ADB Technology Innovation Challenge:
Disease Resilient & Energy Efficient Centralised Air Conditioning Systems

Refrigerant Management for the CAC systems in Public Buildings

Centralised Air Conditioning Vis-à-vis Montreal Protocol and Climate Change – Challenges for Developing Countries

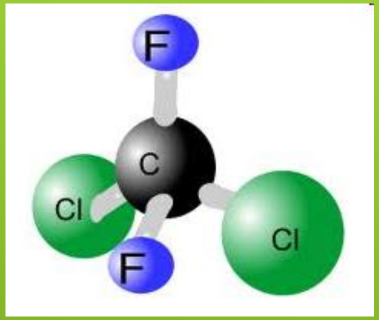
Dr. Sukumar Devotta

(Former Director, NEERI, Nagpur)

Chemical & Environmental Engineering Consultant

sdevotta@gmail.com

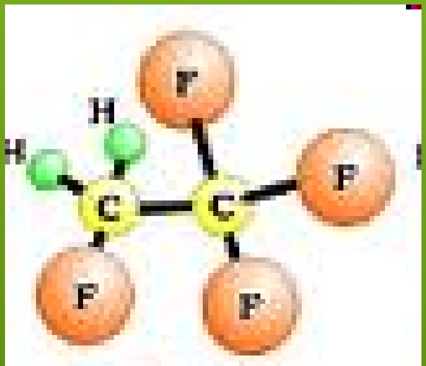
CFCs, HCFCs, HFCs & HCs



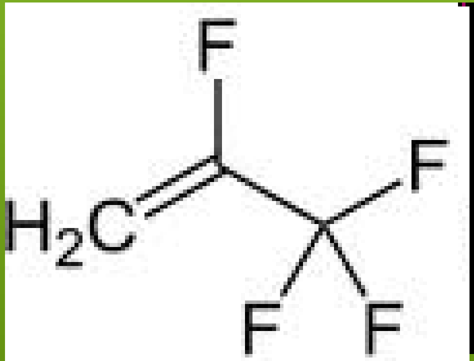
CFC-12

CFC-11

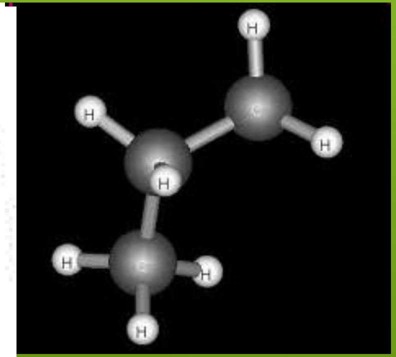
HCFC-22



HFC-134a



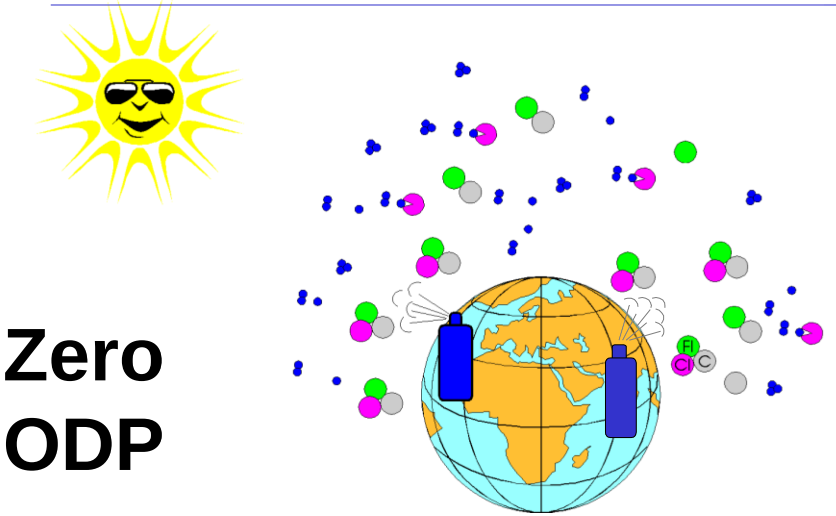
HFO-1234yf



HC-290

Refrigerants & Global Warming

Ozone Layer Depletion



Zero
ODP

Global Warming

Low
GWP

- Refrigerant Emission
- Energy Efficiency
- Recovery & Recycling

ODP & GWP

Refrigerants are evaluated on the basis of:
Ozone Depleting Potential (ODP) – Montreal Protocol and Global Warming Potential (GWP) – Kyoto Protocol (&MP?).

Ozone Depleting Potential (ODP):

It is the measure of the ozone depleting capability of a refrigerant as compared to that of CFC-11 (ODP of 1.0.)

Global Warming Potential (GWP)*:

It is an index which compares the warming effect over time of different gases relative to equal emissions of CO_2 by weight.

e.g.: CFC-12 : ODP= 0.82 and GWP= 8100
HFC-134a: ODP= 0.0 and GWP= 1300
HC-600a : ODP= 0.0 and GWP= 4

*** GWP values are from IPCC AR4 for policy issues but are revised by IPCC periodically for scientific assessments.**

GWP Classification

100 Year GWP	Classification
< 30	Ultra-low or Negligible
< 100	Very low
< 300	Low
300-1000	Medium
> 1000	High
> 3000	Very high
> 10000	Ultra-high

Natural Refrigerants and HFOs

HCFC-123

HFC-152a

HFC-32

HCFC-22, HFC-134a

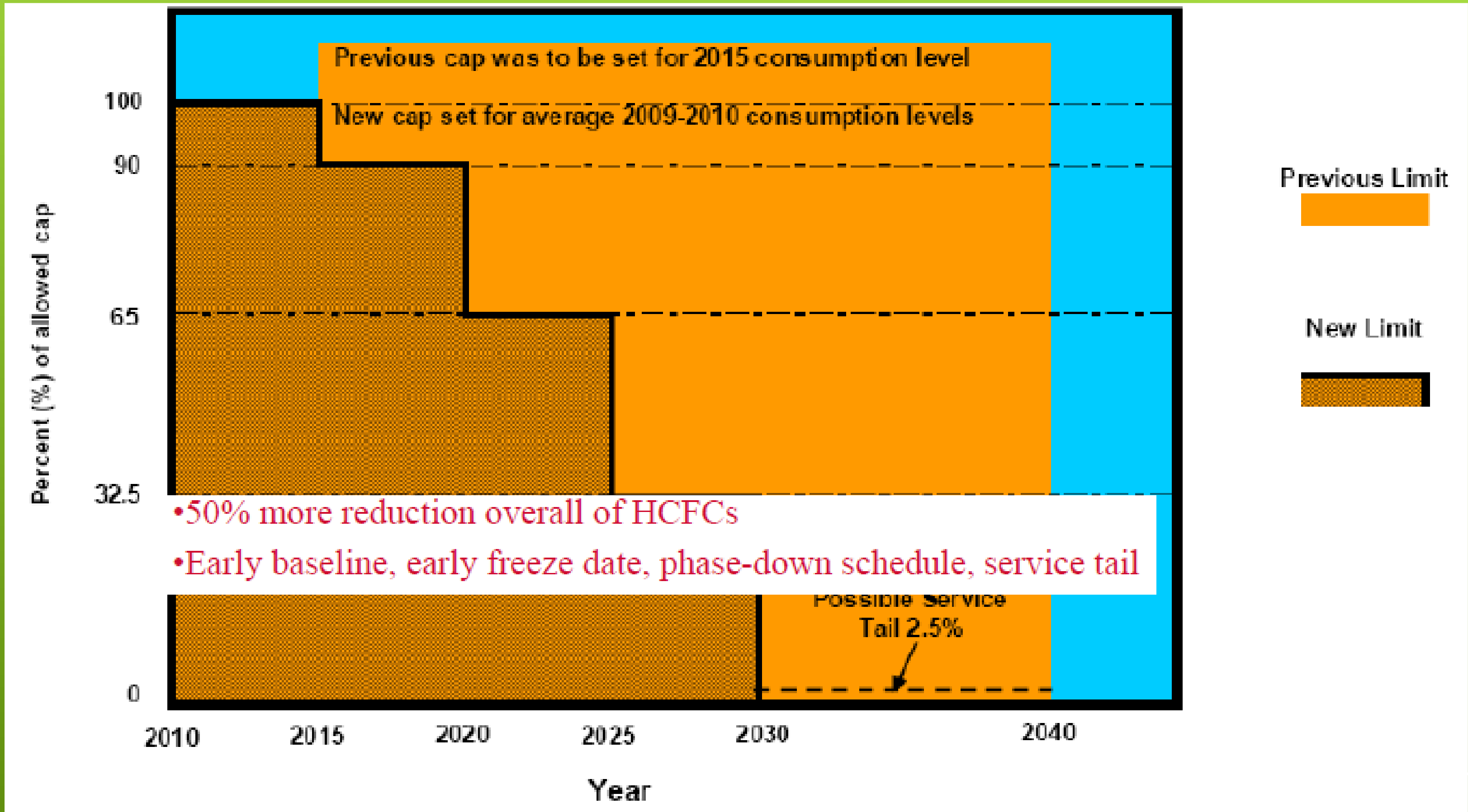
CFC-11, CFC-12, CFC-113, CFC-114, CFC-115

HFC-23

It is extremely difficult to define these classifications with global consensus due to geo-political positions on refrigerants e.g. EU F-gas set the limit of 150 as low GWP

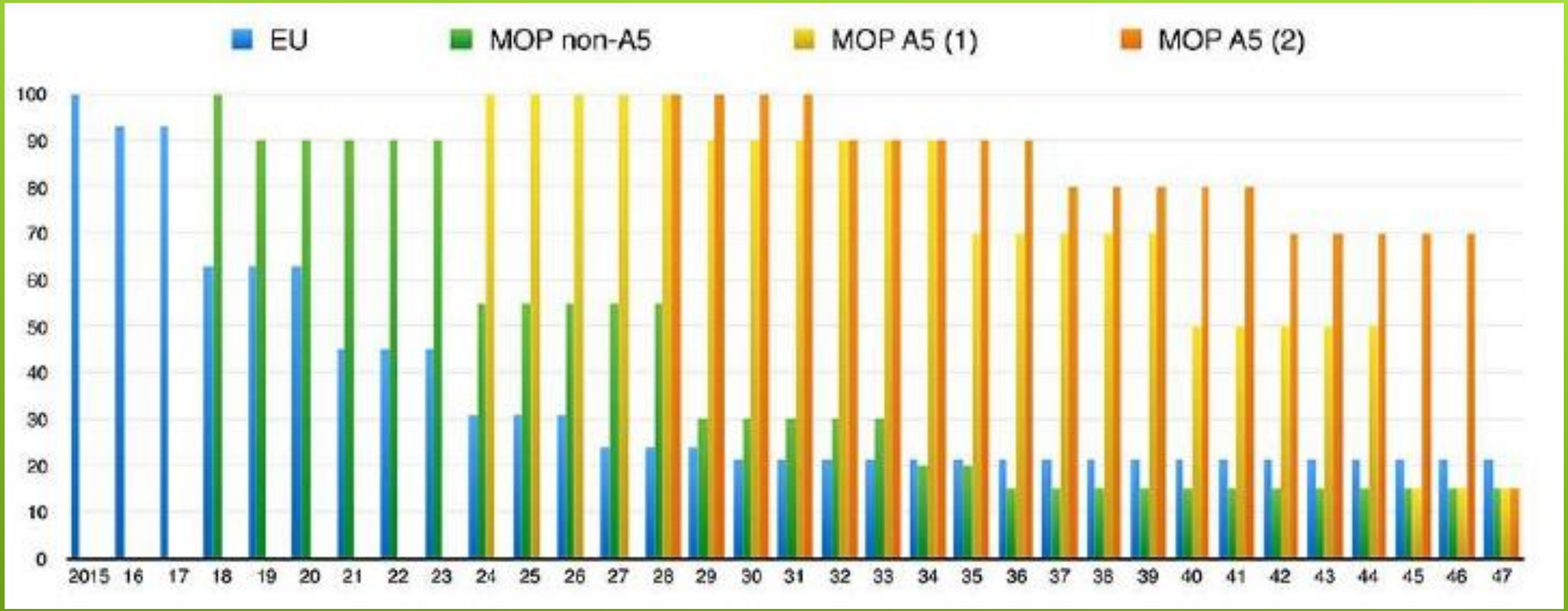
UNEP RTOC, 2018

HCFC Phase-out Schedule for A5 Countries



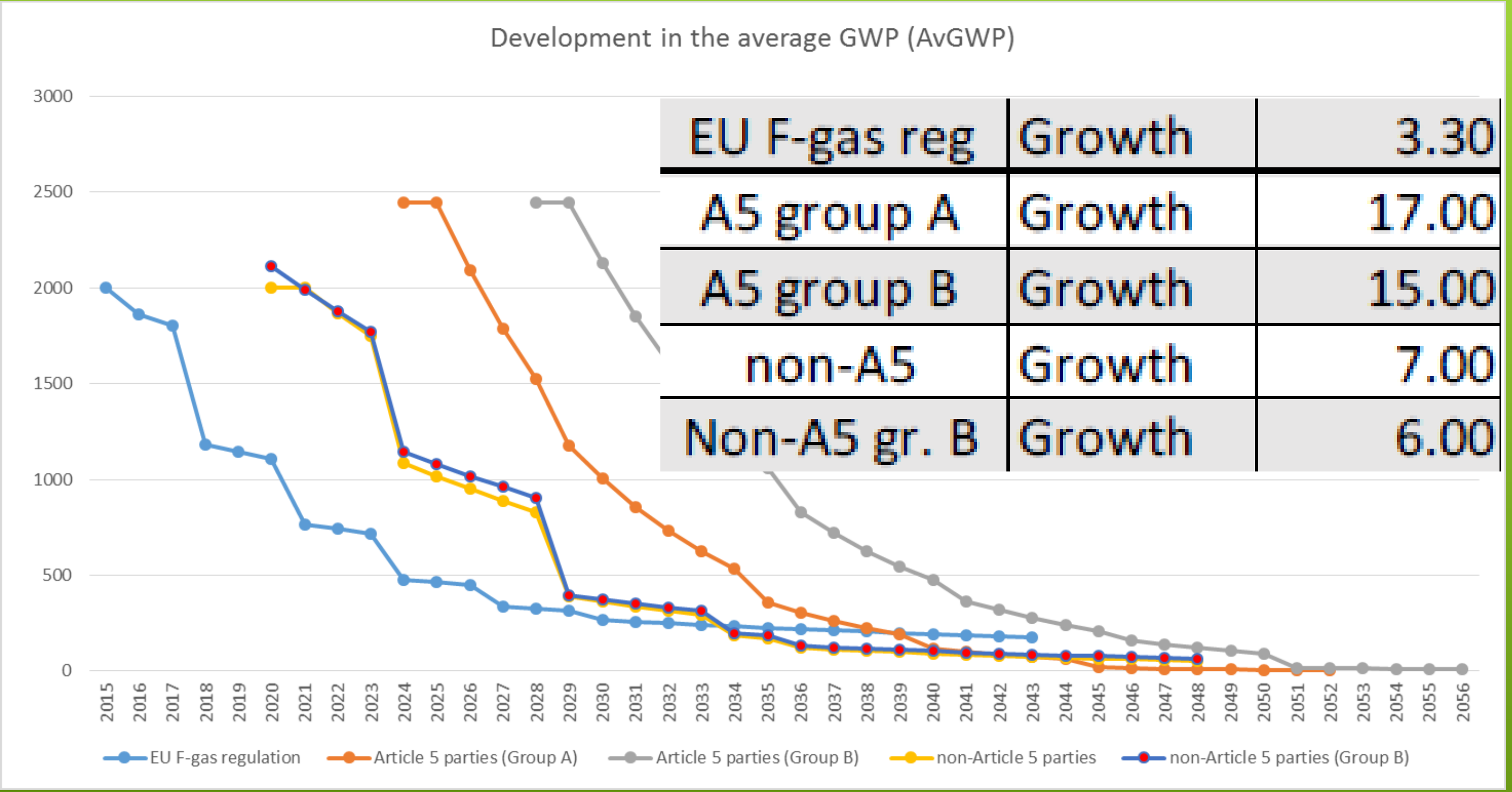
- CFCs have been successfully phased out globally by 2010 or earlier
- Some Non-A5 countries follow much more stringent schedules for HCFC phase out e.g. Europe

Global HFC Phase Down – Kigali Agreement



- Expected to reduce 700 bTCO2Eq
- EU Phase down under F Gas Regulation – Baseline (BL): 2009-12; F: 2015; R: 2016; Reduction by 27% before the other non-A5 countries start. The final target of a 79% phase down is less the final target of an 85% under the Kigali agreement, although it is likely to be much less as they start very early.
- Non-A5 Countries – BL: 2011-13
- A5 (Group 1 includes China) – BL: 2020-22; F: 2024; R: 2029
- A5 (Group 2 includes India) – BL: 2024-26; F: 2028; R: 2032

Kigali Targets and Average GWP



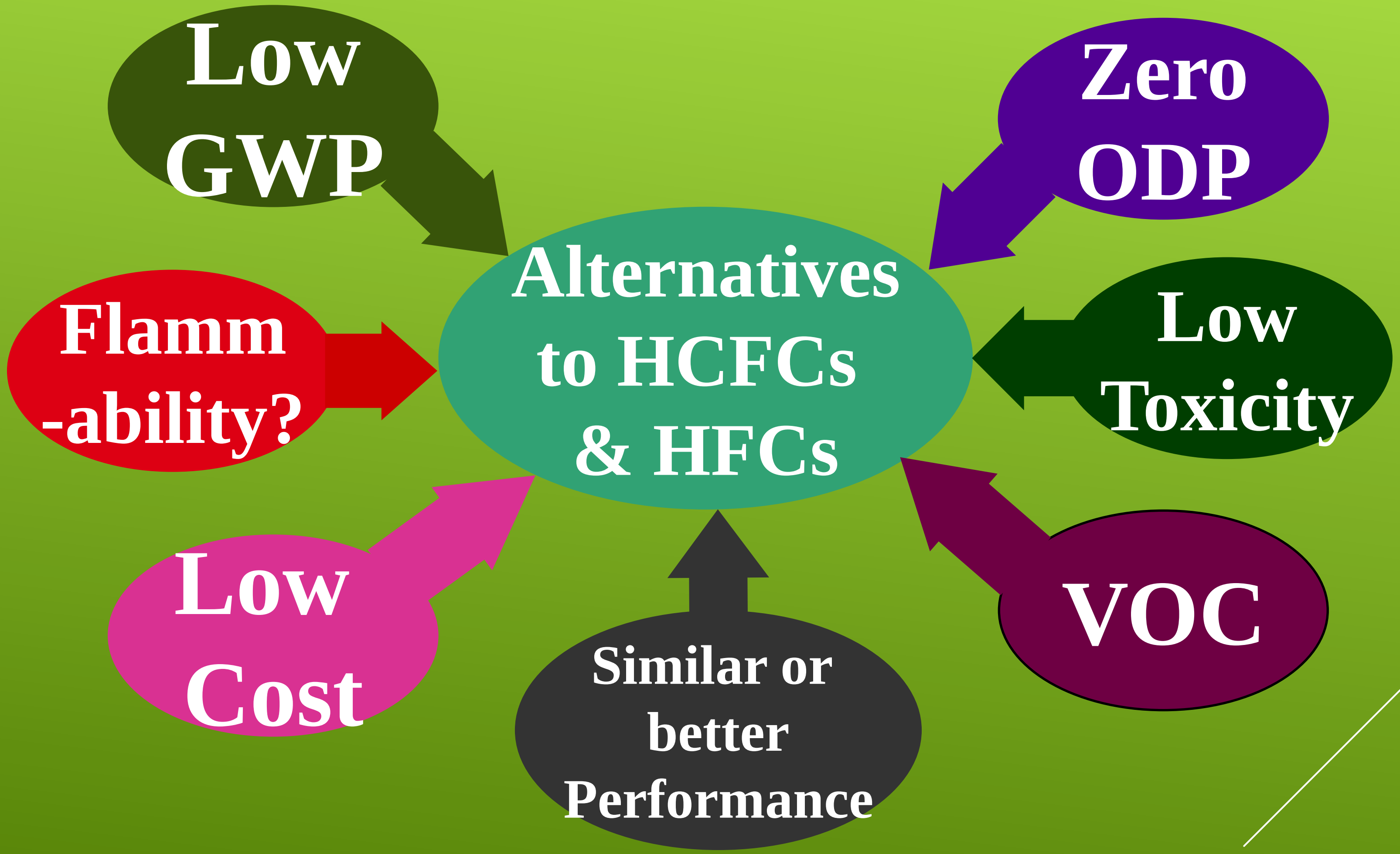
EU F-gas reg	Growth	3.30
A5 group A	Growth	17.00
A5 group B	Growth	15.00
non-A5	Growth	7.00
Non-A5 gr. B	Growth	6.00

A.C. Pachai, L. Kuijpers, A. Vonsild (2018)

- **A model for HVACR growth and Average GWP to meet Kigali targets.**
- **Depending on the Kigali Group, the timelines and the required average GWP threshold varies.**
- **Even for A5, the target GWP is below 400 by 2030 and continues to decline.**
- **This eliminates almost all HFCs.**
- **Only the use of Natural Refrigerants, HFOs and HFO/HFC blends may be possible.**
- **For A 5 Countries, simultaneously phasing down HCFCs and keep HFC growth down under Kigali is a great challenge.**

Alternatives to HCFCs & HFCs- Desirable Characteristics

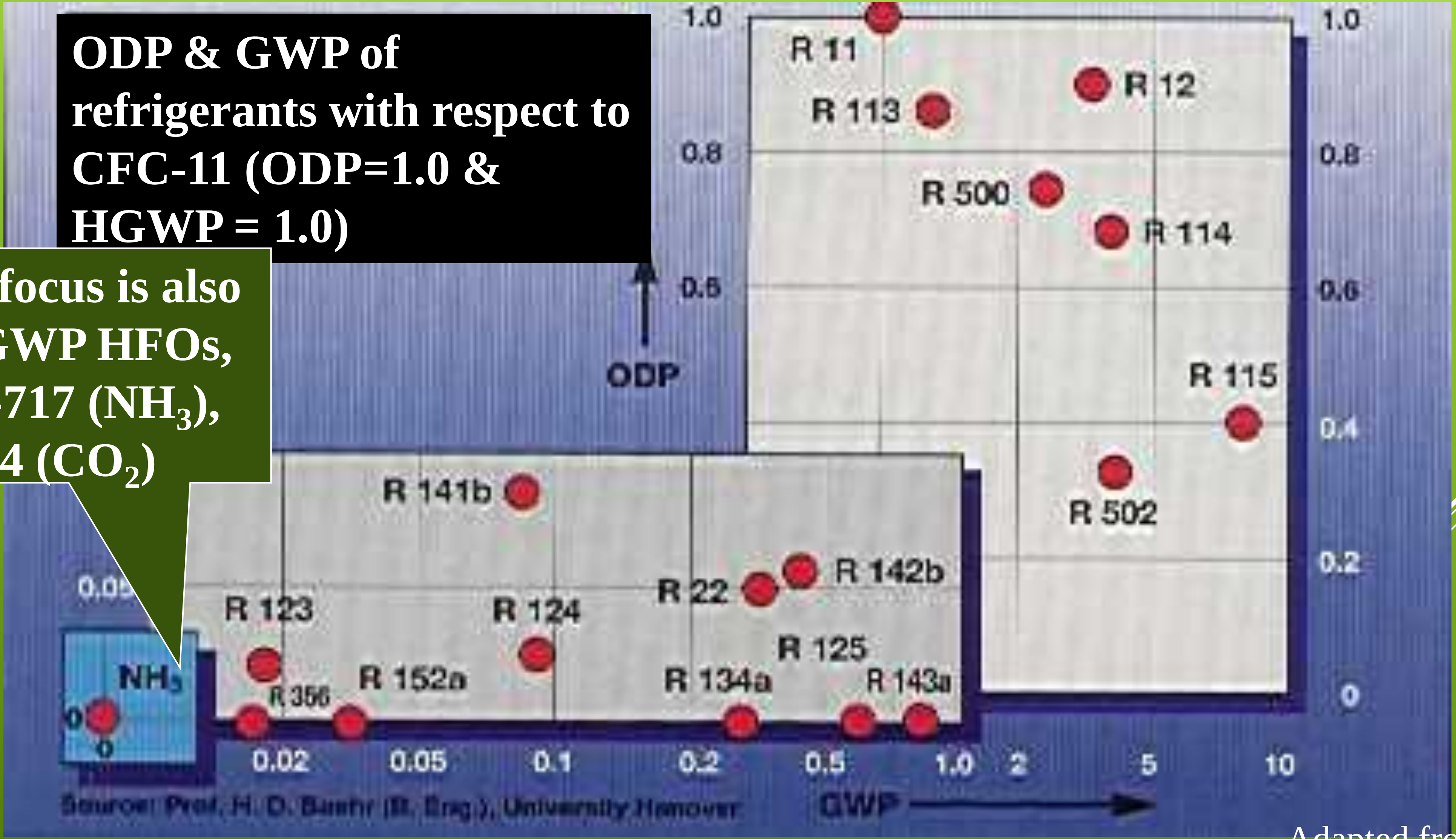
There are no fluids to satisfy all these desirable characteristics and there has to be some compromise



Alternative Refrigerants: ODP & GWP

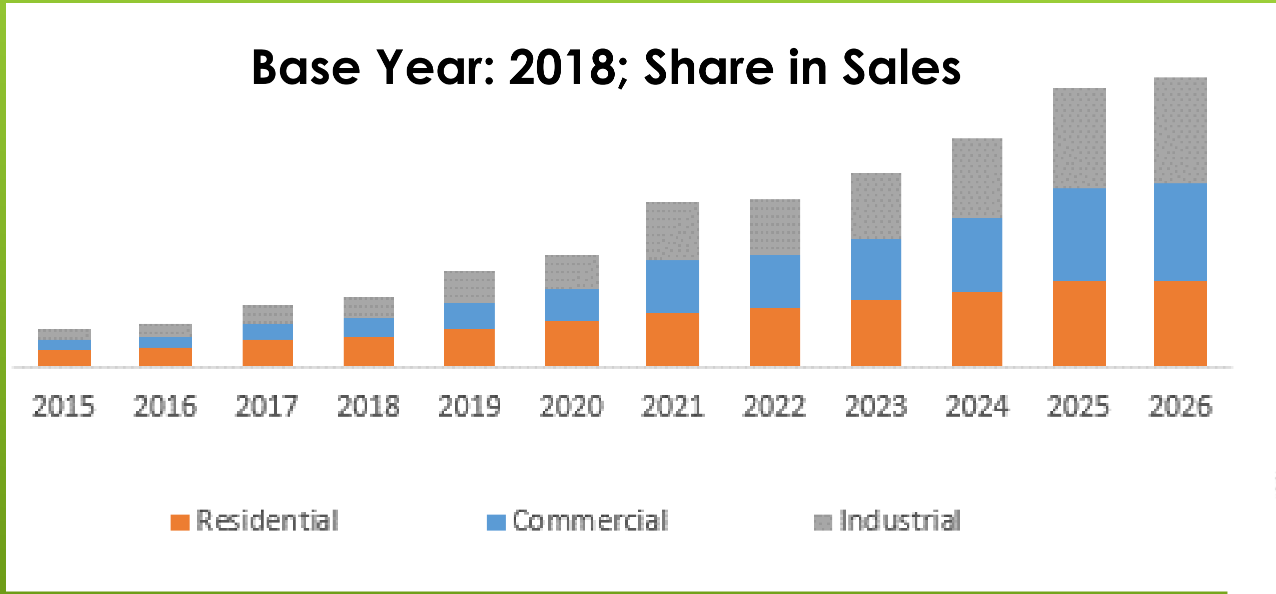
ODP & GWP of refrigerants with respect to CFC-11 (ODP=1.0 & HGWP = 1.0)

Now the focus is also on low GWP HFOs, HCs, R-717 (NH_3), R-744 (CO_2)



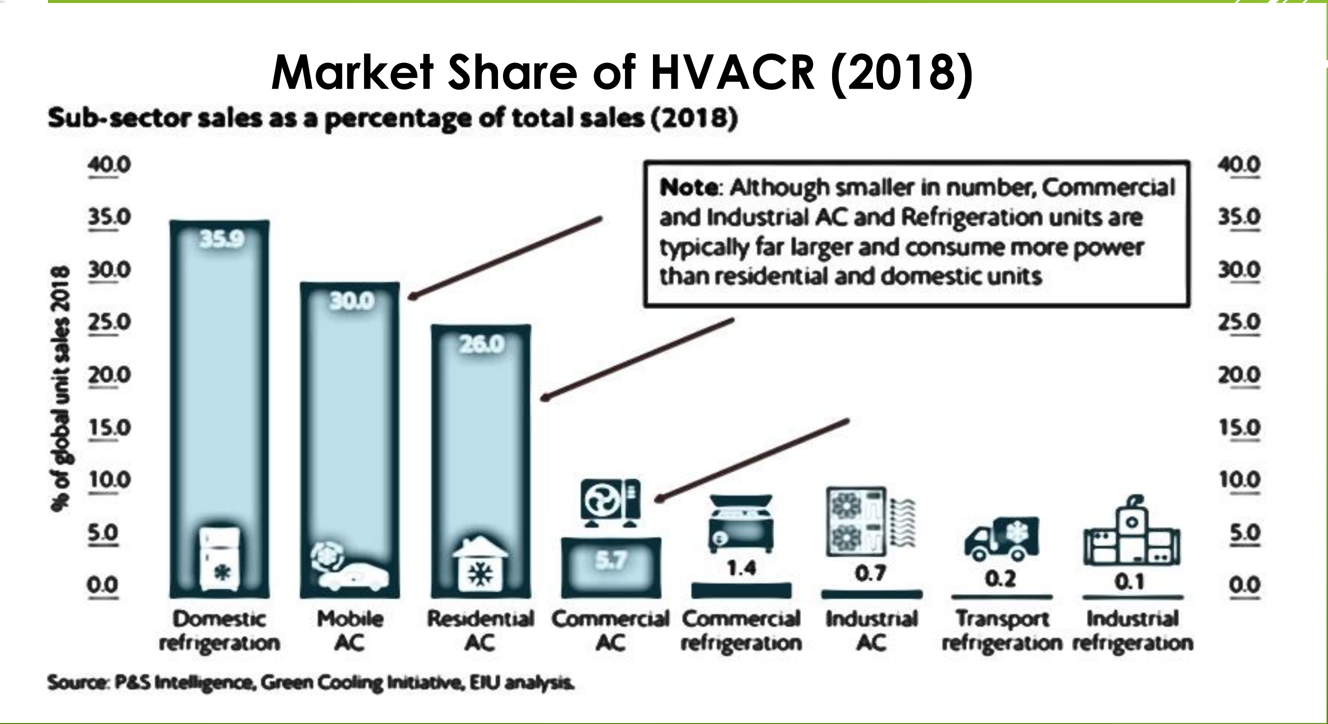
Adapted from Jim Calm

Global HVACR Market Trends

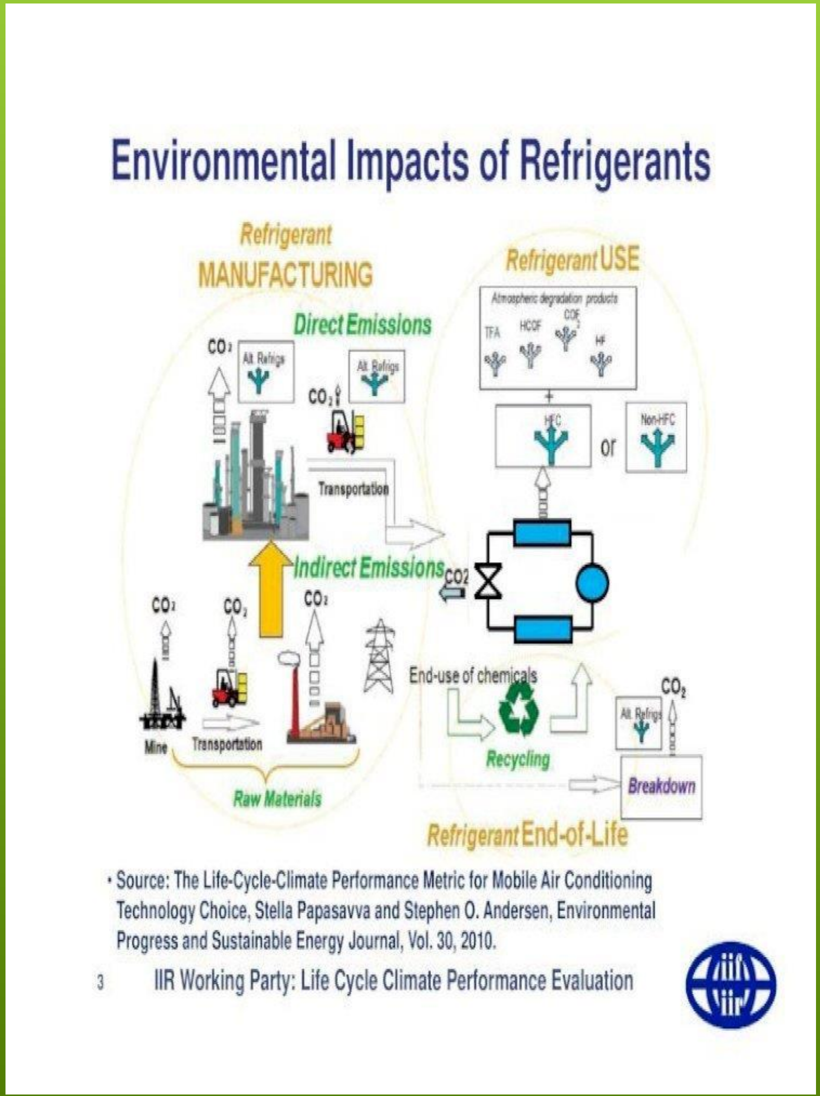


- *HVACR industry is poised for a significant growth*
- *Refrigerant uses will also grow*
- *Keep the average GWP of refrigerants in focus*
- *To meet Kigali targets, most countries need to keep the average GWP of refrigerants around 150*

Refrigerants used are:
HCFC-22 and HCFC-123
HFC-32, HFC-134a, HFO-1234yf, HFO-1234ze HFO-336mzz(Z)
HCFO-1233zd(E)
R-410A , R-452B, R-454B, R-466A
R-513, R-514

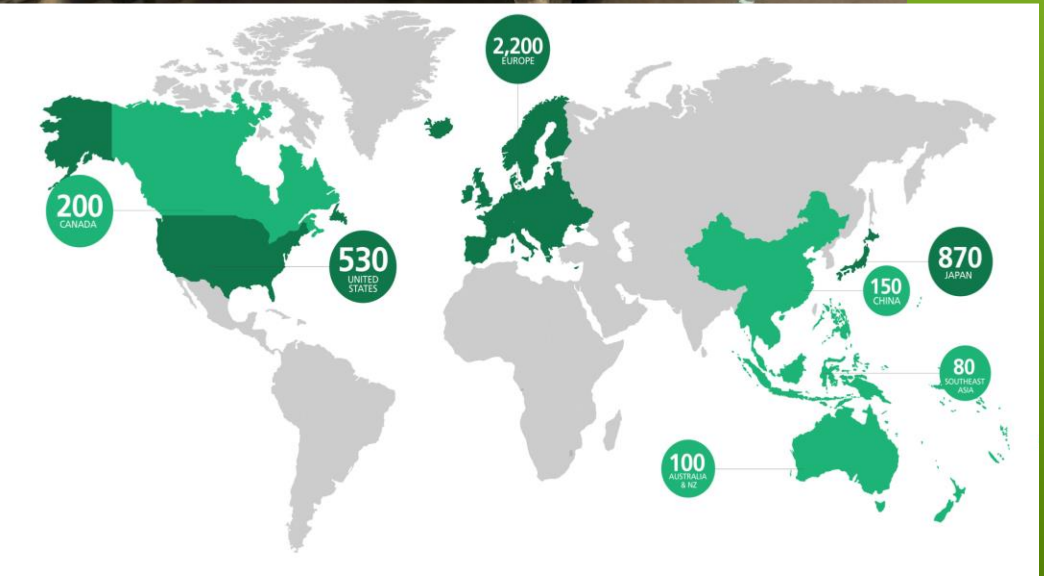


Life-Cycle Climate Performance (LCCP)



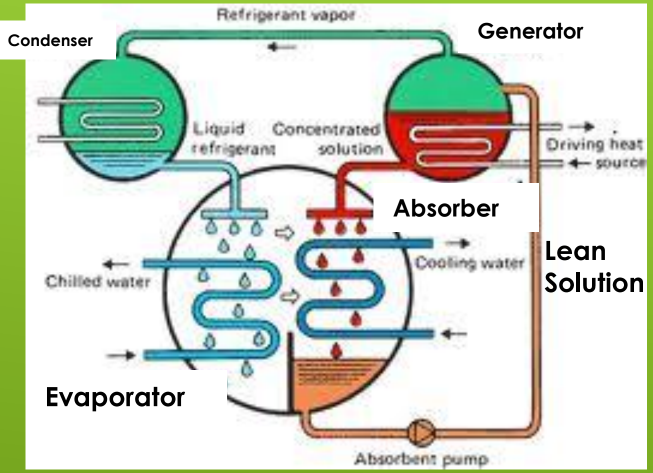
- **In order to comprehensively analyze global warming impacts, the concept of Life-Cycle Climate Performance (LCCP), has been evolved from the earlier concept of "Total Equivalent Warming Impact (TEWI)".**
- **LCCP calculates the cradle-to-grave climate impact of direct and indirect greenhouse gas emissions including inadvertent emissions from chemical manufacture, energy embodied in components, operating energy, and emissions at the time of disposal or recycle. The calculated LCCP also accounts for location specific electrical generation efficiency and power mix and is sensitive to assumptions of the system lifetime, emission losses, and the integration time interval used in the calculation of the global warming potential (GWP) of greenhouse gases. Energy efficiency is often revealed as the most important strategy for reducing primary energy demand and its emissions.**

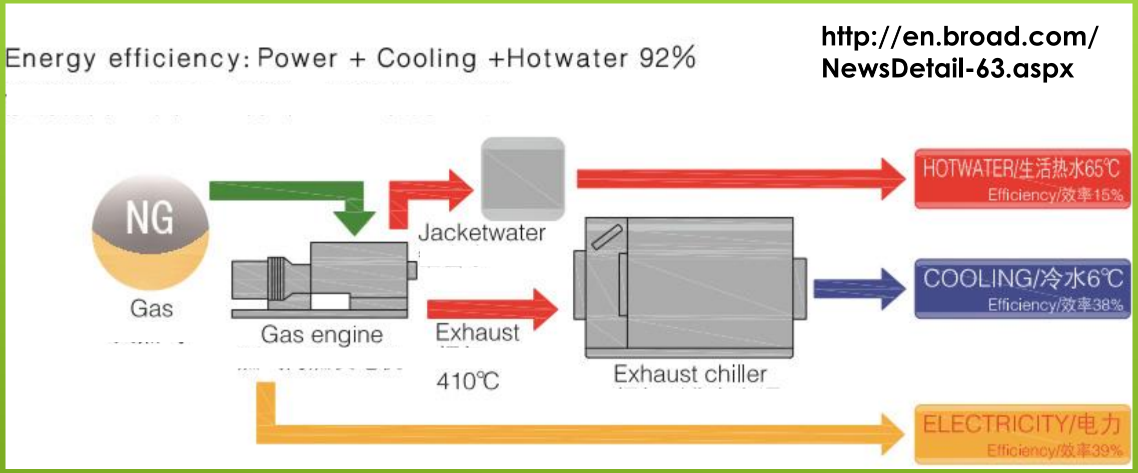
Global installations of Low Charge Ammonia Chillers



- Ammonia - R-717 (B2L) ultra-low GWP, energy efficient and readily available low cost natural refrigerant
- Globally Low charge R-717 chillers (<1.3 kg/kW but) are increasing rapidly with over 4,000 installations in 2019.
- Ultra-low charge R-717 chillers have 0.06 kg/kW, reducing the risk significantly.
- Mostly used for industrial refrigeration.
- In Europe, many plants are now operational with R-717 for air conditioning for space heating e.g., KWN Engineering Vienna (1998), Saab Sweden (1999), Frigopol (2000), Berlin Ostbahnh of Train Station (2000), Stuttgart Airport (2004) Roche's HQ London (2005), Dutch ABN Amro Bank London (2006), Mulligan Letter Sorting Center Switzerland (2008), Ozeaneum Stralsund (2010), Heathrow Airport terminal 4, Oslo Airport, terminal 3 and many more.
- Although Ammonia chillers may be cost-effective for building air conditioning, still barriers continue to stand in the way of wider adoption, even in Non-A5 Countreis.
- Issues are safety concerns, building codes, capex and psychological.
- A 5 countries should first adopt the emerging safety standards and good manufacturing, installation and service practises for R-717 and then only expand its use for CAC.

Absorption Chillers & Poly-generation





Gas engine generator supplies electricity -1.1 MW
Absorption chiller recovers heat from exhaust @ 410C (hot water) for cooling - 1.9 MW
Supplies hot water from jacket cooling at 65ºC
Payback period 2.3 years

- Uses water as the refrigerants with lithium bromide (salt solution) as the absorbent
- COP of an absorption chiller is a thermal (heat) ratio and not directly comparable with COP of vapour compression chillers.
- Single effect- powered by driven by hot water at about 80-90C with COP of 0.4-0.7
- Double effect- powered by steam (2 1. bar or above) with COP of 1.1 -1.3
- Triple effect- powered by steam (2 1. bar or above) with COP of about 1.8
- Can be powered by low grade or waste heat from any other process
- Can be integrated with DG sets to produce power, heating and cooling (polygeneration) for buildings
- Hybrid of both electric chiller and absorption chillers are commercially available
- Favourable where 24x7 Genset is operational (e.g., IT buildings)

Concluding Remarks

- There is no ready single route for both HPMP and Kigali
- High GWP HFCs are still used still in many developed countries.
- Low GWP refrigerants have emerged but yet applied globally with common alignment.
- Europe is avoiding HFCs (by using Natural refrigerants)
- Performance characteristics of low GWP HFCs under Indian conditions are yet to be established.
- A5 Countries should first adopt the emerging safety standards and good manufacturing, installation and service practises for flammable (A2, A2L, B2L, and A3) refrigerants and then expand their uses for CAC.
- There is an urgent need for training engineers and technicians in A5 Countries for all safety guidelines in design, manufacture, transportation, installation and maintenance.
- Should make training and certification on safe handling of flammable refrigerants ang Good practices as mandatory
- Time lines,Technology Transfer, IPR and Techno-economics of Low GWP HFCs are not yet clear
- More R&D and demonstration using LGWP refrigerants are needed in A 5 Countries

Thank you very much!
Any questions?