Sustainable Technologies for Air-Conditioning Sector

Radhey S. Agarwal

Sustainable Technologies Air Conditioning Workshop
Climate and Clean Air Coalition Event
ICAO Headquarter, Montreal, Canada
November 18, 2017

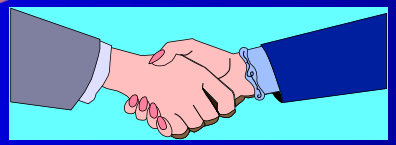
Kigali Amendment: An Opportunity for Search of Sustainable Technologies for A/C

Montreal Protocol Successfully Phasing out ODS since, 1987

Kigali Amendment for Phase-down of HFCs, 2016

Ozone Layer Protection

Climate System Protection



All 197 countries of the world are working together to phase out ODSs

Phase-Down of High-GWP HFCs: Promoting Low-GWP Technologies & Energy Efficiency

Fundamentals: Sustainable Technologies for A/C

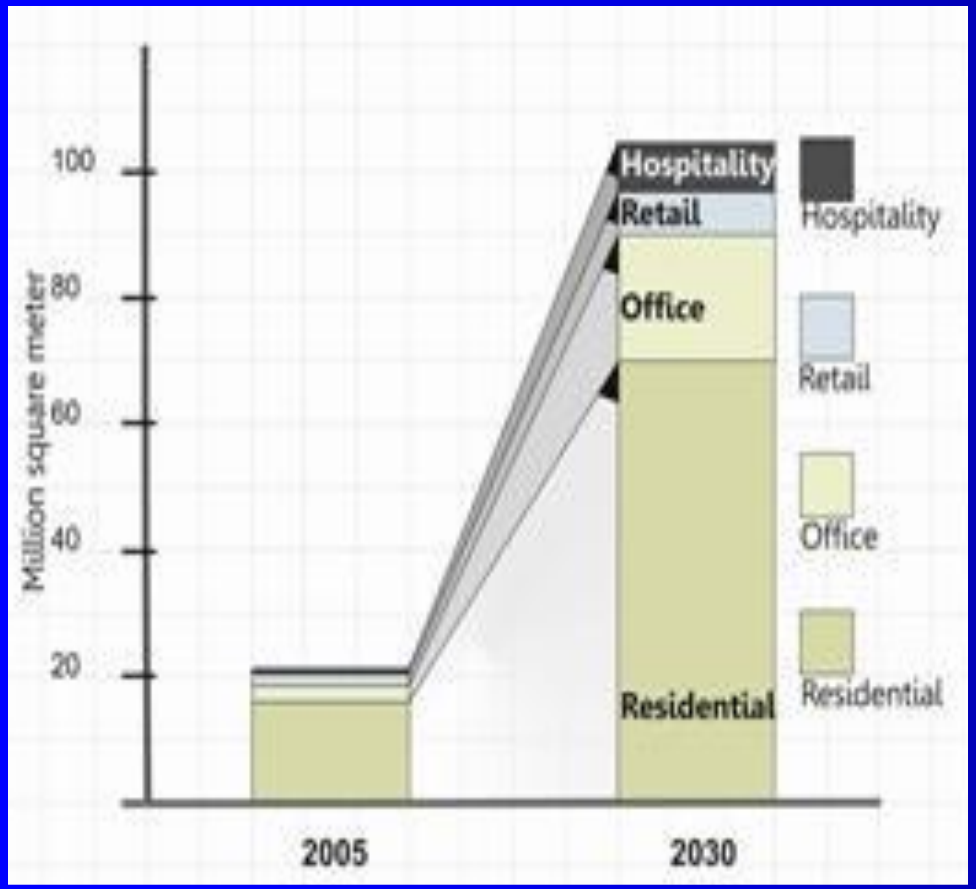
- **Sustaining health of the Earth's subsystems:**
  - Chemical
  - Physical
  - Biological
- **Requires**
  - Minimizing materials use;
  - Minimizing A/C use;
  - Use of low-GWP technologies
  - Minimizing energy use;
  - Using energy efficiently:
    - Tapping natural energy flows (Renewable Energy)
    - Minimizing thermal discharges.

Drivers: Sustainable Technologies for A/C

- **Growing demand for air-conditioning (A/C) in A 5 countries:**
  - Healthy working & living environment for all;
  - Rapid urbanization;
  - Growing GDP;
  - Low penetration of A/C (Indian context less than 5%).
- **Average global temperature stabilization:**
  - Minimizing direct (refrigerant) emissions;
  - Minimalizing indirect (energy consumption) emissions;
  - Minimizing use of materials and promoting recycling.
- **Energy performance standards:**
  - Growing emphasis on enhanced performance requirements [in Indian context Energy Conservation Building Code (ECBC- 2017) and EE Labeling]; Several A5 countries have MEES in place;
  - Awareness among consumers for energy efficient products;
  - Technology innovation.

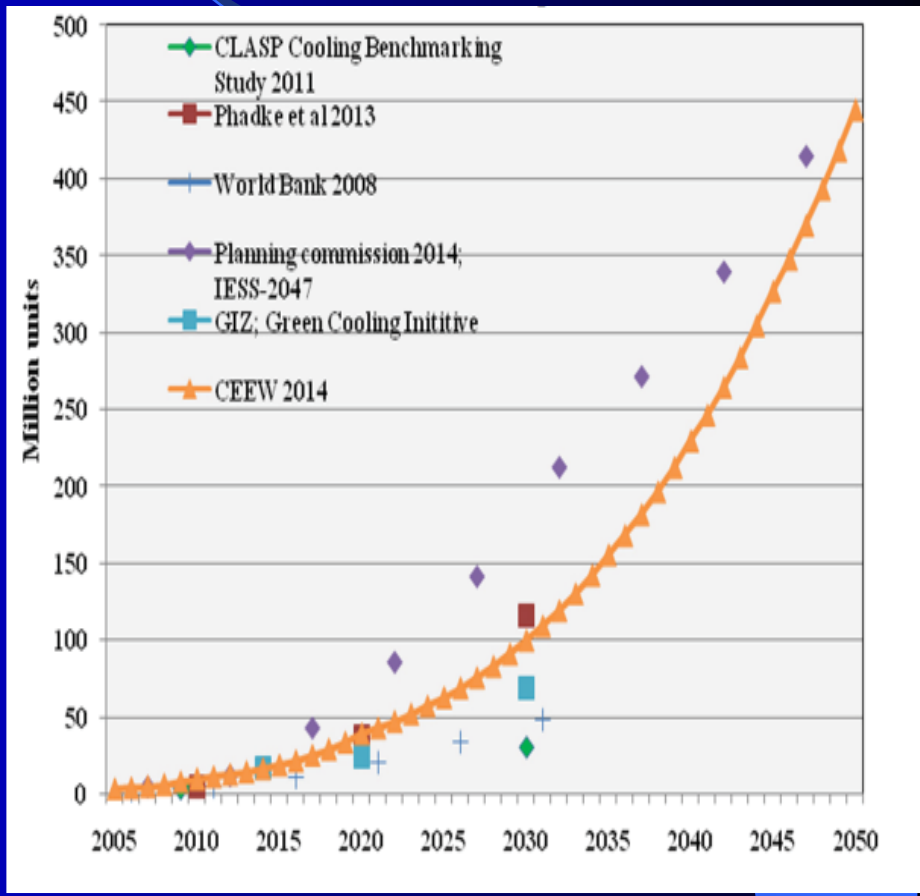
Growing Building & A/C Equipment Stock in India

Building Stock



Guide Book on HCFC Phase-out & EE in Buildings, MoEF & CC

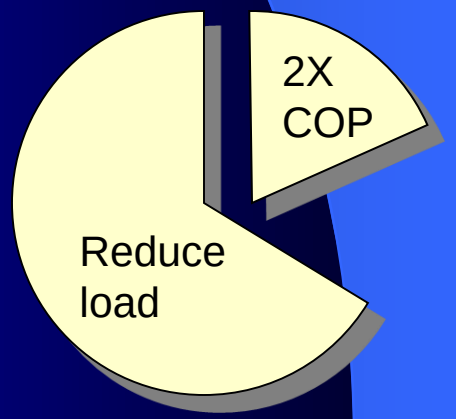
Stock of Residential ACs

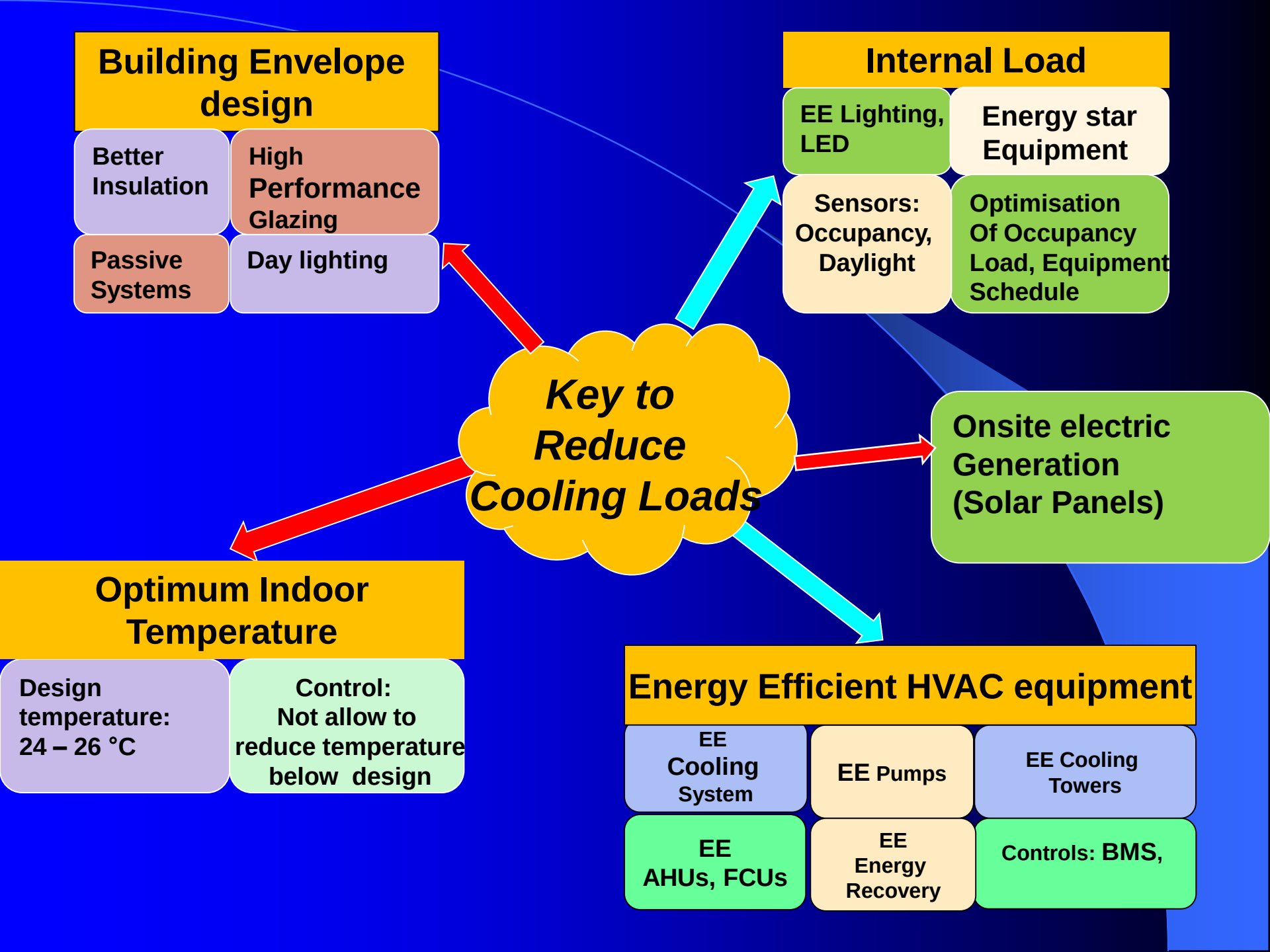


SOURCE: Council on Energy, Environment & Water

Challenges in Meeting Future A/C Demand

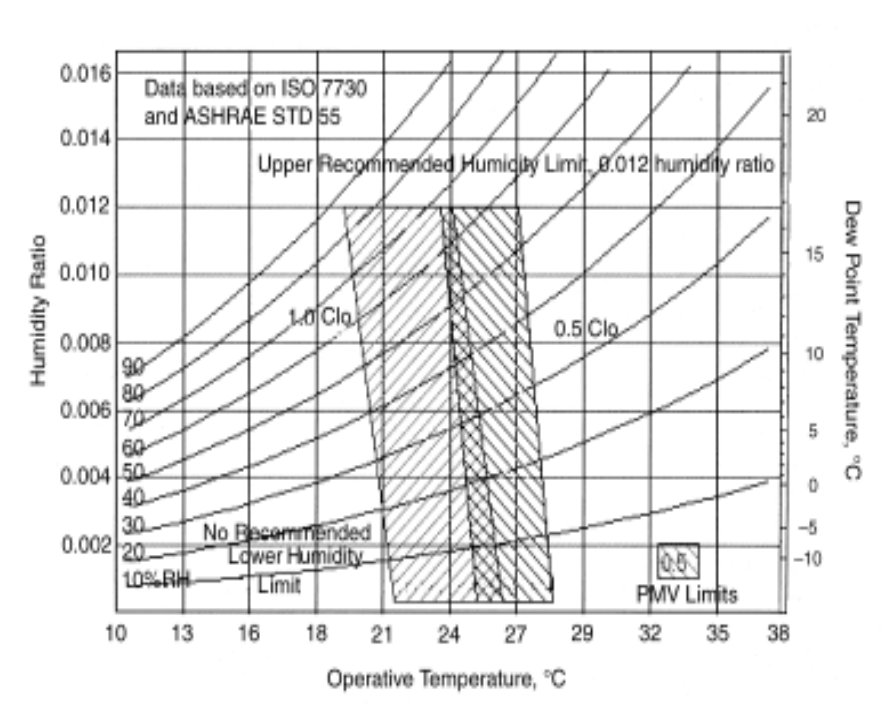
- A/C is energy intensive, it accounts for about 40% of the total electricity consumption;
- Energy efficient and low-GWP technologies are necessary but may not be sufficient to sustain the growing demand of A/C;
- Cooling load reduction and change in use pattern may be necessary for sustainability:
  - Buildings: living patterns vs. W/m ^{2};
  - Maintain healthy comfortable Indoor Conditions in buildings
  - Transportation: driving distance vs. liter/100km
- HVAC example
  - COP = 3.5 ⇨ COP = 7
  - Major effect on scale

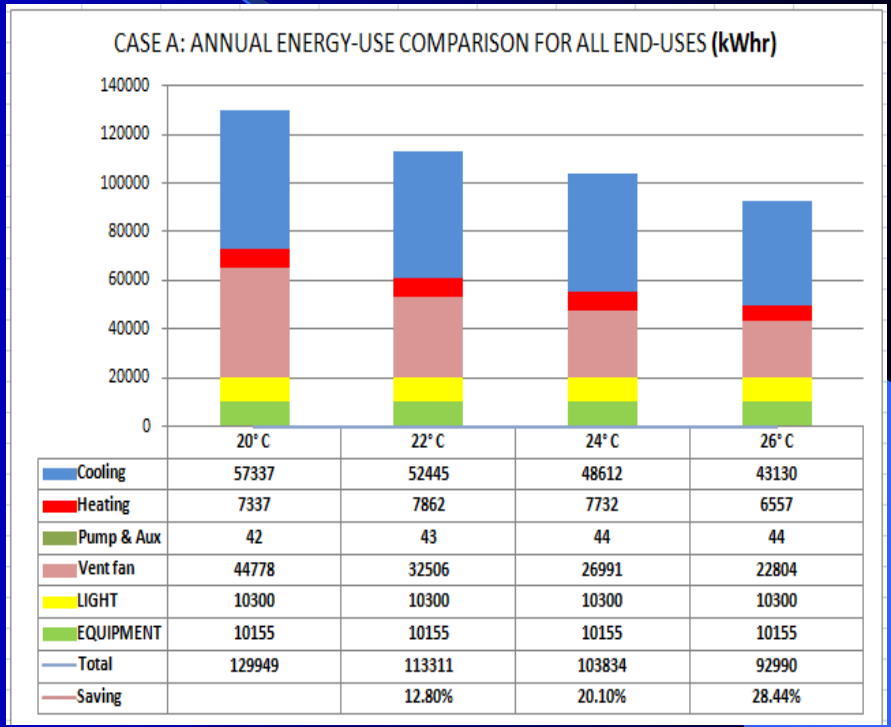



Building Envelope design
Better Insulation
High Performance Glazing
Passive Systems
Day lighting
Internal Load
EE Lighting, LED
Energy star Equipment
Sensors: Occupancy, Daylight
Optimisation Of Occupancy Load, Equipment Schedule
Key to Reduce Cooling Loads
Onsite electric Generation (Solar Panels)
Optimum Indoor Temperature
Design temperature: 24 – 26 °C
Control: Not allow to reduce temperature below design
Energy Efficient HVAC equipment
EE Cooling System
EE Pumps
EE Cooling Towers
EE AHUs, FCUs
EE Energy Recovery
Controls: BMS,

Minimum Setting of Indoor Temperature in the Conditioned Space

Impact of indoor temperature on energy consumption





	20° C	22° C	24° C	26° C
Cooling	57337	52445	48612	43130
Heating	7337	7862	7732	6557
Pump & Aux	42	43	44	44
Vent fan	44778	32506	26991	22804
LIGHT	10300	10300	10300	10300
EQUIPMENT	10155	10155	10155	10155
Total	129949	113311	103834	92990
Saving		12.80%	20.10%	28.44%

Maintaining higher indoor temperature from 20 to 22, 20 to 24, 20 to 26 the annual energy consumption reduces by 12%, 20% and 28% respectively

Post Kigali Technologies for A/C Sector: Single Component Refrigerants

Natural Refrigerants

HCs: R290, Ammonia & CO2

Fluorocarbon Refrigerants

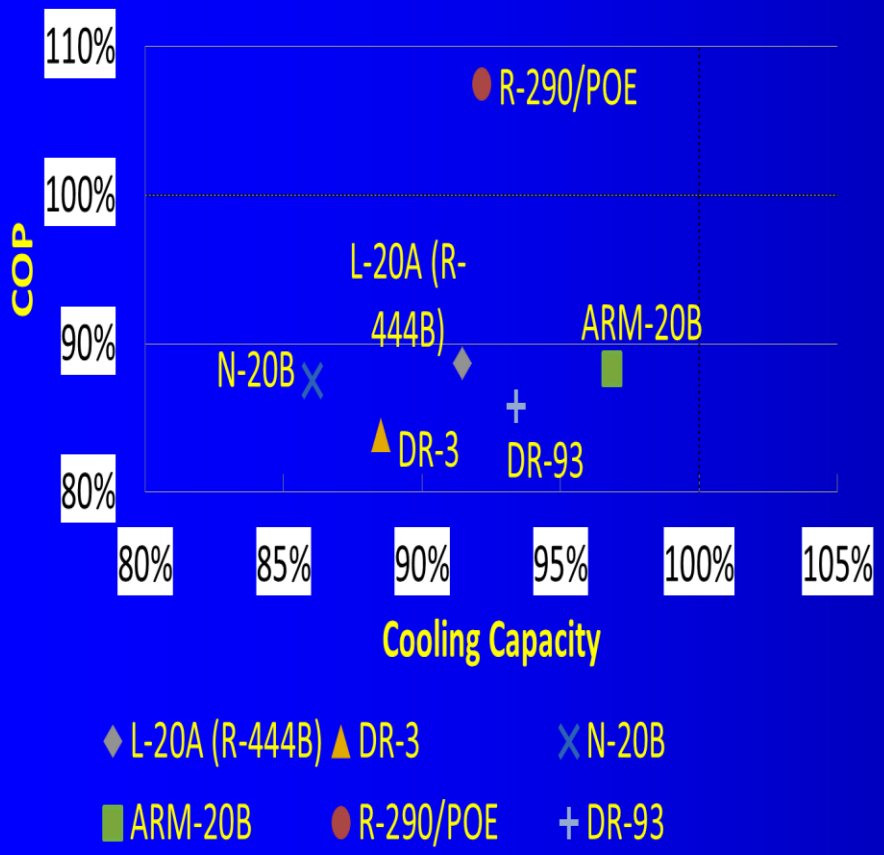
High Pressure:
HCFC-22 Replacements -
HFC-32

Medium Pressure:
HFC-134a Replacements
HFO-1234yf, 1234ze (E)

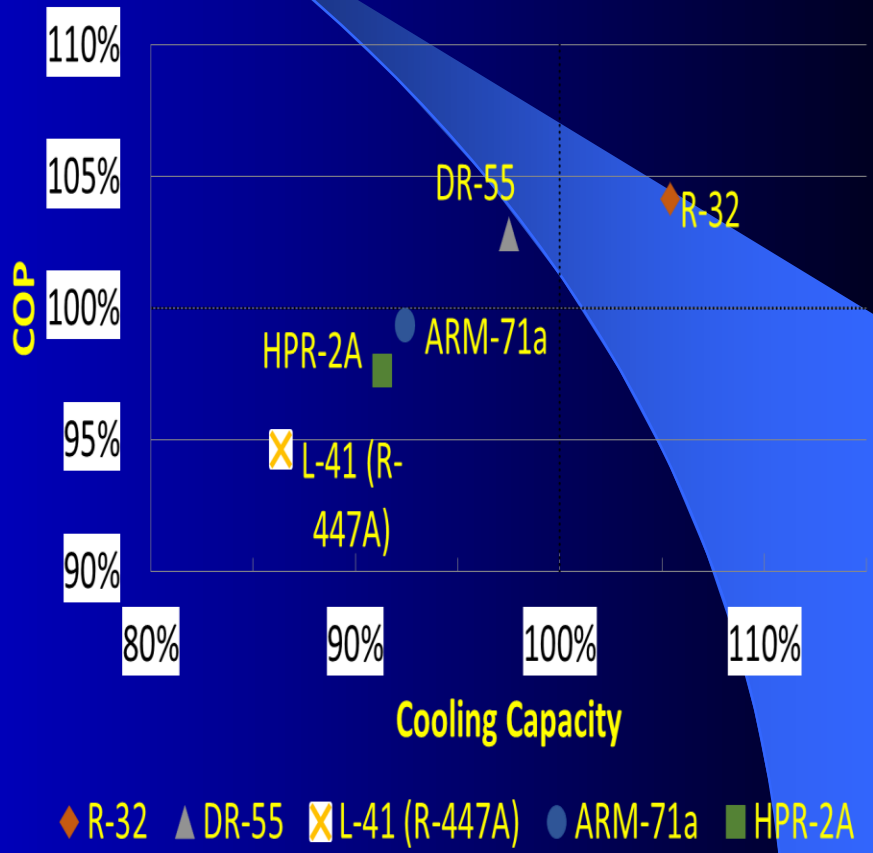
Low Pressure: HCFC-123 Replacements-
HFO-1233zd (E), 1336mzz

Technologies for A/C Sector: Blends of HFO & HFCs (source: ORNL)

HCFC-22 Replacement



R-410A Replacement



Post Kigali Potential Refrigerants for air-conditioning sector

Equipment	HCFC Refrigerant	Prior to Kigali commonly used Refrigerant (GWP)	Post Kigali Potential Low-GWP Refrigerant
Room ACs	HCFC-22 (1810)	R-410A (2100) R-407C (1700)	- HFC-32 (675); A2L - R-290 (3); A3 - R-452B (680); A2L
Ducted & Packaged AC	HCFC-22 (1810)	R-410A (2100) R-407C (1700)	- HFC-32(675) ; A2L - R-452B (680) ; A2L - R-444B (300) ; A2L
Scroll Chiller	HCFC-22 (1810)	R-410A (2100) R-407 C (1700)	- HFC-32 (675) ; A2 L - R-452B (680); A2L

Post Kigali Future Potential Refrigerants for Chillers: Low & Medium Pressure

Equipment	HCFC Refrigerant	Prior to Kigali Refrigerant (GWP)	Post Kigali Potential Low-GWP Refrigerant
Screw Chiller	----	HFC-134a (1430) (Medium Pressure)	Medium Pressure: - HFO-1234yf (< 1); A2L - HFO-1234ze (<1) A2L - R-513A (600) ; A1
Centrifugal Chiller (Low Pressure Chillers)	HCFC-123 (79) (Low-Pressure)	HFC-134a (1430) (Medium Pressure)	Low Pressure - HFO-1233zd (1) , A1 - HFO-1336mzz (2); A1 Medium Pressure - HFO -1234yf (<1); A2L - HFO- 1234ze (<1; A2L
VRF	------	R-410A (2100)	- R-410A

Use of low-quality heat Powered & Low-GWP Refrigerant A/C Technologies

- vapor absorption (VAP) technology;
- District cooling with low-GWP refrigerants- VAP, VC systems;
- Try-generation: power, cooling & heating;
- Evaporative Cooling
- Evaporative cooling with desiccant;
- Solar thermal
  - Space heating (and cooling?)
  - Desiccant regeneration
- Industrial process heat recovery;

Overview of Sustainable Technologies- India

MoEF&CC Delhi

Several Cities in India

District Cooling with low-GWP refrigerants VAP + VC

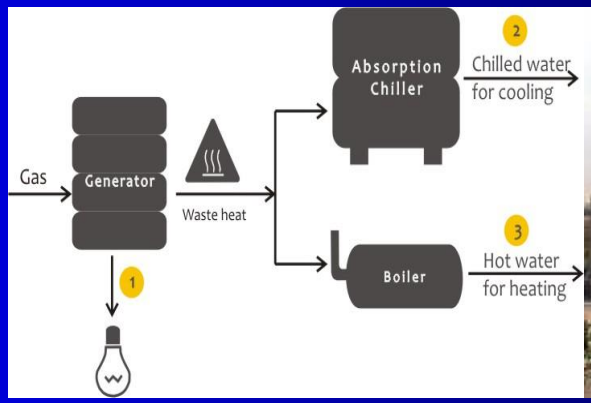
Room A/C with low-GWP Refrigerants

R-290 Split Room AC

Net +ve Energy building with 923 kW solar power generation

(Energy Performance Index : 43.75 kWh/m^2 /y)

Trauma Centre at AIIMS, Delhi (Govt. of India & Germany)



Textile Factory in Rajasthan

Evaporative Cooling

Tri-generation system of 347 kW (Power) + 1250 kW (A/C) + 20 kW (Heating)

Thank You
for your
Kind Attention