

Energy Efficiency Co-Benefits of Alternatives to HFCs

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Introduction to EIA

- Established in 1984, London and Washington DC
- Independent campaigning organisation committed to bringing about change that protects the natural world from environmental crime and abuse.
- Campaigns: Illegal trade in wildlife (tigers, elephants, whales), timber; chemicals
- Investigating illegal trade in ozone depleting substances (ODS) since 1997
- Closely involved in international ozone and climate negotiations for 15 years

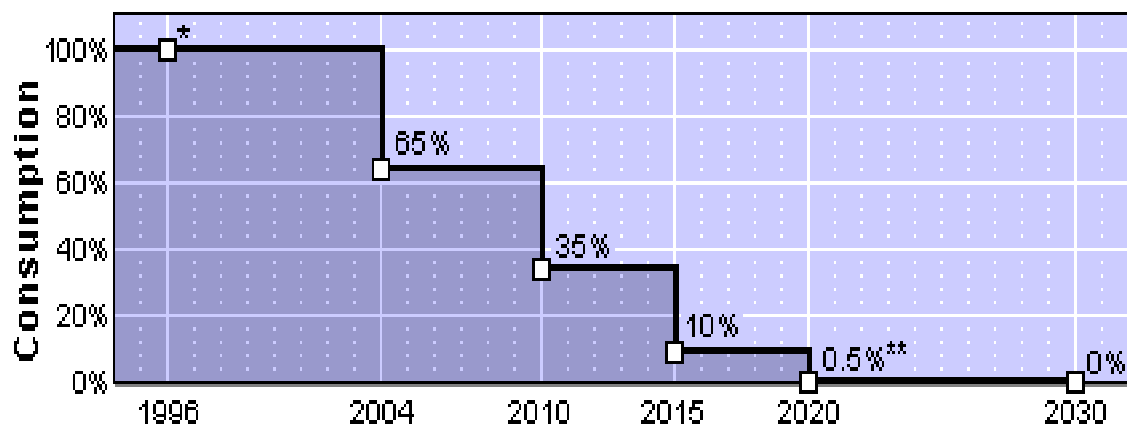


GWP of Common HFCs

Compound	Use	Atm. Lifetime	GWP	
			(100 Yr)	(20 Yr)
HFC-23	Waste gas/Refrig	243	14,800	12,000
HFC-32	Refrigerant	4.9	675	2,330
HFC-125	Refrigerant	29	3,500	6,350
HFC-134a	Multi-use	13.6	1,430	3,830
HFC-141b	Foam	9.3	750	2,250
HFC-142b	Foam	17.9	2,310	5,490
HFC-152a	Ref. and Foam	1.5	190	1,100
HFC-245fa	Foam	7.6	1,030	3,380
HFC-404A	Refrigerant AC	34.2	3,922	6,010
HFC-407c	Refrigerant AC & T		1774	4,115
HFC-410a	Refrigerant AC	>33	2,088	4,340

Accelerated HCFC Phase-out Schedules

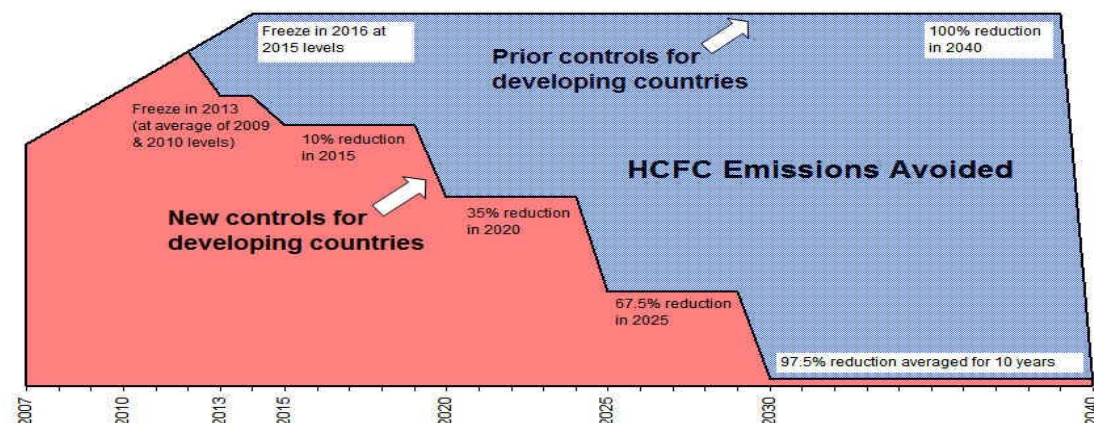
Consumption of HCFCs in Developed Countries



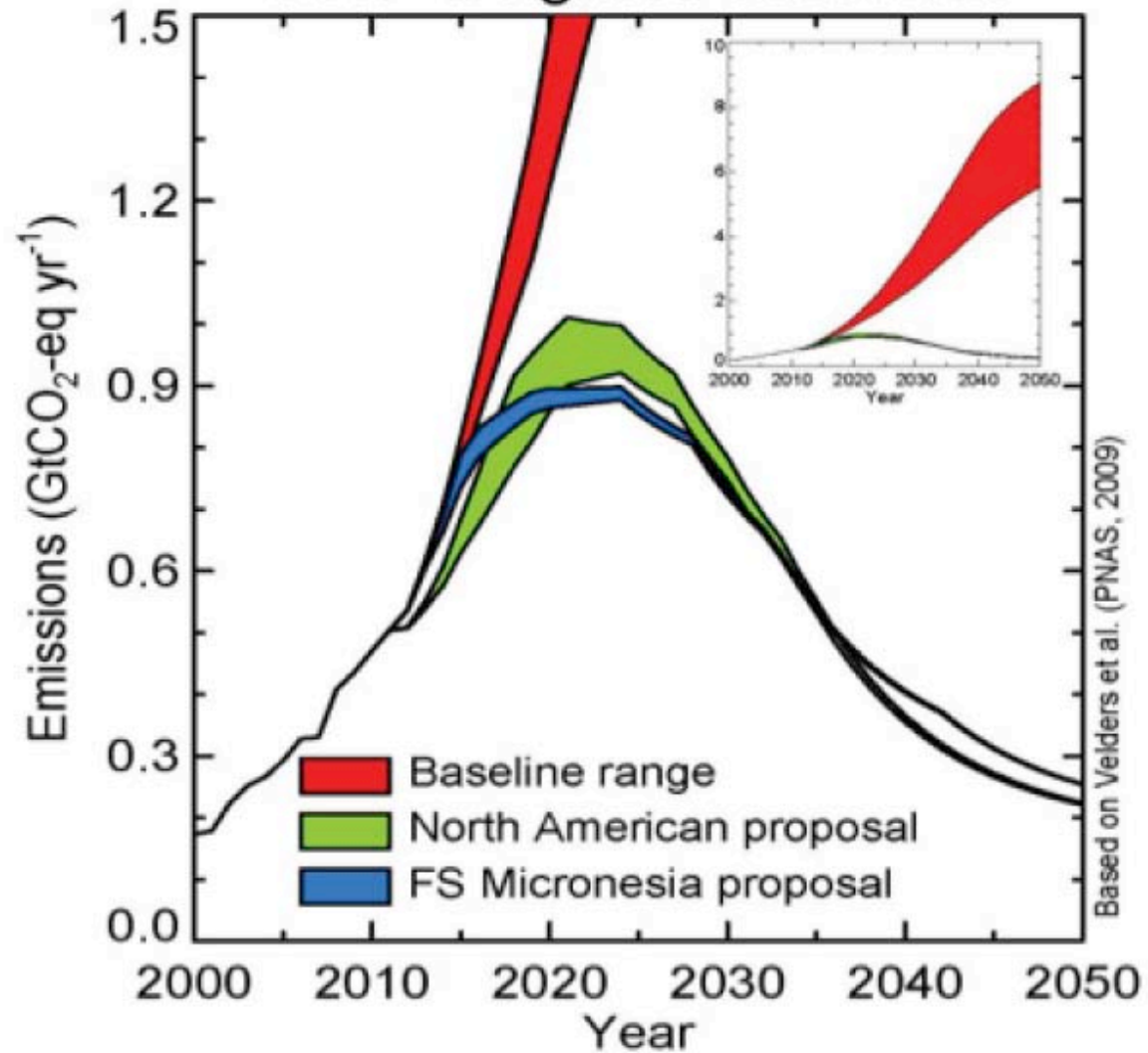
* 100% = 2.8% of CFCs in 1989 plus 100% of HCFCs in 1989

** Service only

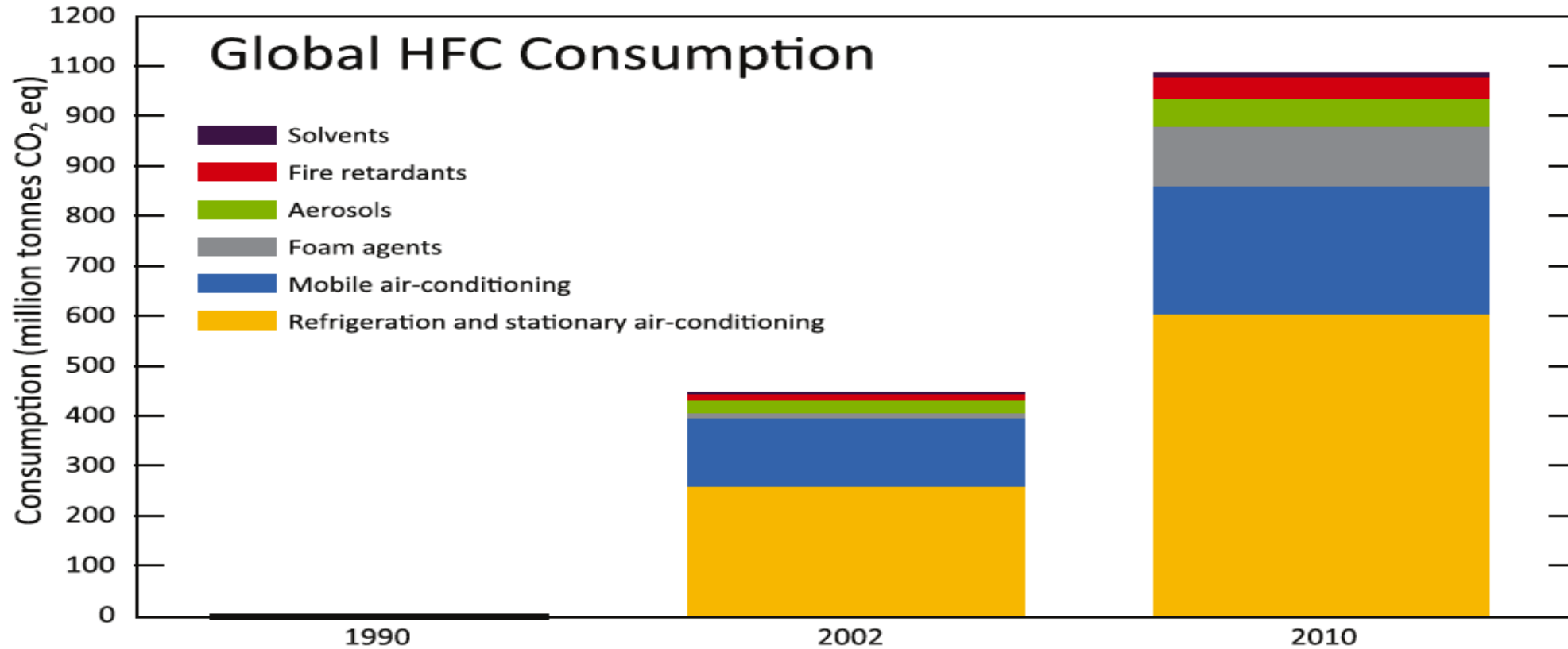
New Stronger Montreal Protocol Controls Reduce Developing Country HCFC Emissions about 58 Percent



GWP-weighted emissions



Growth in HFC Consumption



Two Long-term Options for Eliminating HFCs

1. Using fluorine-free substances with low or zero-GWP. The major proven low-GWP alts include:

- **Ammonia** GWP - 0
- **Hydrocarbons** such as propane, isobutane, propylene, and pentane GWP <4
- **Methyl Formate, Methylal** GWP <25
- **Dimethyl ether** GWP - 1
- **Water**
- **CO₂** - 1
- **Others**

Sectors with Substantial Percentage of Low-GWP Alternatives

SECTOR	EXAMPLES OF ALTERNATIVES	INDUSTRIALIZED COUNTRIES	DEVELOPING COUNTRIES	GLOBAL TOTAL
INDUSTRIAL REFRIGERATION SYSTEM (A)	AMONIA, CO2, HC	92%	40%	65%
INDUSTRIAL AIR CONDITIONING SYSTEM	AMONIA, CO2, HC	40%	15%	~25%
DOMESTIC REFRIGERATORS (VAPOR COMPRESSION CYCLE (B))	HC	51%	22%	36%
FOAM IN DOMESTIC REFRIGERATION	HC	66%	68%	67%
FOAM IN OTHER APPLIANCES (C)	HC	38%	<1%	28%
POLYURETHANE FOAM-BOARDS AND PANELS (C)	HC	82%	21%	76%
FIRE PROTECTION SYSTEM (D)	WATER, FOAMS, DRY CHEMICALS, INERT GASES	-	-	75%
ASTHMA MEDICATION	DRY POWDER INHALERS	-	-	~33%
SOLVENTS (F)	AQUEOUS, NO-CLEAN, ALCOHOLS, OTHERS	>90	>80	>80

Sources: FTOC 2010; TEAP 2009ab; TEAP 2010a.

The percentages in this table refer to: (a) refrigerants used in new installations annually; (b) annual production of new equipment; (c) annual consumption of blowing agents; (d) usage of market; (e) annual medical doses; (f) market penetration in solvent applications.

Barriers to Use of Low-GWP Alternatives

- Many low-GWP alternatives are currently in use, but there are some barriers in certain sectors, such as:
 - Regulations that prohibit use of flammable or toxic alternatives
 - Insufficient supply of components
 - Increased investment costs
 - Lack of trained technicians
- But the current use of low-GWP alternatives shows that these can be overcome
- Denmark has banned all HFCs and still continues to have one of the highest standards of living in the world!

Two Long-term Options for Eliminating HFCs (contd...)

2. Not in kind alternatives, alternative methods and processes, examples include:

- Roll-ons, pump sprays and other alternates to aerosols
- Fiber insulation materials
- Dry-powder asthma inhalers
- Building designs that avoid the need for air conditioning

Considering GWP and Energy in HPMPs

- Many countries will have to transition refrigeration and/or air conditioning in their Stage 2 HPMPs.
- The first question is what sectors can be transitioned where there are proven, commercially available low-GWP alternatives?
- Remembering that there is no one refrigerant choice for all sectors or all uses within a sector.
- Looking first at the GWP of the refrigerant leakage and related excessive energy use in existing systems can account for up to 50% of life time climate impact.
- Making sure to evaluate the energy efficiency of the chosen technology.
- Direct and indirect emissions both impact climate and energy use.

Commercial Refrigeration

- Claims that 90% of emissions are from energy use are incorrect
- High leakage rates (e.g. 15-25%).
- Direct emissions represent 40% of carbon footprint of at least two Europe-based global retailers.



Low-GWP Alternatives for Supermarkets

- Self Contained Units: Propane, isobutene, hydrocarbon blends and CO2
- Condensing Units: CO2 (EU and Japan)
- Rack Systems: CO2, glycol, trans-critical CO2 and cascade systems with CO2 and ammonia
- Central plants: ammonia and ammonia/CO2, water distributed system using HCs or CO2
- Packaged systems: ammonia and CO2 work but increase costs at present, can be replaced by rack or central plant systems
- Refrigerated Transport Systems: CO2 and hydrocarbons (EU)

Energy Efficiency of Ammonia

"Studies indicate a 10 percent to 20 percent improvement in energy efficiency, lower capital cost than ammonia pumped circulation, and paybacks within four years when compared to HFC condensing unit technology."

GEA

examples in
industrial
refrigeration

GEA Grasso NH₃ chillers



Ammonia example: Thai case study

Nestlé, Bangkok, Thailand: The NH₃/CO₂ cascade plant

- Total energy savings compared to standard NH₃/CO₂ design: 13% or 2,780,000 kWh/year
- Approx = €243,000 and 5.42 tonnes CO₂eq. To maximize energy savings the system features:
 - Heat recovery for processes, saving heating costs and improving refrigeration plant efficiency
 - Energy saving solutions on the drives: Variable speed drive compressors; use of high efficiency motors to the EU IE3 standard
 - Falling film chiller for ice water at +1°C: No need for intermediate medium and pumps to cool water at 1°C, resulting to 20kW gain
 - Fans with high efficiency for equipment with air heat exchangers: 70kW less
 - CO₂ brine instead of MEG: 8kW saving (higher evaporation temperature and less energy for pumping)
- Direct emissions: benefit for the planet is 1,905 tonnes/year eq CO₂, or 366 cars driving around the world when compared to an R404A solution (assuming 5000kg, leakage rate 10%).

Malaysian Case Study

- The production firm of The Coca-Cola Company, BIG (Bottling Investment Group): a facility on a 120,000-square-metre site in Malaysia that features an ammonia refrigeration system, that will serve as a showcase for bottlers in the entire region.
- For cooling purposes, cascade-type compressors are used with eco-friendly ammonia as the refrigerant.

CO₂/NH₃ Cascade Cold Storage

- The Zhangzi Island project: first large-scale cold storage logistics base adopting a NH₃/CO₂ cascade refrigeration system in China.
- In the processing plant, CO₂ brine system is installed and sea water is used to cool the high level ammonia refrigeration.
- Reduced ammonia refrigerant charge by more than 90%
- Limits the NH₃ refrigerant to inside the refrigeration control room, fully satisfying safety requirements.
- 30% annual energy savings



2013 China Refrigeration Exhibition in Shanghai

Ammonia innovations on display:

- Alfa Laval: U-Turn system-ammonia capacities from 200 to 1400 kW at 0°C evaporation temperature and from 50 to 500 kW at -40°C evaporation temperature
- Thermowave: ThermoPlus solution for high-pressure applications optimized for cascade NH₃/CO₂ systems & NH₃ high temperature applications
- Yantai Moon Group: Updated NH₃/CO₂ cascade refrigeration system this year. Reduced electricity use for refrigeration by 11.1% every year.

Ammonia: Fish processing plants, cold stores, and ice makers

- **Greenland:** A 10,000 m³ cold fish store was installed at Qasiiannhuit (Christianshab) in only three weeks including an ammonia refrigeration system equipped with a two-stage system for an air blast freezer, a plate freezer and a cold store, and one-stage systems for air conditioning, ice production, and two chill stores;
- **Iceland and the Faroe Islands:** Fish processing installations in Faskruosfjorour and Vestmanna have a 1150 kW and a 1000kW ammonia refrigeration capacity;
- **Philippines:** Both block ice plants, capable of producing 9.2 tonnes of ice blocks per 24 hours in blocks of 25kg, together with a 15-tonne storage container with a refrigeration unit, which ensures a storage temperature of -5°C, have been equipped with a complete ammonia refrigeration system;
- **Pohnpei Island, the Federated States of Micronesia:** Sabroe was commissioned to construct a fish processing plant with a capacity to chill or freeze tuna and reef fish and pack them into consumer cartons. The R-717 refrigeration system is equipped with a two-stage system for an air blast freezer, a plate freezer and a cold store, whereas one-stage systems have been installed for air conditioning, ice production, and two chill stores;
- **Spain:** Descal, a Spanish company has installed an ammonia refrigeration system with a 630kW ice production and freezer capacity and 1555kW cold room capacity.
- Each rated “High Energy efficiency” and resulted in dramatic reduction of HCFC and HFC emissions

Case Study of CO₂ Systems

Capetown/Johannesburg, South Africa: CO₂ Cascade System at Pick & Pay Supermarkets

- 19-26% energy efficiency improvement compared to HCFC system
- CO₂ refrigerant charge less costly
- Reduce 452,500 tons CO₂eq. assuming traditional HCFC system, and 25% leakage rate. This reduces servicing demand.



•AEON, Japan

- Reported to the 2013 Consumer Goods Forum that by perfecting CO₂ Trans-critical System and is achieving **20-30%** energy savings in all climatic regions. As of now the improvements are proprietary. AEON is converting 100 stores by 2015 and all new builds by 2015 which will have similar climate savings for each store.

Further Examples of CO₂ Systems

Istanbul, Turkey: CO₂ Transcritical System at Carrefour

- 15% energy efficiency improvement

Curitiba, Brazil: CO₂ Cascade System (R134a) at Condor

- 20% energy consumption reduction of freezers

Jardin Canada, Brazil: CO₂ Cascade System (R134a) at Verdemar

- 20% energy savings compared to same-sized HCFC-22 store

Turner, Maine: CO₂ Transcritical System at Hannaford (Delhaize America)

- Predicting 5-10% energy savings compared to HFC system

HFC-Free Technologies Are Available in the US Market for the Supermarket- Retail Refrigeration Sector:



Members of the Consumer Goods Forum and retailers worldwide have the tools they need to begin installing HFC-Free technology today and to exclusively install HFC-free equipment by 2015.

A MARKET EVALUATION PREPARED BY THE
ENVIRONMENTAL INVESTIGATION AGENCY
WITH THE ASSISTANCE OF IFC CONSULTING

ENVIRONMENTAL INVESTIGATION AGENCY
WASHINGTON, DC, U.S.A.



Low-GWP alternatives-Air Conditioning

- Heat Pumps: CO₂, ammonia, hydrocarbons
- Unitary AC (ducted and non-ducted): hydrocarbons, CO₂ combined systems
- Window units: hydrocarbons and CO₂
- Packaged Terminal AC: hydrocarbons, ammonia and CO₂
- Chillers: Ammonia and hydrocarbons
- HFC-410A the primary HFC choice: GWP of 2088 and is less energy efficient in hotter climates.



Hydrocarbons

Refrigerant	ODP (R11=1)	Atmospheric lifetime (y)	GWP(100) (kgCO ₂ kg ⁻¹)
CFC 12	1.0	100	10720
HCFC R22	0.055	12	1780
HFC R134a	0	14	1410
HFC 404A	0	14 – 52	3862
HFC 407C	0	5 – 29	1750
HFC 410A	0	5 – 29	2060
Propane HC R290	0	0.04	6
Iso-butane HC R600a	0	0.02	7
Propylene HC R1270	0	0.001	5

Source: Giz Proklima

- Safely used in all types of AC systems except centrifugal
- Nearly drop in replacements for HCFC-22
- Drop GWP of emissions from 1810 to 5-7
- Greater tightness reduces/eliminates emissions saves energy

Hydrocarbons to Non-Hydrocarbons Comparison

- 90% of cases, hydrocarbons offered the highest coefficient of performance
- On average hydrocarbons provided almost 10% efficiency gain over HCFC and HFC units
- High thermal conductivity + low viscosity + affordability + negligible GWP

Efficiency Achieved by Hydrocarbon AC

Geographic Unit Studied	Environmental-Friendly Milestone
Europe	A-rated air conditioner efficiency labeling and min. efficiency of forthcoming Eco-design regulation
China	Grade 2 Rated Energy Efficiency Label
India	Bureau of Energy Efficiency: Five-Star Rating
Australia	Exceeded Minimum Energy Performance Standards (MEPs).
Brazil	Exceeded MEPs

China

- **Gree Electric Appliances Inc.: room air-conditioners with propane (R290).**
- **15% energy improvement over their HCFC-22 units**
- **10% energy efficiency gains and lower cost for R-290 portable AC compared to R-410A**
- **Shenzhen Environment Protection Bureau's training program on hydrocarbon technologies and HCFC-22 replacement for air conditioning technicians: "to establish the correct awareness regarding hydrocarbon refrigerants and address concerns over safety"**

Hydrocarbons: Further Examples

- **Benson Air Conditioning (Australia):** Marketing split-unit domestic hydrocarbon air conditioners, manufactured in China and Thailand. According to the company, the hydrocarbon units perform with 15-20% better energy efficiency than the company's comparable previous HCFC-22
- **Godrej EON (India):** Green Balance range of 5-star air conditioners, not only exceed the energy saving rating specified by the Bureau of Energy Efficiency (BEE) for 2012 but also surpass the ratings specified for 2014 standards. Godrej reports that the new product saves 23% more energy than other 5-star products currently on the market. This will lead to combined direct and indirect emissions savings of approximately 1 million tonnes CO₂e (based on a product lifetime of 10 years).

Mona Campus of the University of West Indies

- Effectively converted many air conditioning units on campus, including central AC, window, and mini-split from HCFC-22 to propane (Duracool 22a)
- 646 units/1,413 tons of cooling which resulted in an estimated 350,039kWh annual savings (\$96,000).
- The hydrocarbon systems also require less maintenance and repair, which creates additional and significant cost benefits

SKI DUBAI



- Ski Dubai achieves such a high level of energy efficiency that it uses just 4 megawatts of the 52 MW consumed by the whole complex.
- Energy costs account for less than ten percent of operating costs.
- Ski Dubai uses new snow every day, the “used” snow is efficiently reused to cool the shopping mall

Ammonia Applications

- Diverse applications of Ammonia ACs throughout the world including at hospitals, office buildings, airports and universities
- The SAS Radisson Hotel in Denmark, a high occupancy building in the heart of Aarhus town center, has been successfully guaranteeing its guests' comfort through the operation of water-cooled ammonia chillers for over five years.
- In the UK, four 6.6 MW ammonia chillers have been installed in the energy center at Heathrow Airport to provide chilled water for the air conditioning system in the new Terminal 5 building.



One of four 6.6 MW ammonia chillers arrives at Heathrow Airport's Terminal 5 project.

Mauritius

- **Two government buildings were converted from CFC-11 and CFC-12 Chillers to ammonia, resulting in an energy savings of 28%.**
- **“Designed to demonstrate the feasibility of ammonia chillers in a tropical climate and the associated enhanced energy efficiency.”**
- **Also reduced GWP from 5,000 for CFC-11 and 8,500 for CFC-12 to 0 for ammonia!**

Vicot (China)/ Rocky Research (USA)



- Joint development
- Solar air conditioning system created utilizing 8kg of ammonia in a 21kW unit.
- Can be applied to domestic, commercial and industrial sectors and utilizes 3 components: solar collector, air conditioner and thermal energy storage system
- Electricity saving is 417kW.h/m² per year.
- Annual CO₂ emission reduction is 370 kg/m²

India



- Solar Energy Centre in Gurgaon (Haryana)
- 100 kw Solar Air-Conditioning System cools 13 rooms by having a 288 square meter “Solar Collector” area which generates nearly 60 kW of 210 °C pressurized hot water.
- Heat is applied in the vapor absorption machine to generate
- Water = system refrigerant which provides a 30% increase in energy efficiency

Masdar

0 carbon city that is expected to be completed by 2016 located in the desert outside Abu Dhabi.

Plans:

- Cooling system will consist of two solar thermal collectors that utilize the sun's energy to heat water for the 50-tonne absorption chiller.
- Dubai-based district cooling company Tabreed and Abu Dhabi's Masdar Institute of Science and Technology have signed an agreement for a research and development (R&D) project which aims to enhance operational performance and reduce energy consumption in district cooling plants.



Low-GWP Alternatives: Foams

- Polyurethane foam: Rigid - CO₂, supercritical CO₂, hydrocarbons, methyl formate, methylal
- Polyurethane foam: Flexible – CO₂, hydrocarbons, methyl formate
- Extruded polyurethane boardstock: CO₂, hydrocarbons and blends, inert gases



Benefits of Leapfrogging HFCs

- There are substantial market opportunities both as Article 2 countries engage in secondary transitions out of HFCs due to their climate impacts and as Article 5 countries make their initial transitions away from HCFCs.
- Consuming Article 5 countries can avoid the cost and disruption to their industries of yet another phase-out by transitioning directly from HCFCs to low-GWP or not-in-kind alternatives.

Conclusions

- Countries will benefit most in their Stage 2 HPMPs
 - if aware of all refrigeration and air conditioning options available,
 - AND the transitions are maximized in sectors and uses where low-GWP and high energy efficiency alternatives are available.
- Countries could consider dividing their Stage 2 into two HPMPs as just allowed by the Multilateral Fund to give time for the full range of alternatives to be commercialized before committing to transitions.

Conclusions (contd...)

- Servicing countries:
 - 50% of climate impacts of refrigeration and air conditioning is from leaks and increased energy use due to improper charge size due to leakage → implement good operation and maintenance practices.
 - By improving maintenance practices: savings in both the cost and climate impact of the refrigerant and substantial energy savings.

Thank you

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