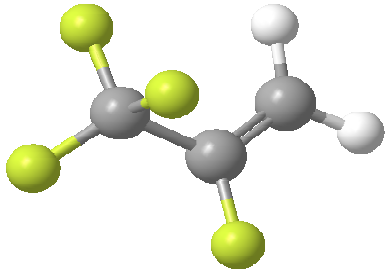
GLOBAL WARMING IMPACT OF LOW GWP CHILLER REFRIGERANTS: LCCP/TEWI vs GWP LCCP/TEWI vs Other Factors

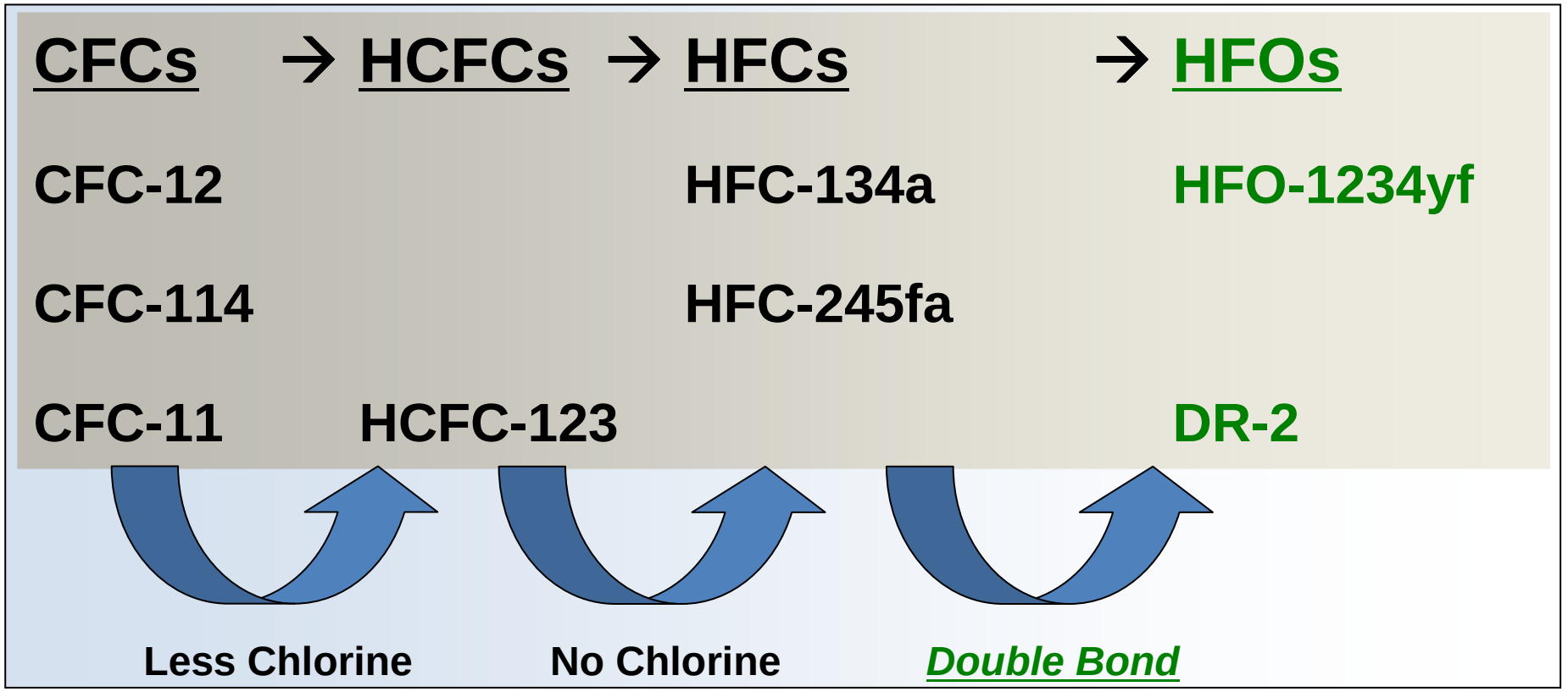
IIR Working Party
Life Cycle Climate Performance Evaluation
Delft, The Netherlands -- June 28, 2012

Kostas Kontomaris, Ph.D.
DuPont Fluorochemicals R&D

HFOs



Hydro-Fluoro-Olefins



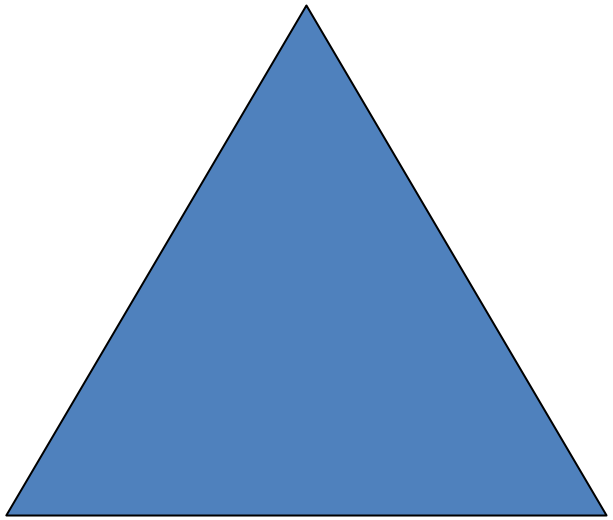
Conventional Wisdom:
Unsaturated fluorocarbons are not sufficiently stable to be used as refrigerants!

Paradigm Shift:
Unsaturated fluorocarbon refrigerants decompose rapidly in the atmosphere but can remain stable in a system!

Weighing the Tradeoffs

Safety

Flammability: no or low
Toxicity: low
Environmental: no ODP, *LOW CLIMATE IMPACT*



Performance

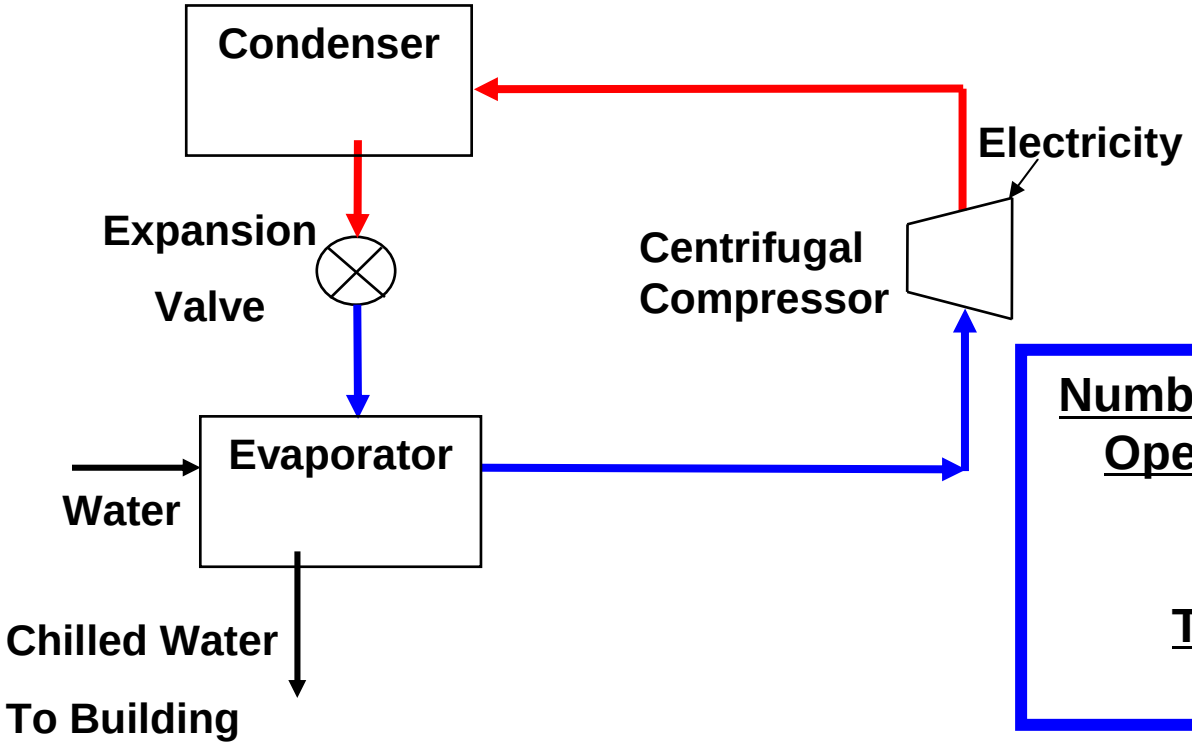
Energy Efficiency
Cooling Capacity
Chemical Stability

Cost

Near Drop-In
First & Operating

No Perfect Refrigerant – Best Balance for each Application

Centrifugal Water Chillers



Number of centrifugal chillers in Operation around the world:
Over 130,000

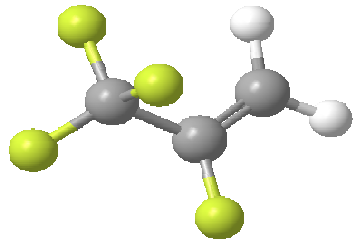
Total refrigerant bank:
ca. 60,000 tonnes

Previous centrifugal chiller refrigerants and transitions

CFC-11→HCFC-123 CFC-12→HFC-134a

Ozone Depleting ***High GWP***

Mid-Pressure Chiller Fluids:
HFO-1234yf



	HFC-134a	HFO-1234yf
Chemical Formula	CH_2FCF_3	$CF_3CF=CH_2$
MW	102	114
Flammability	None	2L
ALT [yrs]	14	0.0301 (11 days)
ODP	None	None
GWP_{100}	1,430	4
T_{cr} [ºC]	101.1	94.7
P_{cr} [MPa]	4.06	3.38
T_b [ºC]	-26.1	-29.5

Marginally Flammable

Very Low GWP

Mid-Pressure Chiller Fluids:
XP10

Marginally Flammable *Non-flammable*

	HFC-134a	HFO-1234yf	**XP10**
Chemical Formula	CH_2FCF_3	$CF_3CF=CH_2$	**Azeotrope**
Flammability	None	2L	**None**
ODP	None	None	**None**
GWP_{100}	1,430	4	**~600**
T_{cr} [°C]	101.1	94.7	**97.5**
P_{cr} [MPa]	4.06	3.38	**3.85**
T_b [°C]	-26.1	-29.5	**-29.2**
Glide [°C]	N/A	N/A	**Negligible**

Mid-Pressure Chiller Fluids:
DR-14

	HFC-134a	HFO-1234yf	XP10	**DR-14**
Chemical Formula	CH_2FCF_3	$CF_3CF=CH_2$	Azeotrope	**Azeotrope**
Flammability	None	2L	None	**None**
ODP	None	None	None	**None**
GWP_{100}	1,430	4	~600	**~380**
T_{cr} [^oC]	101.1	94.7	97.7	**111.6**
P_{cr} [MPa]	4.06	3.38	3.85	**3.96**
T_b [^oC]	-26.1	-29.5	-29.2	**-20.5**
Glide [^oC]	N/A	N/A	Negligible	**Negligible**

A Low Pressure Chiller Candidate: DR-2

	HCFC-123	DR-2
Flammability	None	**None**
Atmospheric life time [yrs]	1.3	**0.0658** (24 days)
ODP	0.02	**None**
$GWP_{100\ YR\ ITH}$	77	**<10**
Critical Temperature [ºC]	183.7	**171.3**
Critical Pressure [MPa]	3.7	**2.9**
Normal Boiling Point [ºC]	27.9	**33.4**

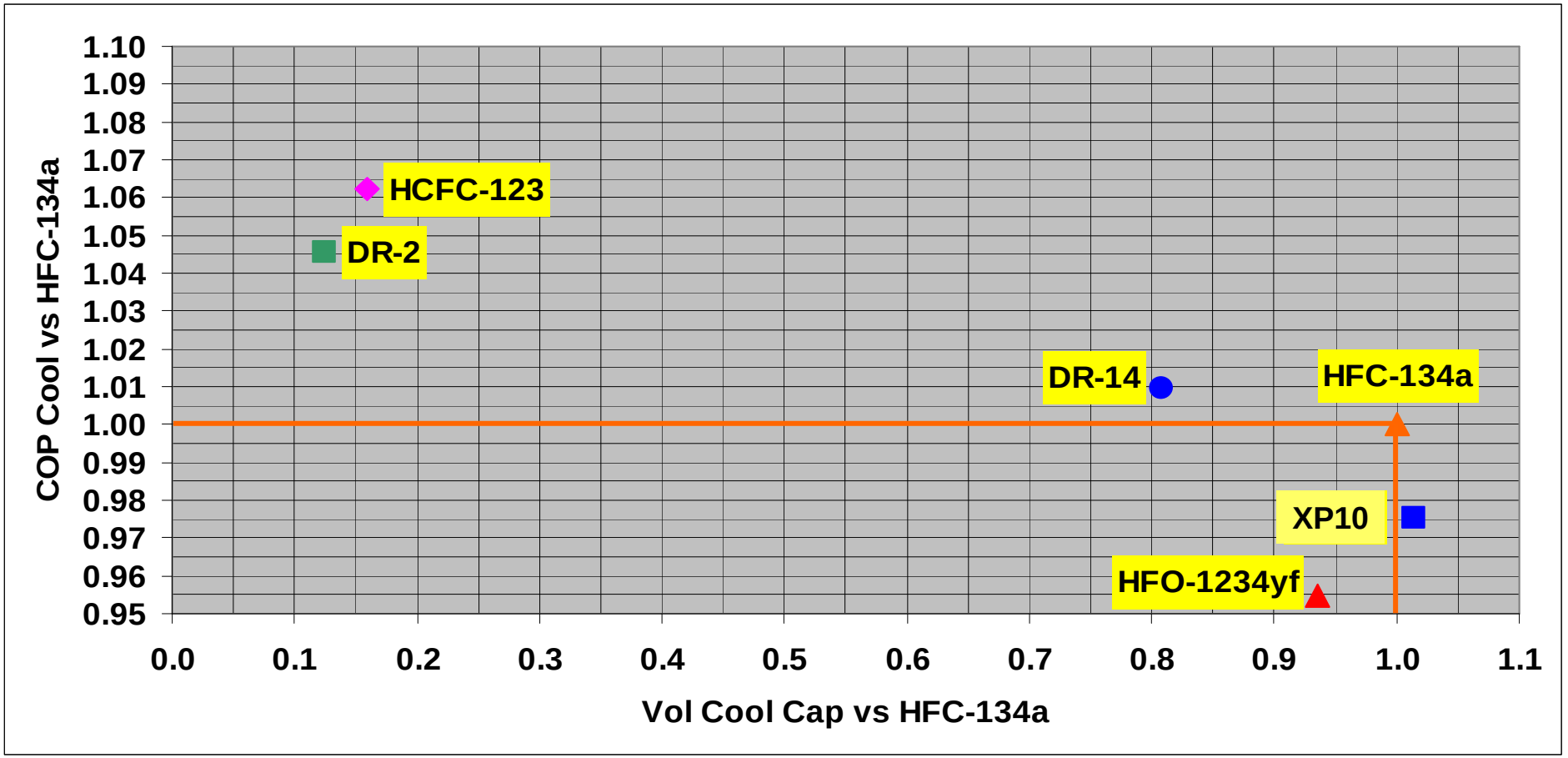
Low GWP Replacements for HFC-134a in Chillers: Summary

	HFO-1234yf	XP10	DR-14
FLAMMABILITY	Marginal	Nonflammable	Nonflammable
Theoretical Energy Efficiency vs HFC-134a	-4.5%	-2.5 %	+0.7 %
Cooling Capacity vs HFC-134a	-6.5%	+1.5%	-19.3 %
HFC-134a Retrofit	-	Near drop-in	--
GWP_{100}	4	~600	~380

Preferred Refrigerant?

XP10: would require no major equipment and no safety code modifications; it could be adopted earlier and more widely

Low GWP Chiller Refrigerants: Performance



DR-2 vs	DR-14	XP10	1234yf
COP	3.6%	7.2 %	9.5%

Warming Impact of Low GWP Chiller Refrigerants

$$TEWI = EM_{NRG} + EM_{RFG} + EM_{EOLrf}$$

EM_{NRG} [$kgCO_2$-eq] = CI x E

E [kwh] = P(COP) x HRS x N

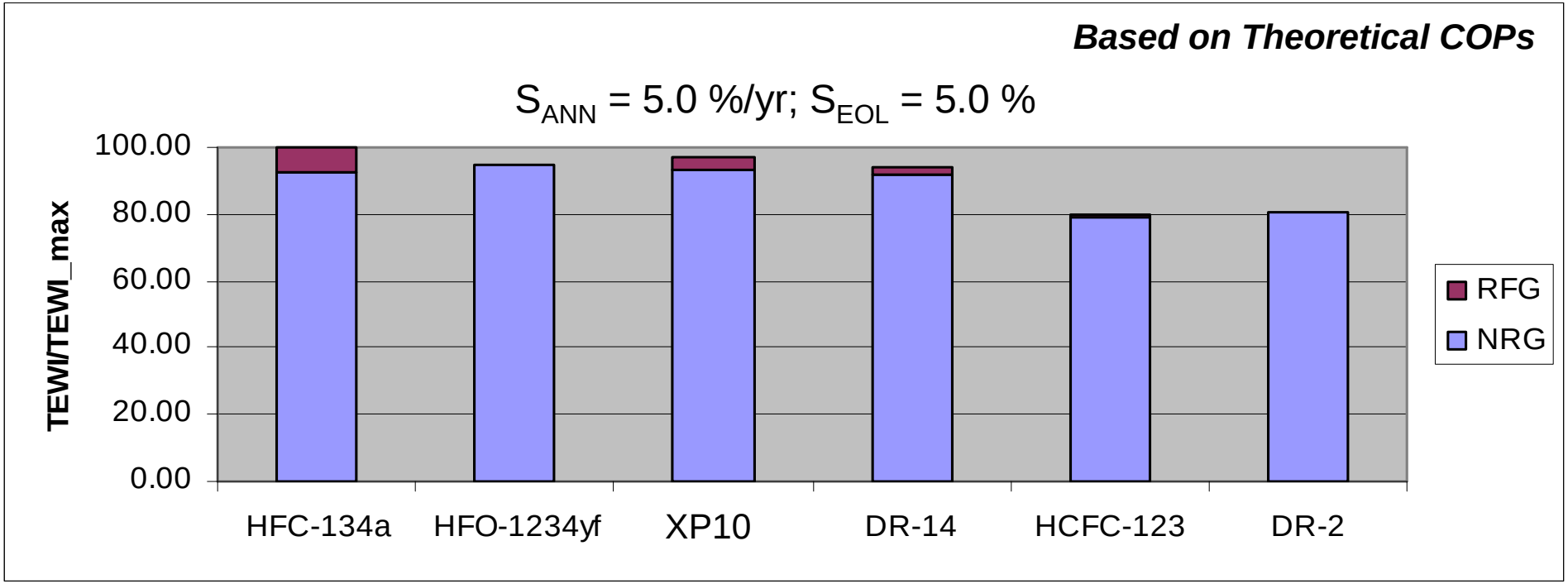
$EM_{RFG} = M_r \times S_{ANN} \times N \times GWP$

S_{ANN} = annual % charge loss

$EM_{EOLrf} = M_r \times S_{EOL} \times GWP$

S_{EOL} = End-Of-Life % charge loss

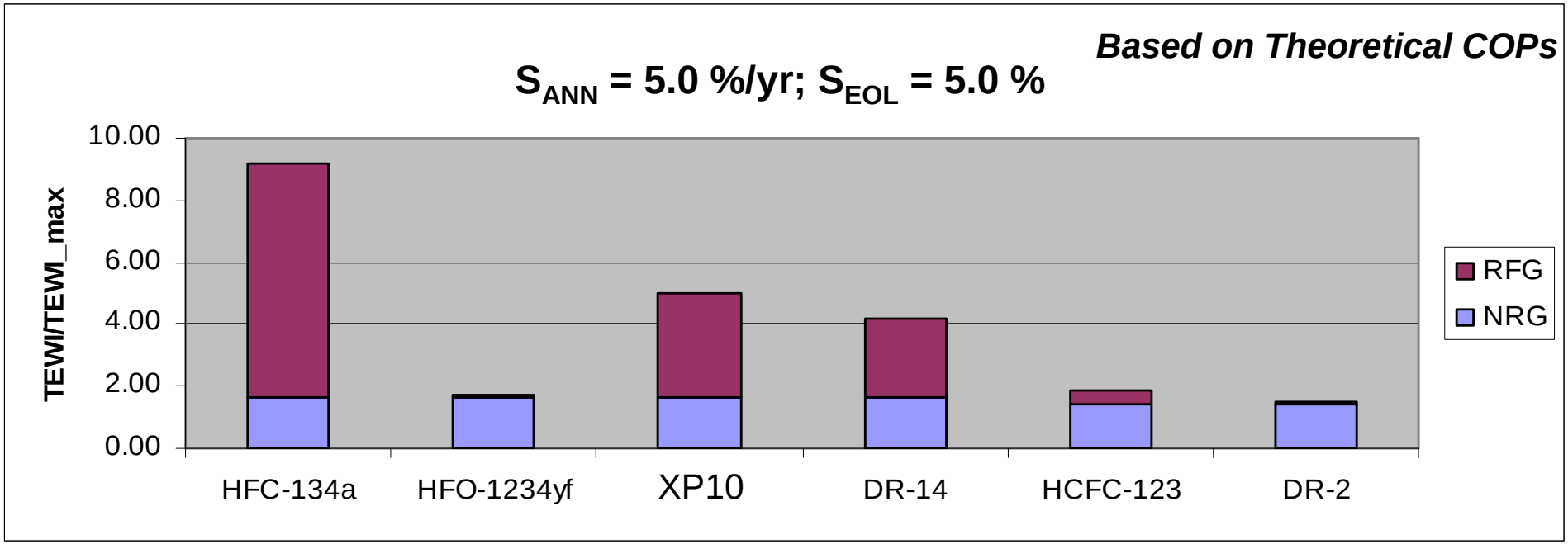
TEWI: High Carbon Intensity Scenario
(0.8445 kgCO_2-eq/kwh--China)



GWP=1,430 **4** **~600** **~380** **77** **~10**

Minimization of GWP does not necessarily lead to maximum Warming Impact reduction

TEWI: Low Carbon Intensity Scenario
(0.0150 kgCO_2-eq/kwh--Switzerland)



GWP=1,430	4	~600	~380	77	~10

Summary-Conclusions

HFOs: a rich class of low GWP compounds each with each own idiosyncrasies; pipeline of candidates tailor-made for various applications emerging

XP10: a sensible nearer-term replacement for HFC-134a in emissive chiller applications

DR-2: promising longer-term, low-pressure fluid for commercial air conditioning and low temperature heat utilization

Refrigerant selection should consider application impact, not just refrigerant attributes: e.g. refrigerant with lowest GWP may not lead to maximum warming impact reduction

Flexible climate protection regulations to allow acceptance of optimum refrigerants/trade-offs

Thank you!

Email: Konstantinos.Kontomaris@usa.dupont.com