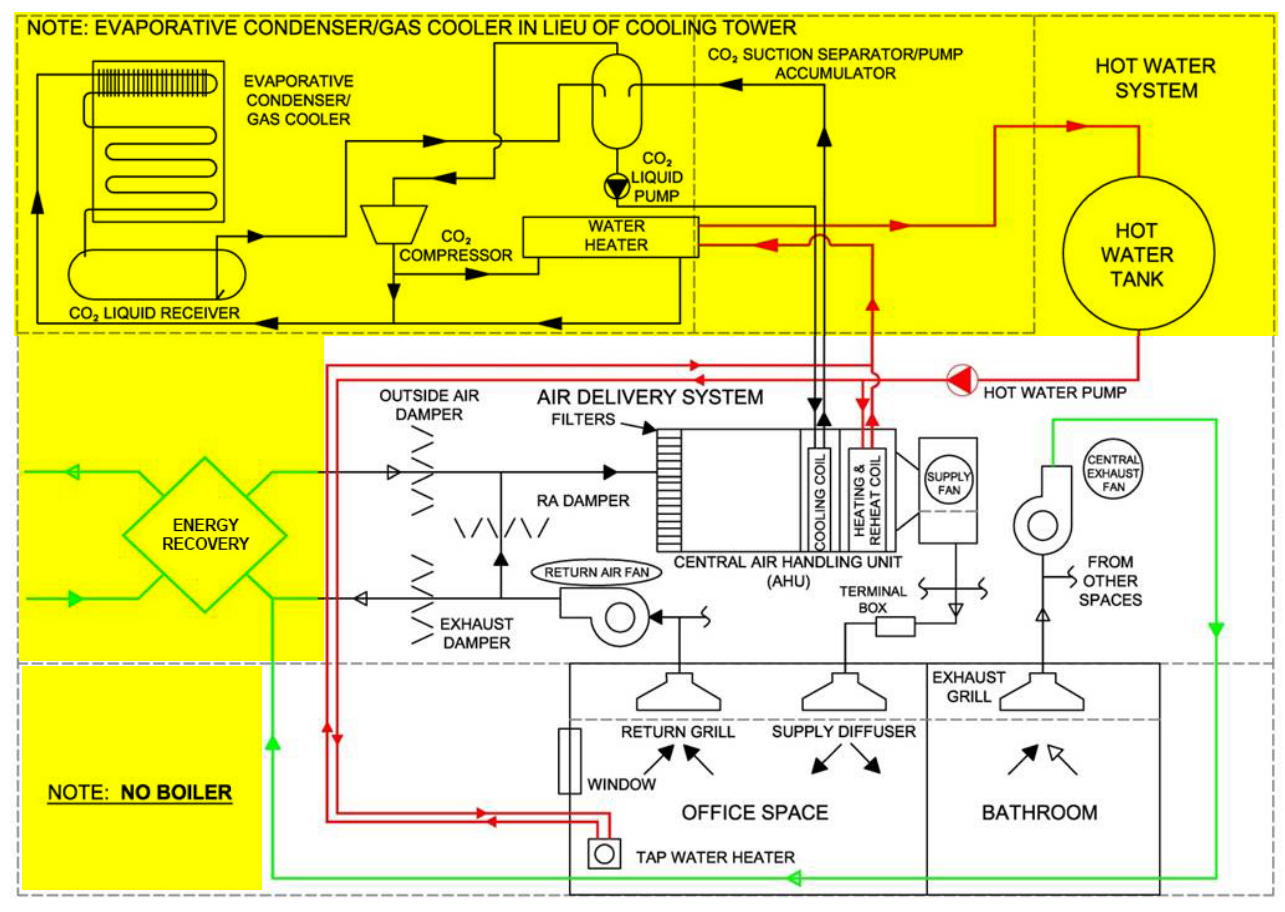
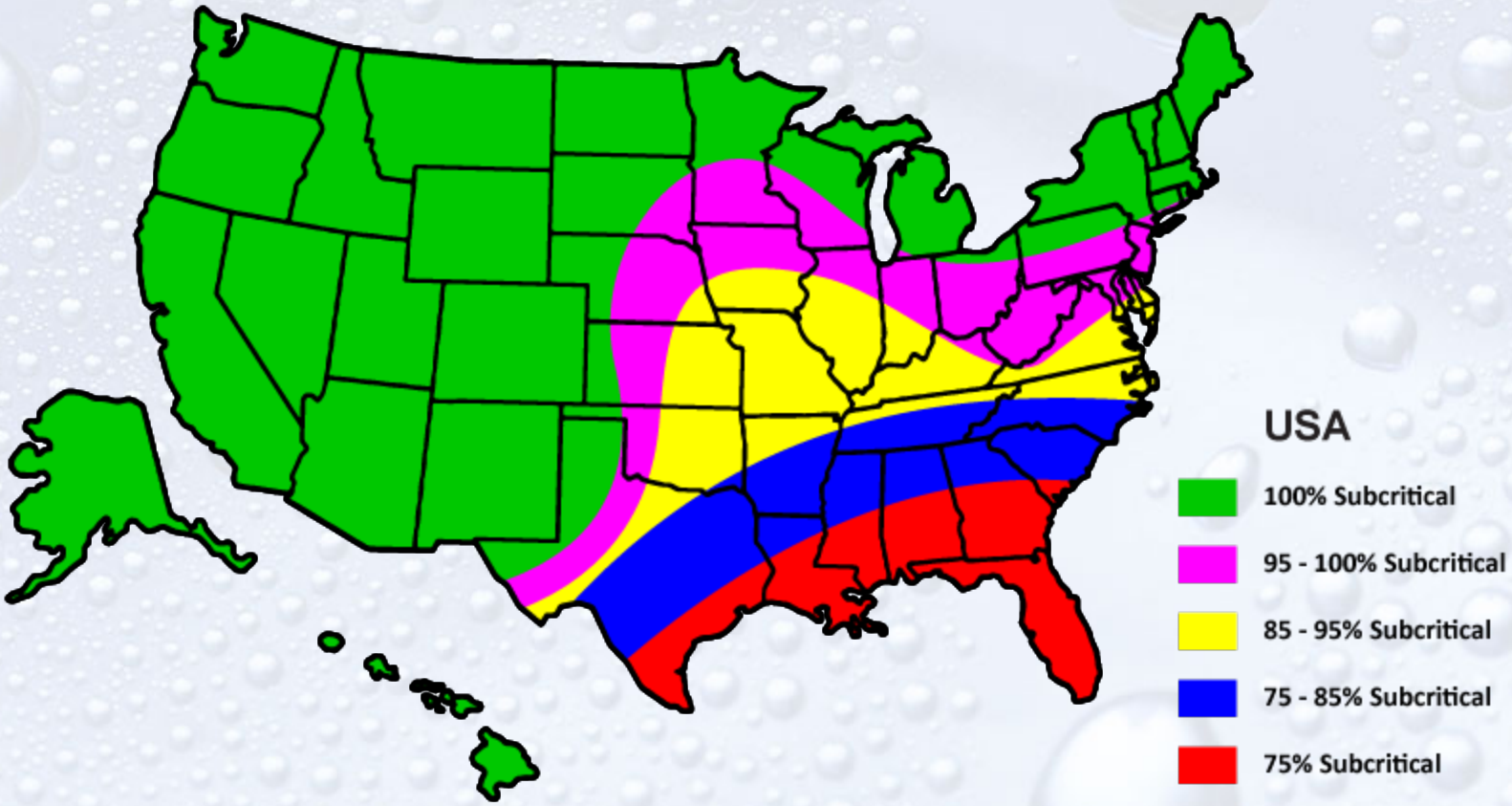


Figure 12: USA Climate Zones: % of a year when Subcritical CO_2 can be Condensed.



Conclusions.

- CO_2 refrigerating systems offer a number of advantages over conventional chemical when applied to the cooling and heating in the built environment.
  All issues are addressed.
- Suitable for retrofitting replacing chillers, cooling towers and space heating boilers.
- Retrofitting future proofs a system with respect to 79% HFC Phase Down by 2030, G20 Policy implemented by Montreal Protocol.
- Large reduction in energy consumption.

Conclusions. (Continued)

- Large reduction in cooling water consumption if used with Hybrid Evaporative Condensers.
- Large reduction in carbon emissions due to both reduced energy consumption and no fugitive gases from chemical refrigerants.
- Large reduction in costs for energy, water, water treatment and disposal to sewer.
- Even better results if applied to new buildings with convective hydronic cooling & heating.
- Low cost refrigerant.

Questions?

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