PROKLIMA

Technical Options for reducing greenhouse gas emissions using natural refrigerants and energy efficiency

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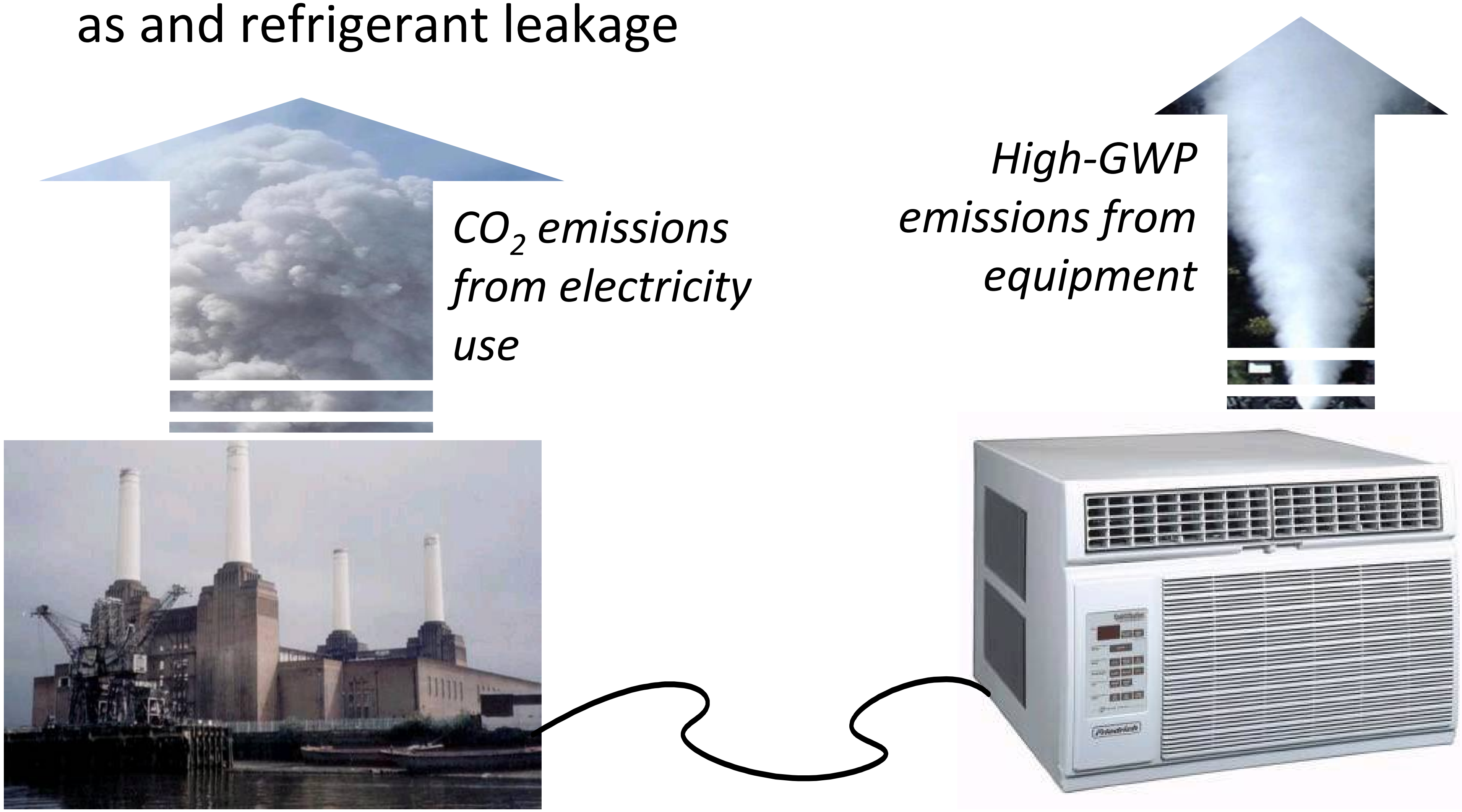
Global warming gas emissions also come from energy use as and refrigerant leakage



Many different refrigerant options and applications

?

How to determine which suits which?

Agenda

- 1. Description of subsectors
- 2. Discussion of technical options (TOs)
- 3. General description of technical options and examples
- 4. Examples of technical options
- 5. Refrigerant effect on efficiency
- 6. Reducing energy use in RAC equipment
- 7. Concluding remarks

1. Subsectors – Introduction

- Description of subsectors and system types
  - Provide overview of types of applications and common systems

1. Subsectors

- Many different uses of refrigerants
- Important to reduce down to manageable categories
- Main sectors: Refrigeration; Air conditioning
- Initially divide system types, then categorise into subsectors where evaluation of TOs is similar
  - Not practicable to evaluate TOs for each and every miniscule system type
- Neglect certain subsectors
  - Small market (minimal refrigerant use)
  - Complicate, non-uniform types of systems

1. Subsectors

- Summary of subsectors – air conditioning

Sub-sector	*System type*	*BAU refrigerant*
Unitary air conditioning	*Self-contained air conditioners*	*[R22], R410A, R407C*
	Split residential air conditioners	*[R22], R410A, R407C*
	Split commercial air conditioners	*[R22], R410A, R407C*
	Duct split residential air conditioners	*[R22], R410A, R407C*
	Commercial ducted splits	*[R22], R410A, R407C*
	Rooftop ducted	*[R22], R410A, R407C*
	Multi-splits	*[R22], R410A, R407C*
Chillers	*Air conditioning chillers*	*[R22], R410A, R407C*
	Process chillers	*[R22], R410A, R407C*
Mobile AC	*Car air conditioning, large vehicle*	*[R22], R410A, R407C*

R22 GWP = 1800; R410A GWP = 2100, R407C GWP = 1700

1. Subsectors

- Summary of subsectors - refrigeration

Sub-sector	*System type*	*BAU refrigerant*
Domestic refrigeration	*Domestic refrigeration*	*R134a*
Commercial Refrigeration	*Stand-alone equipment*	*R134a, R404A*
	Condensing units	*[R22], R404A*
	Centralised systems for supermarkets	*[R22], R404A*
Industrial refrigeration	*Low-temperature non-food-industry*	*[R22], R404A*
	Stand-alone (FPCS)	*R134a, R404A*
	Condensing units (FPCS)	*[R22], R404A*
	Centralised systems (FPCS)	*[R22], R404A*
Transport Refrigeration	*Refrigerated trucks/trailers*	*R134a, R404A*

*FPCS = food processing and cold storage

R22 GWP = 1800; R134a GWP = 1400, R404A GWP = 3800

2. Technical Options – Introduction

- Discussion of technical options (TOs)
  - Provide a summary of technical options that may be considered for different subsectors in order to reduce global warming emissions
  - Identifying the most suitable options

2. Technical Options (TOs)

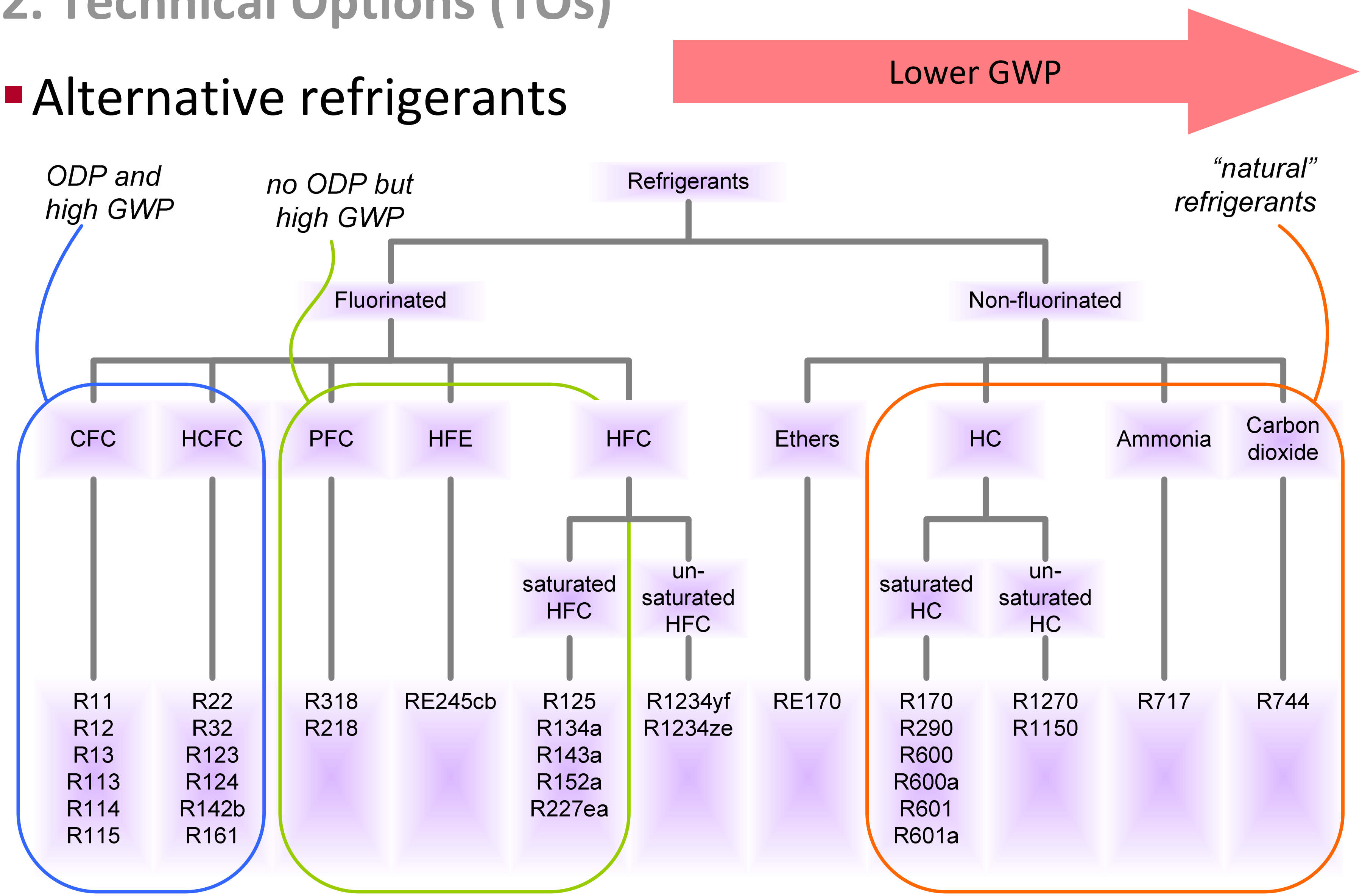
- Purpose of adopting TOs – to reduce emissions
  - (Direct) refrigerant-related emissions
  - Energy-related emissions → *In Costa Rica the emissions from electricity production is very low, to energy-related emissions are negligible*
- Several different categories of technical options
  - Containment
  - Alternative refrigerants
  - Alternative refrigerants and alternative system
  - Not-in-kind cycles
  - Efficiency improvements

2. Technical Options (TOs)

- Containment (and similar)
  - Leak reduction (design/construction of system)
  - Leak reduction (through service & maintenance practices)
  - Charge size reduction (system/component design)
  - Recovery and recycling (improved tooling and practices)

2. Technical Options (TOs)

- Alternative refrigerants



2. Technical Options (TOs)

- Alternative refrigerants
  - HC R600a (GWP = 3, flammable, low pressure)
  - HC R290/ R1270 (GWP = 3, flammable)
  - HFC R161 (GWP = 12, flammable, toxivity under reveiw)
  - HFC R152a (GWP = 140, flammable)
  - R717 (GWP = 0, low flammability, higher toxicity)
  - R744 (GWP = 1, high pressure, low critical temperature)
  - R718 (GWP = 0, very low pressure, freezing point = 0 deg C)
  - unsat-HFC (e.g., R1234yf, R1234ze, etc; GWP < 10, low flammability)
  - HFC/unsat-HFC blends (unknown to date; GWP 300 – 1000...?)
  - DME/R-E170 (GWP = 3, flammable)

2. Technical Options (TOs)

- Alternative refrigerants + systems
  - Low-GWP + liquid secondary [centralised] (e.g., glycol, brine)
  - Low-GWP + PCM secondary [centralised] (e.g., ice slurry)
  - Low-GWP + CO2 secondary [centralised]
  - Low-GWP + liquid secondary [discrete] (e.g., glycol, brine)
  - Low-GWP + CO2 cascade
  - Distributed water-cooled (central chiller with localised water-cooled condensing units)

* “Low-GWP” includes any low-GWP refrigerant (HCs, R717, unsat HFCs, etc)

2. Technical Options (TOs)

- Not-in-kind cycles
  - Air cycle (Brayton)
  - Absorption (liquid) (solar or gas driven)
  - Adsorption (solid) (solar or gas driven)
  - Desiccant/evaporative (solar or gas driven)
  - Thermo-electric (Peltier)
  - Magnetic
  - Stirling
  - Ejector cycle (solar or gas driven)
- Generally all of these have low efficiency, high cost, limited applicability, etc

2. Technical Options (TOs)

- Not all TOs are suitable for all applications
- Many TOs are therefore filtered out, according to various criteria
- TEWI rating (incl. energy related + GWP emissions)
  - GWP, charge size, in-use leak rate, EOL leakage, seasonal efficiency, energy production emissions factor
- Degree of demonstration (for subsector)
  - Has TOs been proven, demonstrated, only theory, etc
- Extent of application of TOs (for subsector)
  - What is maximum percentage of subsector that could be viably covered by TOs (limited by cost, efficiency, regs, etc)

2. Technical Options (TOs)

- Selected TOs used for deeper evaluation
  - Leak reduction (design/const)
  - Leak reduction (maintenance)
  - Charge size reduction
  - Recovery and recycling
  - HC600a
  - HC290/HC1270
  - R717
  - R744
  - unsat-HFC
  - HFC/unsat-HFC blends (R4???)
  - Low-GWP + liquid secondary (centralised)
  - Low-GWP + CO2 secondary (centralised)
  - Low-GWP + CO2 cascade (centralised)
  - Low-GWP + liquid secondary (discrete)
  - Low-GWP + distributed water-cooled cond units

2. Technical Options (TOs)

- Summary of subsectors – air conditioning

<table>
<tr><th>Sub-sector</th><th>System type</th><th>Technical options</th></tr>
<tr><td rowspan="7">Unitary air conditioning</td><td>Self-contained air conditioners</td><td rowspan="6">HC R290/HC 1270
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2. Technical Options (TOs)

- Summary of subsectors – air conditioning

Sub-sector	*System type*	*Technical options*
Chillers	*Air conditioning chillers*	*HC R290/HC 1270* *R717 (ammonia)* *R744 (CO2)* *Unsat-HFC (R1234yf, etc)* *HFC/unsat-HFC blends (R4???)*
	Process chillers	
Mobile AC	*Car air conditioning, large vehicle*	*HC R290R744 (CO2)* *Unsat-HFC (R1234yf)*

2. Technical Options (TOs)

- Summary of subsectors - refrigeration

Sub-sector	*System type*	*Technical options*
Domestic refrigeration	*Domestic refrigeration*	*HC 600a* *Unsat-HFC (R1234yf, etc)*
Commercial Refrigeration	*Stand-alone equipment*	*HC 600a, HC 290* *R744 (CO2)* *Unsat-HFC (R1234yf, etc)*
	Condensing units	*HC 290/HC 1270* *HC 290/HC 1270 (discrete indirect)* *Unsat-HFC (R1234yf, etc)* *HFC/unsat-HFC blends (R4???)*
	Centralised systems for supermarkets	*Low-GWP + liquid secondary* *Low-GWP + CO2 secondary* *Low-GWP + CO2 cascade* *Low-GWP + distributed low-GWP water-cooled cond units*

2. Technical Options (TOs)

- Summary of subsectors - refrigeration

Sub-sector	*System type*	*Technical options*
Industrial refrigeration	*Stand-alone (FPCS)*	*HC 600a, HC 290* *R744 (CO2)* *Unsat-HFC (R1234yf, etc)*
	Condensing units (FPCS)	*HC 290/HC 1270* *HC 290/HC 1270 (discrete indirect)* *Unsat-HFC (R1234yf, etc)* *HFC/unsat-HFC blends (R4???)*
	Centralised systems (FPCS)	*Low-GWP + liquid secondary* *Low-GWP + CO2 secondary* *Low-GWP + CO2 cascade* *Low-GWP + distributed low-GWP water-cooled cond units*
Transport Refrigeration	*Refrigerated trucks/trailers*	*HC 290/HC 1270* *R744 (CO2)* *HFC/unsat-HFC blends (R4???)*

3. TOs – general – Introduction

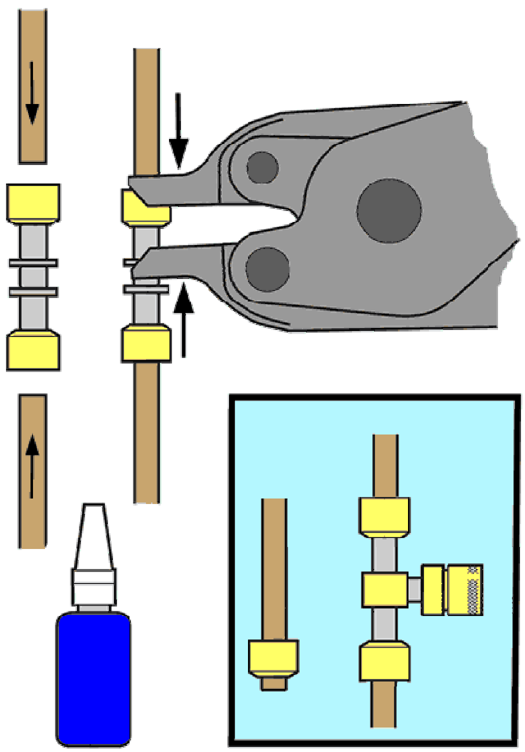
- Description of technical options (TOs) in general
  - A general description of what the technical options are
  - Brief explanation of the safety implications of certain refrigerants, including safety standards

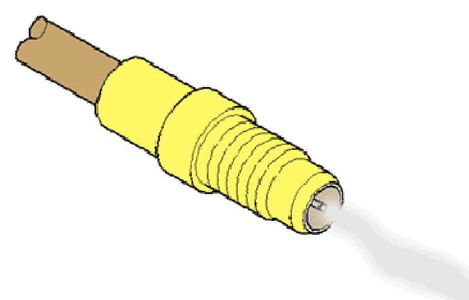
3. TOs – general – Leak reduction (design/construction)

- Improve the tightness of systems (use existing refrigerant)
- Good design
  - Avoid vibration, external mechanical impact, possibility of corrosion, etc
- Selection of components
  - Avoiding flare connections, schraeder valves, good parts
  - Components tested under EN 16084 (Qualification of tightness of components and joints)
- Tightness testing
  - Systematic testing of systems, use of helium tracer gas and high sensitivity gas detectors

3. TOs – general – Leak reduction (maintenance)

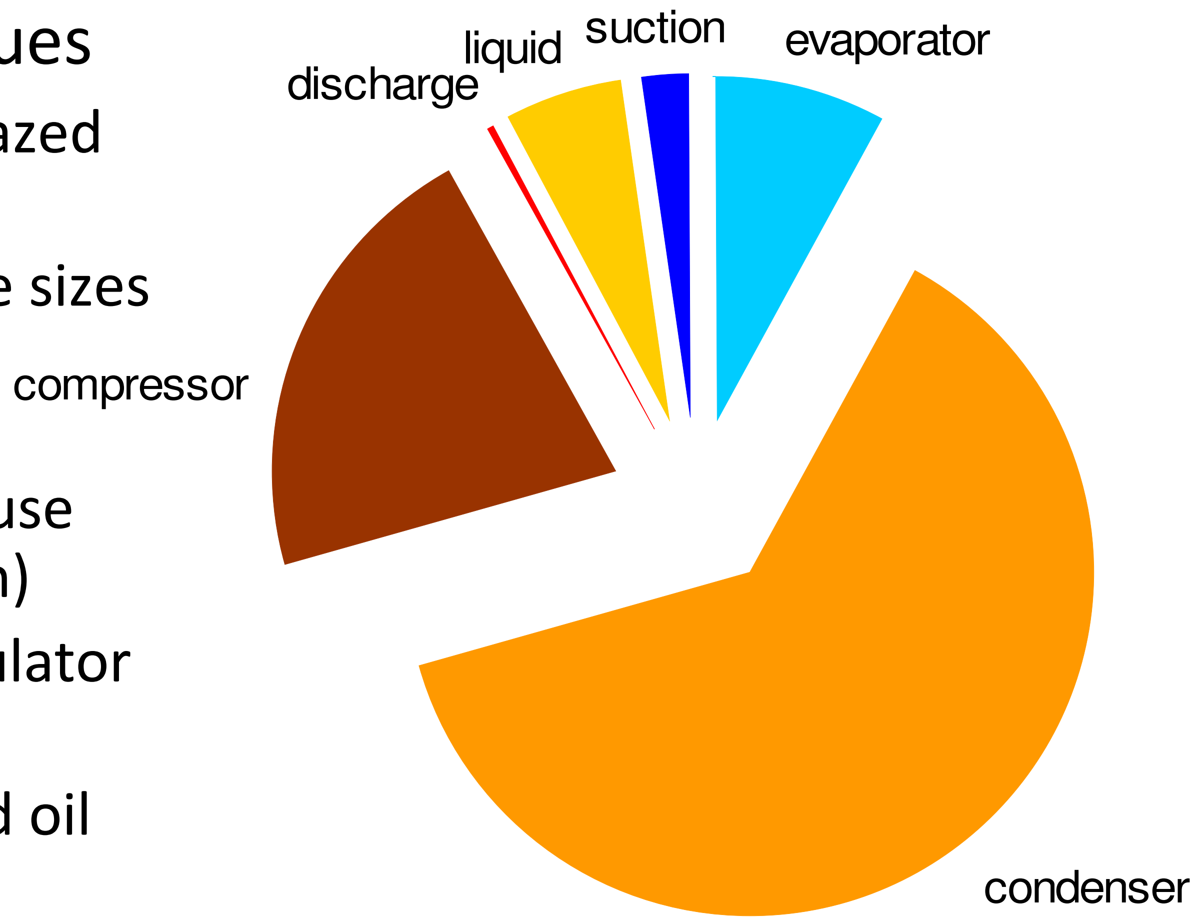
- Minimise emissions of refrigerant by improved service and maintenance
- Encourage more conscientious behaviour of technicians





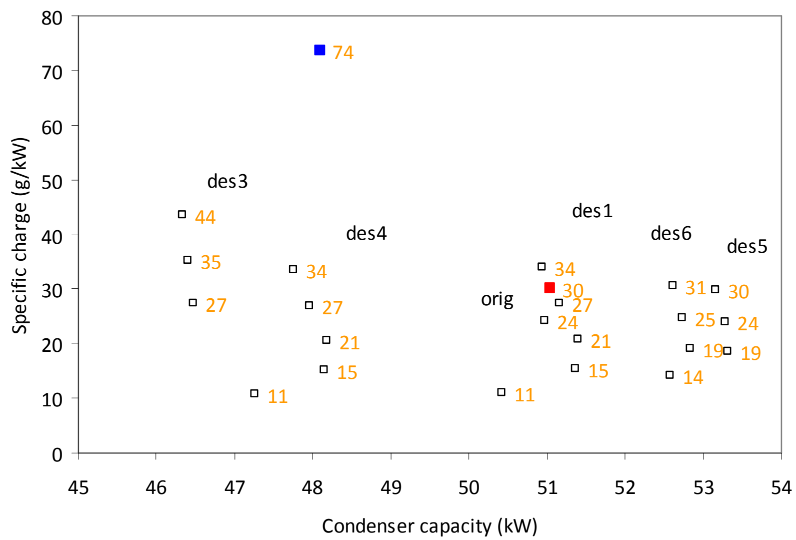
3. TOs – general – Charge size reduction

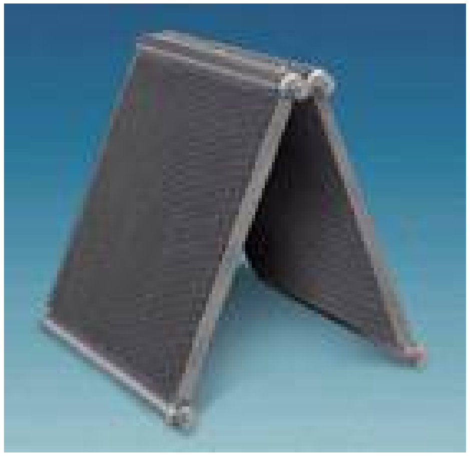
- If refrigerant charge can be reduced, total emitted quantity will be less
- Standard techniques
  - —Compact HXs, brazed plate, etc
  - —Smaller liquid line sizes Mini-channel condensers
  - —Avoid receivers (use subcooling region)
  - —Minimise accumulator volume
  - —Carefully selected oil (low solubility)

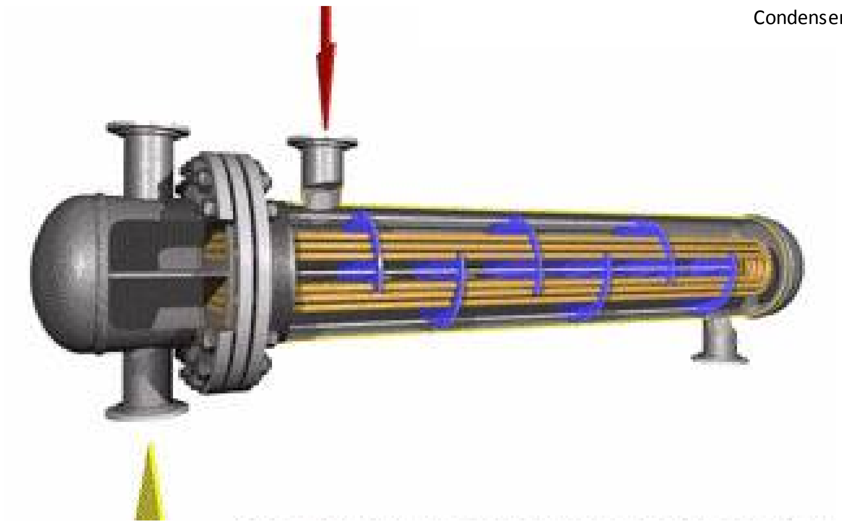


3. TOs – general – Charge size reduction

- Selection of heat exchangers







3. TOs – general – Recovery and recycling

- Minimise emissions of refrigerant by improved refrigerant recovery
  - During service and maintenance and particularly at end of life/disposal
- Encourage more conscientious behaviour of technicians
- Availability of recovery machines, recovery cylinders and take-back scheme for recovered refrigerant

3. TOs – general – alternative refrigerants

Refrigerant	R-600a (iso-butane)
Type	Hydrocarbon
ODP	0
GWP	<3
Safety classification	A3 (high flammable, low toxicity)
Vapour pressure	3.5 bar @ 25 deg C
Experience	Extensive
Availability	Good
Price	$2 – 6 / 7 – 20 per kg

3. TOs – general – alternative refrigerants

Refrigerant	R-290 (propane)
Type	Hydrocarbon
ODP	0
GWP	<3
Safety classification	A3 (high flammable, low toxicity)
Vapour pressure	9.5 bar @ 25 deg C
Experience	Extensive
Availability	Good
Price	$2 – 6 / 7 – 20 per kg

3. TOs – general – alternative refrigerants

Refrigerant	R-1270 (propylene)
Type	Hydrocarbon
ODP	0
GWP	<3
Safety classification	A3 (high flammable, low toxicity)
Vapour pressure	11.5 bar @ 25 deg C
Experience	Extensive
Availability	Good
Price	$2 – 5 / 3 – 20 per kg

3. TOs – general – alternative refrigerants

Refrigerant	R-717 (NH_3)
Type	Ammonia
ODP	0
GWP	0
Safety classification	B2 (low flammable, higher toxicity)
Vapour pressure	10.0 bar @ 25 deg C
Experience	Extensive
Availability	Good
Price	$0.5 – 2 / 1 – 4 per kg

3. TOs – general – alternative refrigerants

Refrigerant	R-744 (CO_2)
Type	carbon dioxide
ODP	0
GWP	1
Safety classification	A1 (non-flammable, low toxicity)
Vapour pressure	64.3 bar @ 25 deg C
Experience	Extensive
Availability	Good
Price	$0.5 – 2 / 5 – 7 per kg

3. TOs – general – alternative refrigerants

Refrigerant	R-1234yf
Type	HFC
ODP	0
GWP	3
Safety classification	A2 (low flammable, low toxicity)
Vapour pressure	6.8 bar @ 25 deg C
Experience	Limited
Availability	Not commercially available
Price	$45 – 65 / 45 – 80 per kg

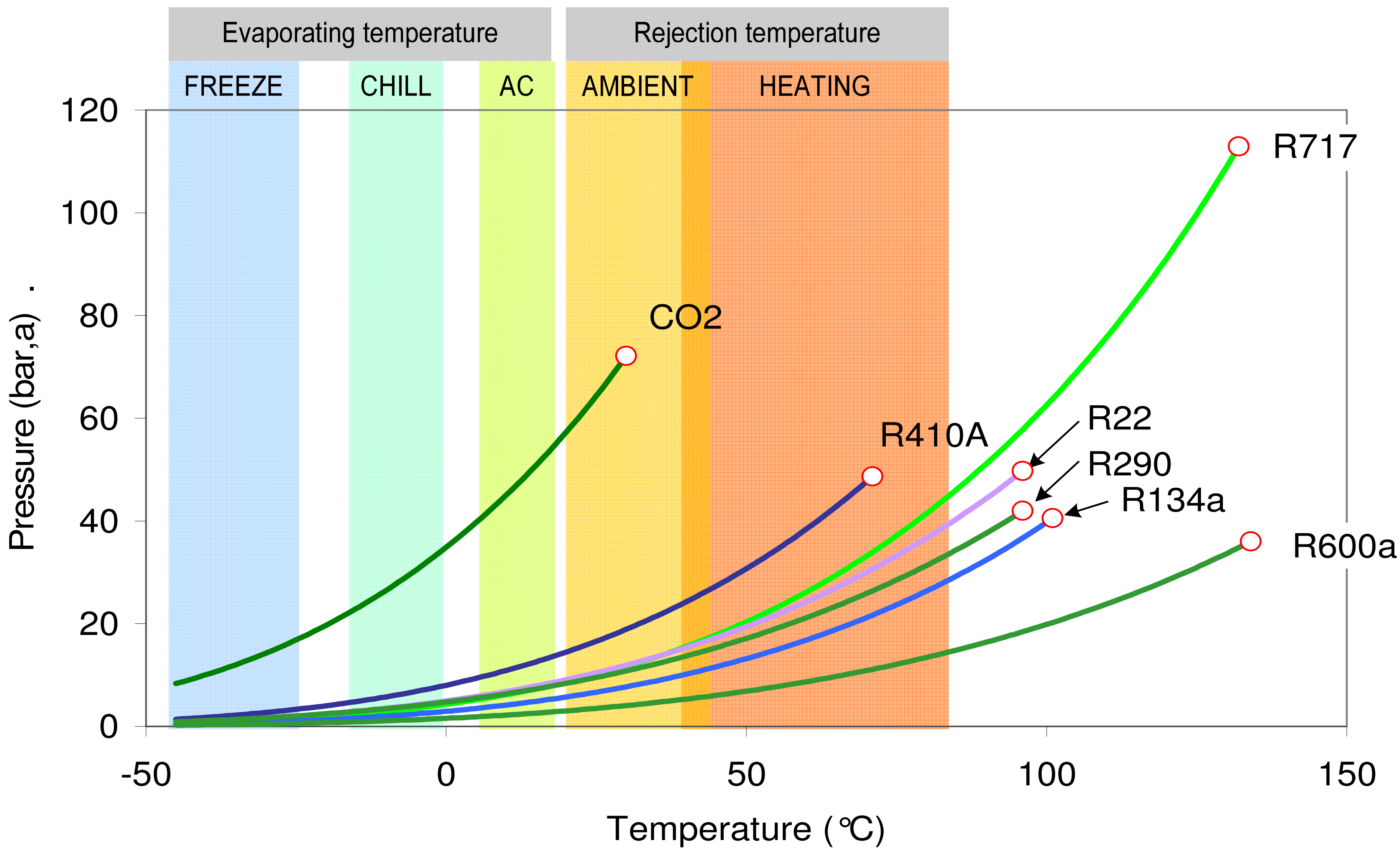
3. TOs – general – alternative refrigerants

Refrigerant	R-1234ze
Type	HFC
ODP	0
GWP	12
Safety classification	A2 (low flammable, low toxicity)
Vapour pressure	5.0 bar @ 25 deg C
Experience	Limited
Availability	Limited
Price	$30 – 50 / 30 - 65 per kg (?)

3. TOs – general – alternative refrigerants

Refrigerant	R-4??? [not yet known]
Type	HFC/unsat-HFC blend
ODP	0
GWP	300 – 1000 ???
Safety classification	A1, A2 (non-/low flammability, low toxicity)
Vapour pressure	[not known]
Experience	None
Availability	Not commercialised
Price	$ high

3. TOs – general – alternative refrigerants pressure range



3. TOs – general – alternative refrigerants safety characteristics

Refrigerant	Safety class	ATEL (kg/m3)	LFL (v/v)	Pressure (bar)
HCFC-22	**A1**	**0.3**	**-**	**10.4**
R-744	A1	0.07	-	64.3
HFC-1234ze	A2(L)	[0.28]	7.5%	5.0
HFC-1234yf	A2(L)	0.47	6.3%	6.8
HFC-152a	A2	0.14	4.8%	6.0
HC-1270	A3	0.01	2.5%	11.5
HC-290	A3	0.09	2.1%	9.5
R-717	B2(L)	0.00035	13%	10.0

3. TOs – general – safety rules for alternative refrigerants

Implications of refrigerant classification

	Lower (chronic) toxicity	Higher (chronic) toxicity
No flame propagation	A1 HCFC-22, R-744	B1
Lower flammability	A2 HFC-1234ze, HFC-1234yf - - - HFC-152a	B2 - - - R-717
Higher flammability	A3 HC-290, HC-1270, [HFC-161]	B3

More onerous requirements

More onerous requirements

3. TOs – general – safety rules for alternative refrigerants

Main topics within RAC safety standards

- Classification of refrigerants, occupancy, systems
- Refrigerant charge size – limits
- Safe design and testing of components and pipes
- Safe design and testing of assemblies (systems)
- Electrical safety, sources of ignition
- Installation areas, positioning, pipework, mechanical ventilation, gas detection
- Instructions, manuals, data-plates
- Refrigerant handling

3. TOs – general – safety rules for alternative refrigerants

Standard	Equipment type	Covers
EN 378	Commercial and industrial	Components, safety devices, system design, location, charge size limits, refrigerant classification, installation site, maintenance
[ISO 5149]*	Commercial and industrial	
60335-2-24	Domestic fridges and freezers	Marking, pressure testing, electrical
60335-2-40	Factory built a/c and heat pumps	Marking, pressure testing, maintenance, electrical, charge limits
60335-2-89	Factory built commercial fridges	Marking, pressure testing, electrical

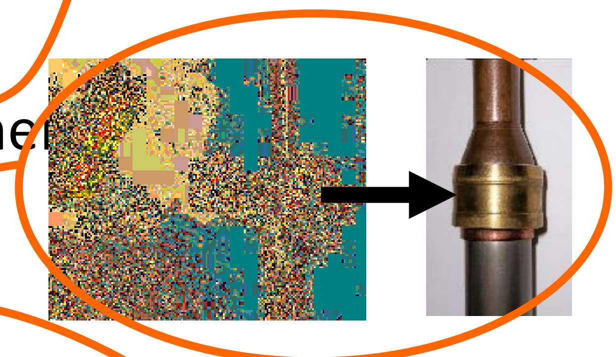
** Currently still at draft stage*

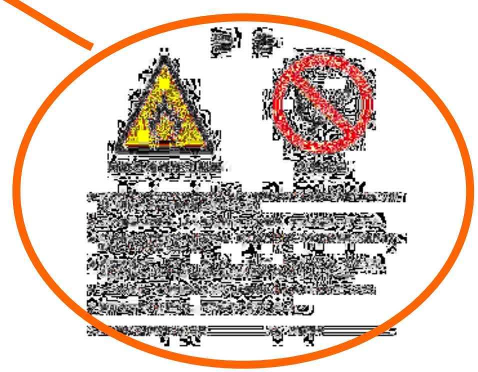
3. TOs – general – safety rules for alternative refrigerants

	Max charge (occupied)	PL (g/m^3)	Max charge - outside	Safe electrics
HCFC-22	**No limit**	**300**	**No limit**	**No**
R-744	No limit	100	No limit	No
HFC-1234ze	3.1 – 25 kg	[40]	No limit	Yes
HFC-1234yf	2.3 – 25 kg	60	No limit	Yes
HFC-152a	5 – 25 kg	27	No limit	Yes
HC-290 HC-1270	1 – 2.5 kg	8	25 kg/no limit	Yes
R-717	2.5 – 25 kg	0.4	No limit	Some

3. TOs – general – safety rules for alternative refrigerants

- Must recognise that some new refrigerants (HCs, unsat-HFCs) are flammable
  - —Conventional refrigerants non-flammable
- Must therefore follow new measures
  - —Limiting charge size of direct systems
  - —Avoid potential ignition sources on equipment
  - —Minimise leakage
  - —Marking on equipment
- All must be handled by trained technicians
  - —Should be certified
- Follow safe application guidelines
  - —E.g., for servicing, conversion, etc





4. Examples of application of technical options (TOs)

- Examples of application of (TOs)
  - For different subsectors and system types, examples of where different technical options are being used

4. Examples of TOs

Sub-sector	*System type*	*Technical options*
Unitary air conditioning	***Self-contained air conditioners***	***HC R290/HC 1270***
	Split residential air conditioners	
	Split commercial air conditioners	

4. Examples of TOs – Residential room AC

- De’Longhi
  - Portable type air conditioners
- Safety aspects
  - Designed to EN 60335-2-40
  - Charge size up to 400 g of R290
- Cost of R290 systems same as HFC products
- Energy consumption
  - R290 gives 5-10% higher efficiency than HFC options

4. Examples of TOs – Residential room AC

- Godrej company
  - Since 1897, appliances business since 1958
  - One of largest privately held industrial corporations in India
- R290 AC production line
  - Capacity approx. 180,000 units annually
  - Expected emissions reduction 500,000 tonnes CO_2 per year

designed by curiosity

Godrej | APPLIANCES

4. Examples of TOs – Residential room AC

- Godrej products
  - Currently two sizes developed
  - Each has four models, corresponding to different Indian efficiency star rating categories
  - Data for "five star" products

Model Name	R290-12K	R290-18K
Operating Mode	Cooling	Cooling
Cooling Capacity	3400 W	4900 W
Rated Power Input	914 W	1318 W
Rated Input Current	4 A	6 A
EER	3.72	3.72
Refrigerant	R 290	R 290
Refrigerant Charge	0.290 kg	0.340 kg

High efficiency

Very low specific refrigerant charge (<80 g/kW)

Also includes leak safety mechanism to leak safe

4. Examples of TOs – Residential room AC

- Midea company
  - One of China's largest air-conditioning companies
  - Main production of domestic AC, commercial AC, central AC, refrigerators, other home appliances, compressors, etc
- R290 AC production line
  - Approx. 200,000 per year
  - Production expected to begin mid-2012
  - (Also converted compressor production line for R290)

4. Examples of TOs – Residential room AC

- Midea products
  - Currently two sizes developed
  - Both reversible
  - Other products developed
  - Safety systems under development

Model	Indoor unit (mm)	Outdoor unit (mm)	Cooling capacity	EER	Heating capacity	COP	R290 charge
KFR-26GW/N7Y-Y(C4)	850 × 275 × 160	780 × 540 × 250	2.6 kW	3.4	2.8 kW	3.6	290 g
KFR-35GW/N7Y-Y(C4)	900 × 285 × 160	780 × 540 × 250	3.5 kW	3.4	3.7 kW	3.6	350 g

4. Examples of TOs – Residential room AC

- Gree company
  - Worlds largest air-conditioner producer
  - Room AC, ducted, centralised, chillers, etc
- R290 AC production line
  - R290 AC production line approx. 100,000 per year
  - Initial runs production began 2011

4. Examples of TOs – Residential room AC

- Gree products
  - Several models developed
  - Split, window, portable
  - Reversible and cooling only
  - Products have safety system integrated to reduce leak amount
  - Lower cost than equivalent R22, R410A models

Capacity (kW)	EER (W/W)	Charge (g)	Max noise ID/OD (dB)	Dimensions (mm)
2.7	3.55	265	38/52	Indoor 830×284×205 Outdoor 760×257×5
3.5	3.52	330	41/52	

4. Examples of TOs – Residential room AC

- Benson air conditioning
  - Single cooling-only, reversible and heat-recovery splits
- Safety aspects
  - Designed to AS/NZS 1677 (similar to EN 378)
  - Charge size up to 1000 g of R290
- Cost of R290 systems less than R410A
- Efficiency (cooling and heating) better than competing R410A and R22 products

		BENHC 24 R / RC	BENHC 34 R / RC	BENHC 50 R / RC	BENHC 65 R / RC	BENHC 85 / RC
Cooling Capacity	Watts	2310	3400	5100	6300	8200
Heating Capacity	Watts	2600	3400	5600	6600	8400
Energy Efficiency Cooling	EER (W / W)	3.12	3.17	2.91	2.9	2.96
Energy Efficiency Heating	COP (W / W)	3.71	3.57	3.07	3.3	2.91

4. Examples of Technical Options (TOs)

Sub-sector	*System type*	*Technical options*
Unitary air conditioning		***HC R290***
	Commercial ducted splits	
	Rooftop ducted	

4. Examples of TOs – Rooftop and ducted splits

- Aicool, Indonesia
  - —Rooftop ducted and ducted split systems developed to use R290
- Safety aspects
  - —Designed to EN 378; up to 2.5 kg of R290 per refrigerant circuit
  - —Cost slightly higher than R22 systems

4. Examples of TOs – splits

- Advansor
  - Air-cooled R744 (CO_2) condensing untis for ducted systems
- Safety aspects
  - Designed to EN 378
- Cost more than HFC
- R744 gives higher efficiency than HFC in cooler climates

Model: compFORT	AC 1x0	AC 2x0	AC 3x0	AC 4x0	AC 5x0	AC 6x0	AC 7x0
Compressors MT	1	2	3	4	5	6	7
MT capacity [kW] [At 3°C evaporating and 32°C outdoor air]	50	100	140	172	215	258	301

4. Examples of TOs

Sub-sector	*System type*	*Technical options*
Chillers	***Air conditioning chillers***	***HC R290/HC 1270 R717 (ammonia) R744 (CO2)***
	Process chillers	

4. Examples of TOs – Chillers

- Several manufacturers using HCs
  - Benson, Bright, Earthcare, Frigadon, Futron, Klima-therm, Weatherite, York/JCI, others…
- All produce chillers using HC and other refrigerants (HFC, HCFC, ammonia, etc)
- Used for both refrigeration as well as air conditioning applications

4. Examples of TOs – Chillers

- York/JCI
  - Air-cooled chillers
- Safety aspects
  - Designed to EN 378; up to 25 kg of R290
- Cost marginally more than HFC products, but with “green premium”
- R290 gives ~15% higher COP than R407C, R410A products

Type	Cap.* kW at 50 Hz	Power input kW	COP unit dim
HSAS-95-1	95	27,6	3,84
HSAS-95-2	95	27,0	3,84
HSAS-140-1	132	38,8	4,01
HSAS-140-2	132	35,1	3,95
HSAS-200-1	178	53,2	4,24
HSAS-200-2	178	46,0	4,29
HSAS-260-1	218	59,2	4,01
HSAS-260-2	218	54,2	4,01
HSAS-340-1	265	75,5	4,22
HSAS-340-2	265	68,1	4,19

4. Examples of TOs – Chillers

- Frigadon
  - Air-cooled chillers
- Safety aspects
  - Designed to EN 378
  - Charge size up to 15 kg of R1270
- Cost of R1270 systems marginally more than HFC products
- Energy consumption
  - R1270 gives higher efficiency

Cooling capacities/ flow rates	Cooling capacity* Brine temp return/flow			
Unit	+22/+17°C	+12/+7°C	0/-4°C	-4/-8°C
FWC-15	1,8	1,3	0,8	0,7
FWC-25	3	2,2	1,4	1,1
FWC-35	4,3	3,1	1,9	1,6
FWC-50	5,9	4,1	2,3	1,9
FWC-80	9,2	6,7	4,1	3,3
FWC-110	13,3	9,7	6	4,8
FWC-130-MT	-	-	7,6	6,2
FWC-130	18,3	13	7,6	6,2
FWC-170	22,5	16,3	10	8,1
FWC-220	-	20,7	12,8	10,5
FWC-220-S(1)	-	-	14,7	12
FWC-220-S(2)	-	-	-	15
FWC-300	36,7	28,2	20	15,2
FWC-400-MT	-	-	27	21,1
FWC-400	50	39,4	27	21,1
FWC-500	-	45,4	31,5	24,3
FWC-500-S(3)	-	54,2	34,3	28,6
FWC-500-S(4)	-	-	42,8	35,6
FWC-500-S(5)	-	-	52	43,8
FWC-650	79,9	59,4	39,5	32,8
FWC-720	93,5	69,9	45,9	38,1
FWC-870	-	86,5	56,1	47,2
FWC-870-S(5)	-	-	66,4	55,9
FWC-870-S(6)	-	-	78,7	66,1
FWC-870-S(7)	-	-	86,4	72,5
FWC-870-S(8)	-	-	95,1	80
FWC-870-S(9)	-	-	-	88,8

4. Examples of TOs – Chillers

- Benson
  - Air-cooled (scroll, screw)
  - Water-cooled (scroll, screw)
- Safety aspects
  - Designed to AS/NZS 1677
  - Charge size up to 25 kg of R290 (per circuit)
- Cost of R290 systems not more than HFC
- R290 gives higher efficiency than HFC

Model Number	kWr	Heat Recovery kW	kW Input
BENCW-1P-CHCS-130CO3WHR	129.8	32.5	29.1
BENCW-1P-CHCS-170CO3WHR	167.3	41.8	34.6
BENCW-1P-CHCS-190CO3WHR	189.2	47.3	39.8
BENCW-1P-CHCS-250CO3WHR	252.9	63.2	54.2
BENCW-1P-CHCS-280CO3WHR	280.6	70.2	58.7
BENCW-1P-CHCS-320CO3WHR	318.2	79.6	67.7
BENCW-1P-CHCS-400CO3WHR	399.4	99.9	82.7
BENCW-1P-CHCS-480CO3WHR	484.9	121.2	96.8
BENCW-1P-CHCS-570CO3WHR	572.3	143.1	115.0
BENCW-1P-CHCS-630CO3WHR	627.7	156.9	127.7
			146.9
			162.1
			174.7
			193.6
			230.0
			243.8
			255.4
			285.7
			293.7
			324.2
			323.1
			349.4
			380.9
			571.4
			646.2

Model Number	kWr Cooling	kW Input Cool
BENCW-1P-CHSC-145CO3A	146.7	44.8
BENCW-1P-CHSC-165CO3A	165.9	51.3
BENCW-1P-CHSC-220CO3A	221.8	71.4
BENCW-1P-CHSC-250CO3A	249.2	77.4
BENCW-		
BENCW-		
BENCW-		
BENCW-		
BENCW-		
BENCW-		
BENCW-		
BENCW-		

Model Number	kWr Cooling	kW Input Cool
BENCW-1P-CH-28CO3A	27.8	8.4
BENCW-1P-CH-33CO3A	33.3	10.2
BENCW-1P-CH-42CO3A	41.9	12.7
BENCW-1P-CH-55CO3A	54.8	16.8
BENCW-1P-CH-65CO3A	65.6	20.3
BENCW-1P-CH-80CO3A	82.6	25.5
BENCW-1P-CH-110CO3A	109.7	33.5
BENCW-1P-CH-130CO3A	131.1	40.7
BENCW-1P-CH-145CO3A	144.4	42.8
BENCW-1P-CH-165CO3A	165.3	50.9
BENCW-1P-CH-215CO3A	216.6	65.7
BENCW-1P-CH-255CO3A	257.4	78.2
BENCW-1P-CH-285CO3A	284.5	88.6



4. Examples of TOs – Chillers

- Grasso/GEA
  - Air-cooled and water-cooled R717 (ammonia) chillers
- Safety aspects
  - Designed to EN 378
  - Possible to install in public areas
- Cost more than HFC
- R717 gives higher efficiency than HFC

Department store 120 kW

University 900 kW

Bank 2,400 kW

Event hall 5,200 kW

Railway station 1,250 kW

Institute 1,050 kW

Shopping mall 1,020 kW

Office complex, 4220 kW

GEA Grasso BluAstrum

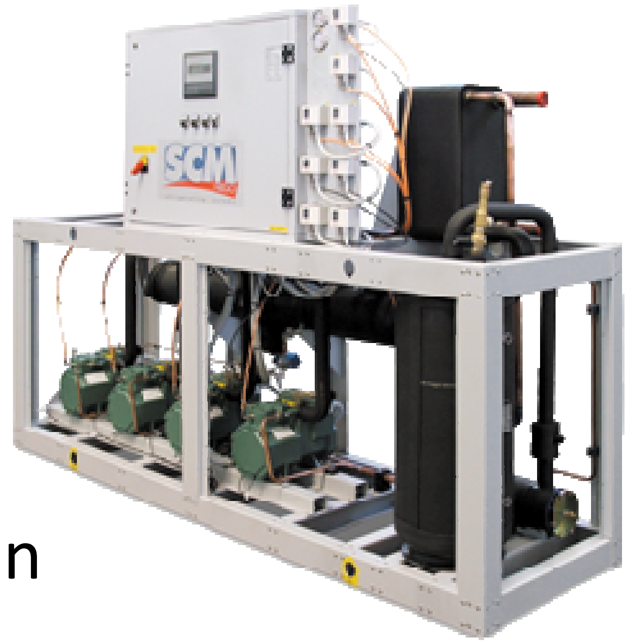
Chiller type	Cooling capacity (kW)	Condensing capacity (kW)	Electric power (kW)	EER
	R717 +12/+6 °C	R717 +30/+35 °C		
BluAstrum 500	576	684	118	4.88
BluAstrum 800	752	892	154	4.88
BluAstrum 900	869	1,029	176	4.94
BluAstrum 1000	1,100	1,295	215	5.12
BluAstrum 1500	1,385	1,636	275	5.04
BluAstrum 1800	1,710	2,011	330	5.18

BluAstrum 1000 is already available; other types will follow in 2012/2013

4. Examples of TOs – Chillers

- Star
  - Air-cooled and water-cooled R717 (ammonia) chillers
- Safety aspects
  - Designed to EN 378
- Cost more than HFC
- R717 gives higher efficiency than HFC
- Some models thermosyphon/free-cooling

4. Examples of TOs – Chillers



- Green& Cool
  - Air-cooled and water-cooled R744 (CO_2) chillers
- Safety aspects
  - Designed to EN 378
- Cost more than HFC
- R744 gives higher efficiency than HFC in cooler climates

4. Examples of Technical Options

Sub-sector	*System type*	*Technical options*
Domestic refrigeration	***Domestic refrigeration***	***HC 600a***

4. Examples of TOs – Domestic refrigeration (fridges, freezers)

- About 30 – 40% of new domestic fridge/freezers on HCs (R600a)
  - Total production ~ 450 m
  - All European manufacturers using R600a in majority of production
  - Large proportion from Korea, Japan, China
  - Introduction in South America and now North America
- Charge size up to 150g

4. Examples of Technical Options (TOs)

Sub-sector	*System type*	*Technical options*
Commercial Refrigeration	***Stand-alone equipment***	***HC 600a, HC 290 R744 (CO_2)***

4. Examples of TOs – Commercial refrigeration (stand-alone)

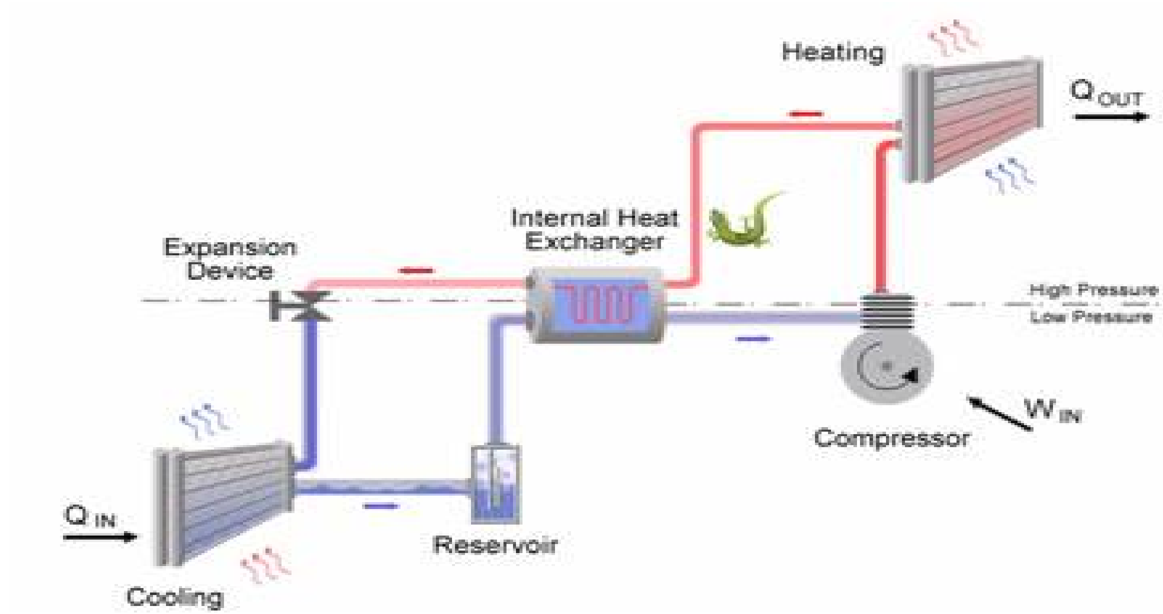
- Many integral commercial units on HCs
  - Numerous manufacturers
  - Range from mini glass door bottle coolers, vending machines, ice-cream freezers, catering units, to multi-deck cabinets
  - Charge sizes from 100g to 1kg

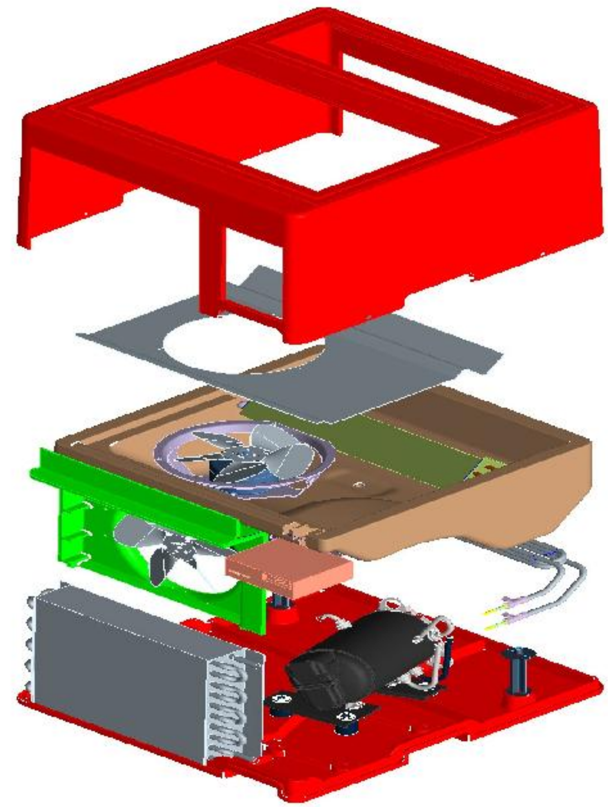
4. Examples of TOs – Commercial refrigeration (stand-alone)

- Verco
  - Commercial display cabinets
- Safety aspects
  - Designed to EN 378
  - Charge size up to 500 g of R290
- Cost of R290 systems similar to HFC products
- Energy consumption
  - R290 gives 15-20% lower power than HFC options

4. Examples of TOs – Commercial refrigeration (stand-alone)

- Coca Cola adopting "cassette" concept for bottle coolers and vending machines
  - The components of a CO_2 refrigeration system are similar to those used in an R134a system





4. Examples of TOs – Commercial refrigeration (stand-alone)

FKDv3412

CDM550

CDM1000

Europa 130

MD600

V544

FV650

4. Examples of TOs – Commercial refrigeration (stand-alone)

- CO_2 and R134a global S-Cassette (Cassette design 1) tested in a 510L cabinet
  - Energy savings between brackets
  - CO_2 cassette equipped with capillary tube. R134a cassette equipped with expansion valve. This gives an advantage of few % for R134a system

TCCC's Test Conditions	CO_2 - (KWh/day)	R134a – (KWh/day)
D (40.6°C - 75%RH)	8.25	7.78 (5.7% lower)
C (32.2°C - 65%RH)	5.79 (16% lower)	6.91
B (23.9°C - 45%RH)	4.97 (3.3% lower)	5.14

4. Examples of TOs – Commercial refrigeration (stand-alone)

- CO2 and R134a global S-Cassette (cassette design 2) tested in 550L cabinet & different CO2 comp
  - Energy savings between brackets
  - Both CO2 AND R134a cassettes are equipped with capillary tube

TCCC's Test Conditions	CO2 - (KWh/day)	R134a – (KWh/day)
D (40.6°C - 75%RH)	9.67 (24% lower)	12.77
C (32.2°C - 65%RH)	5.78 (30% lower)	8.30
B (23.9°C - 45%RH)	4.40 (21.8% lower)	5.63

4. Examples of TOs – Commercial refrigeration (stand-alone)

- Palfridge
  - All types of commercial stand-alone cabine
  - Factory based in Swaziland, southern Afric
- Complete conversion January 2010
  - By GTZ, funded by German finance ministr
  - Complete conversion of production line
  - Charge size up to 300 g of R290 and R600a
- Cost of R290 models lower than R134a, R404A models (better prod line)
- Energy use much lower than HFC options (between 8 – 24% lower, so far)
  - Partly due to refrigerant, partly due to improved design

4. Technical Options (TOs)

Sub-sector	*System type*	*Technical options*
Commercial Refrigeration		
	Condensing units	***HC 290/HC 1270*** ***HC 290/HC 1270 (discrete indirect)*** ***R744***

4. Examples of TOs – condensing units

- Danfoss
  - Range of R290 condensing units
  - Smaller capacity range
- Safety aspects
  - Designed to EN 378/EN 6035-2-89
- High efficiency

Evap. temp in °C	-45	-40	-35	-30	-25	-23.3	-20	-15	-10	-5	0
SC18CNX -BG3		271	374	491	621	669	766	924	1096		
SC18CNX -BG4		287	395	519	658	710	814	986	1173	1376	1594

Evap. temp in °C	-45	-40	-35	-30	-25	-23.3	-20	-15	-10	-5	0	5
SC12CNX -BG3		219	284	358	446	479	547	665	799	949	1116	1298
SC12CNX -BG4		225	292	369	462	497	571	698	846	1014	1202	1410

4. Examples of TOs – condensing units

- Advansor
  - Range of R744 (CO_2) condensing units
- Safety aspects
  - Designed to EN 378
- Cost more than HFC
- R744 gives higher efficiency than HFC

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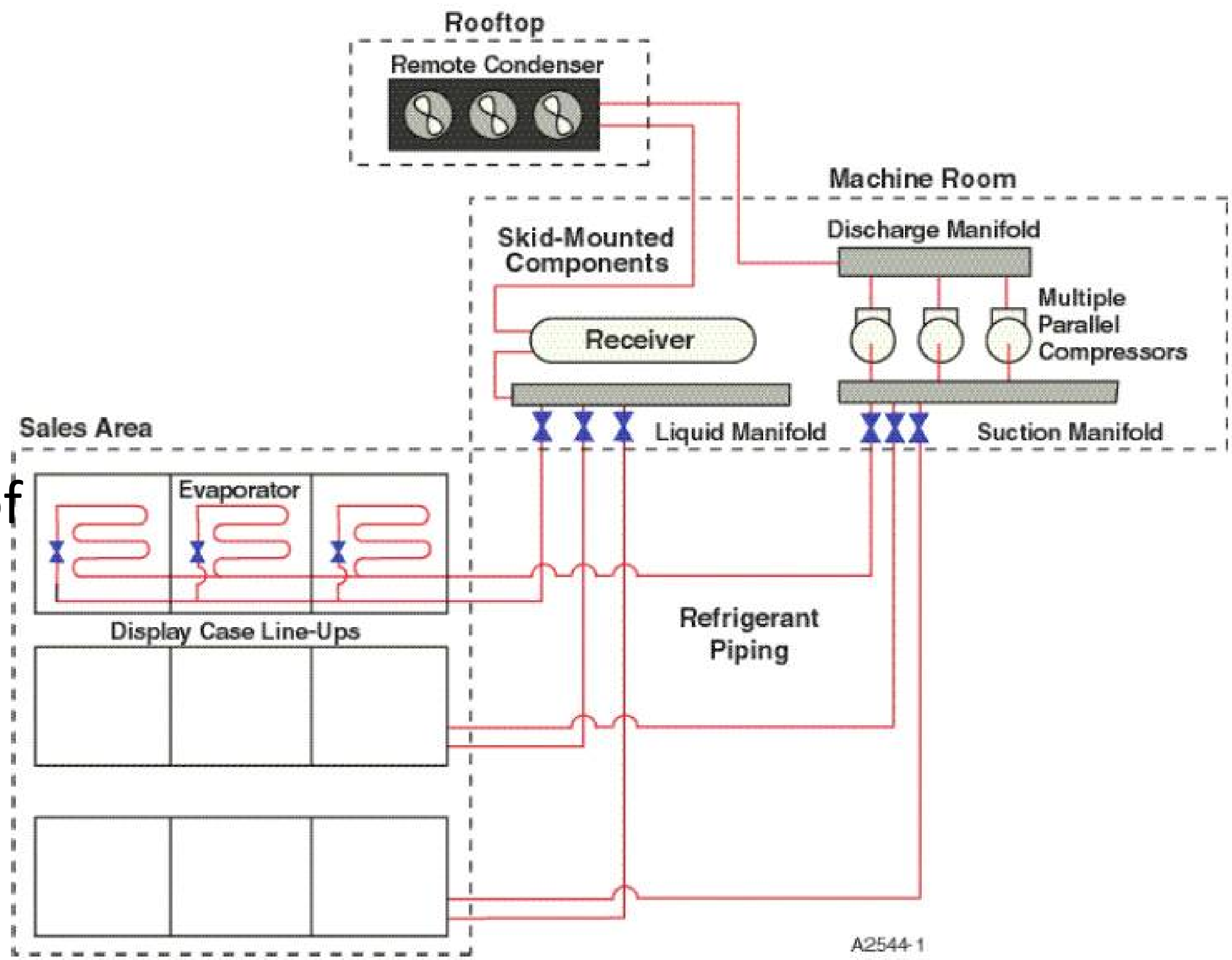
4. Examples of Technical Options (TOs)

Sub-sector	*System type*	*Technical options*
Commercial Refrigeration		
	Centralised systems for supermarkets	***Low-GWP + CO_2 secondary*** ***Low-GWP + CO_2 cascade*** ***Low-GWP + distributed low-GWP water-cooled cond units***

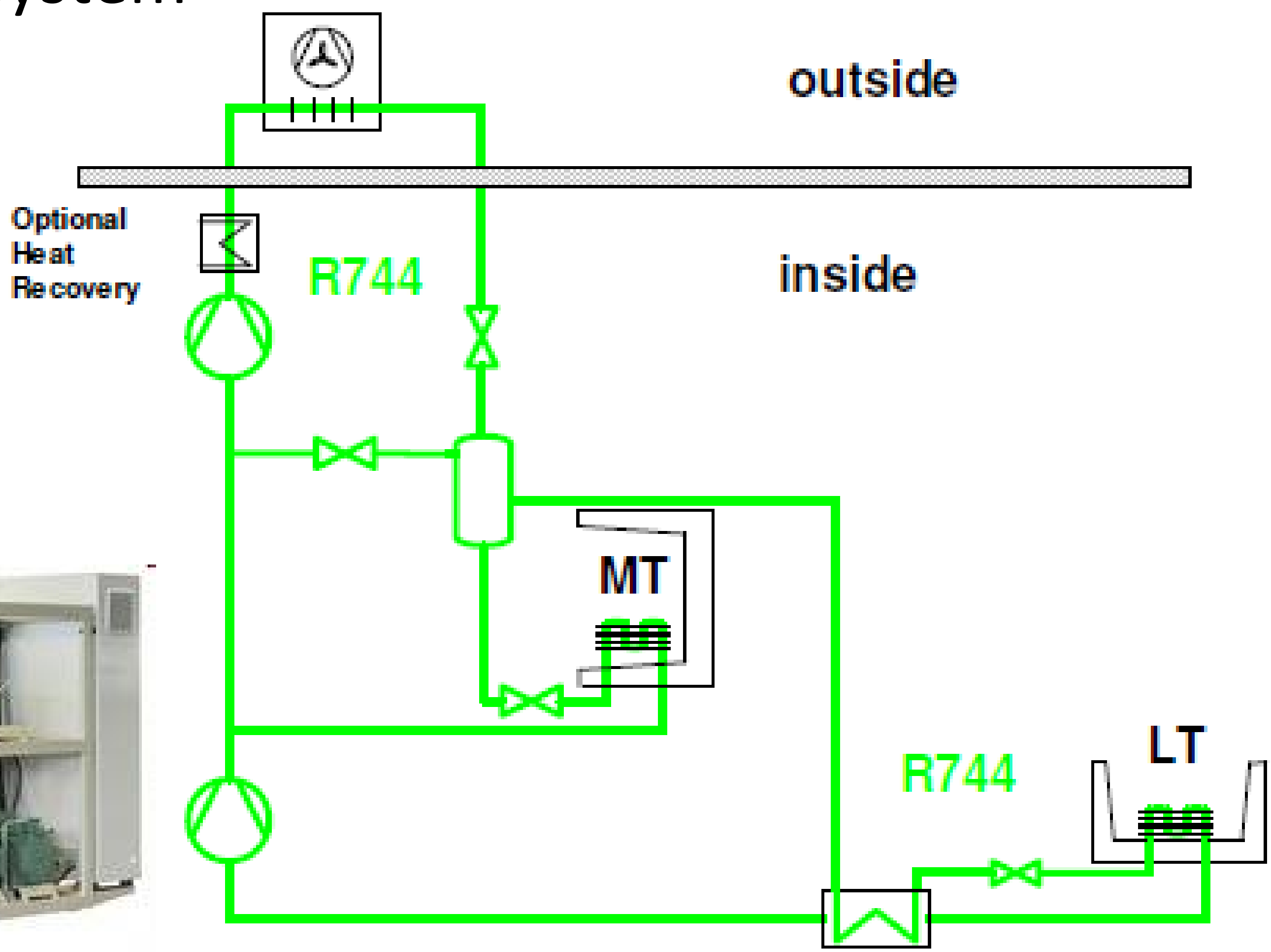
4. Examples of TOs – Commercial refrigeration (centralised systems)

- Conventional system
  - Pack system, pipework distributed to cases and coldstores
  - Large quantities of R404A
- Separate ventilation and heating system



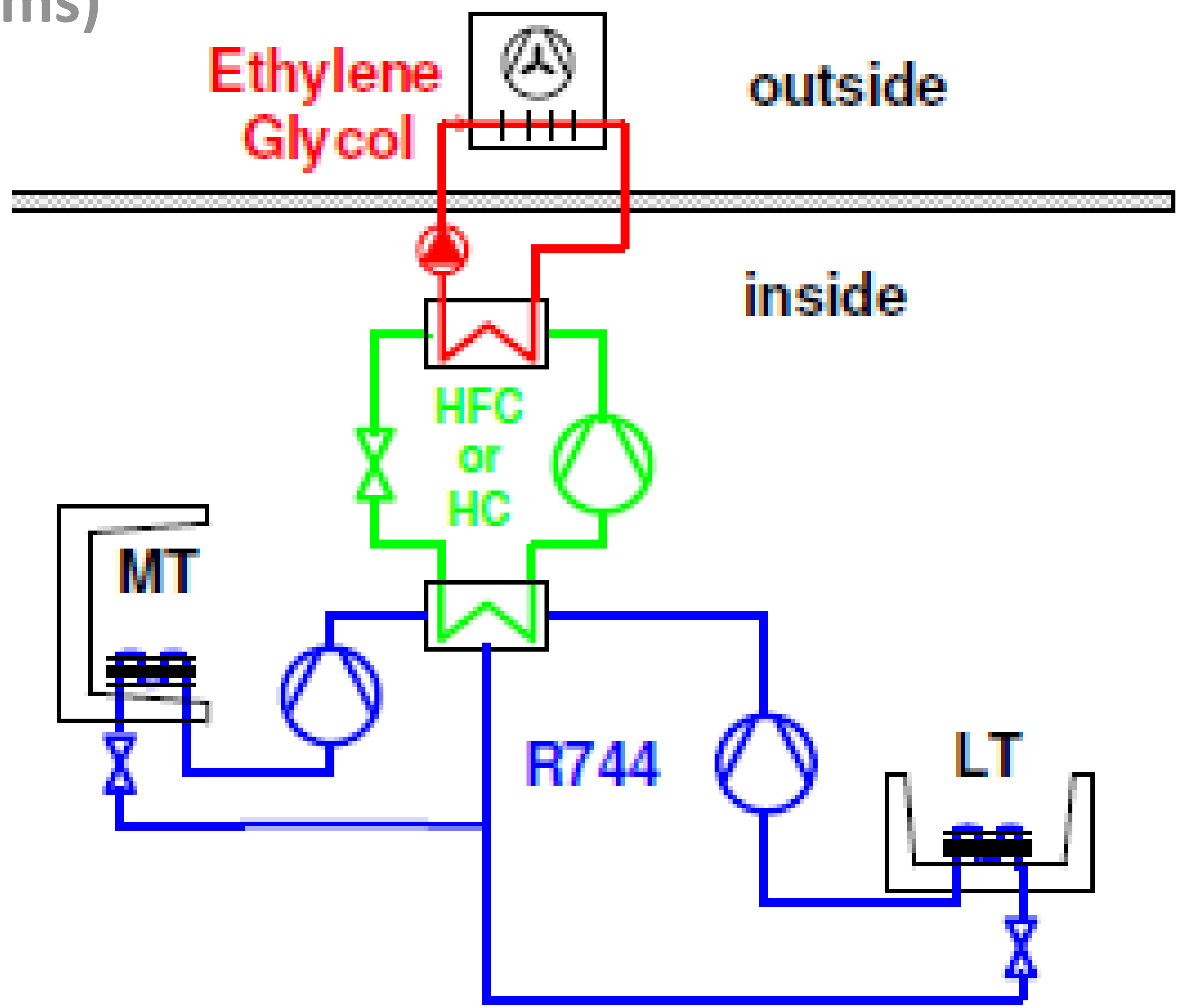
4. Examples of TOs – Commercial refrigeration (centralised systems)

- Two stage CO2 system
  - Entirely CO2



4. Examples of TOs – Commercial refrigeration (centralised systems)

- Cascade Indirect Multiplex System with CO2
  - Utilises HFC, HC or NH3 in high stage
  - CO2 in low (LT and MT) stages

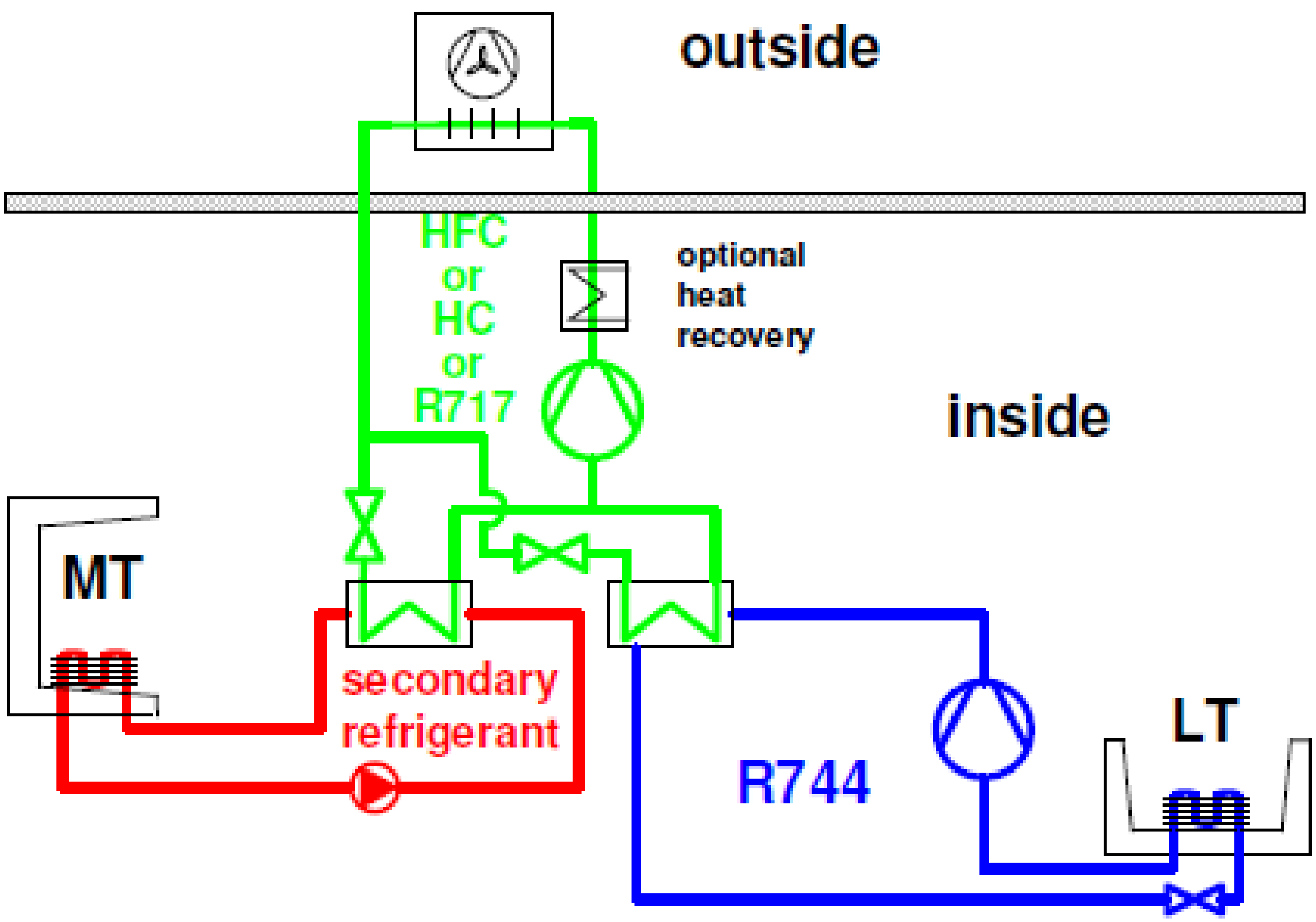


4. Examples of TOs – Commercial refrigeration (centralised systems)

- Example of
  - Supermarket installation
  - air-cooled gas cooler
  - Compressor racks

4. Examples of TOs – Commercial refrigeration (centralised systems)

- Part Indirect Multiplex System with CO_2

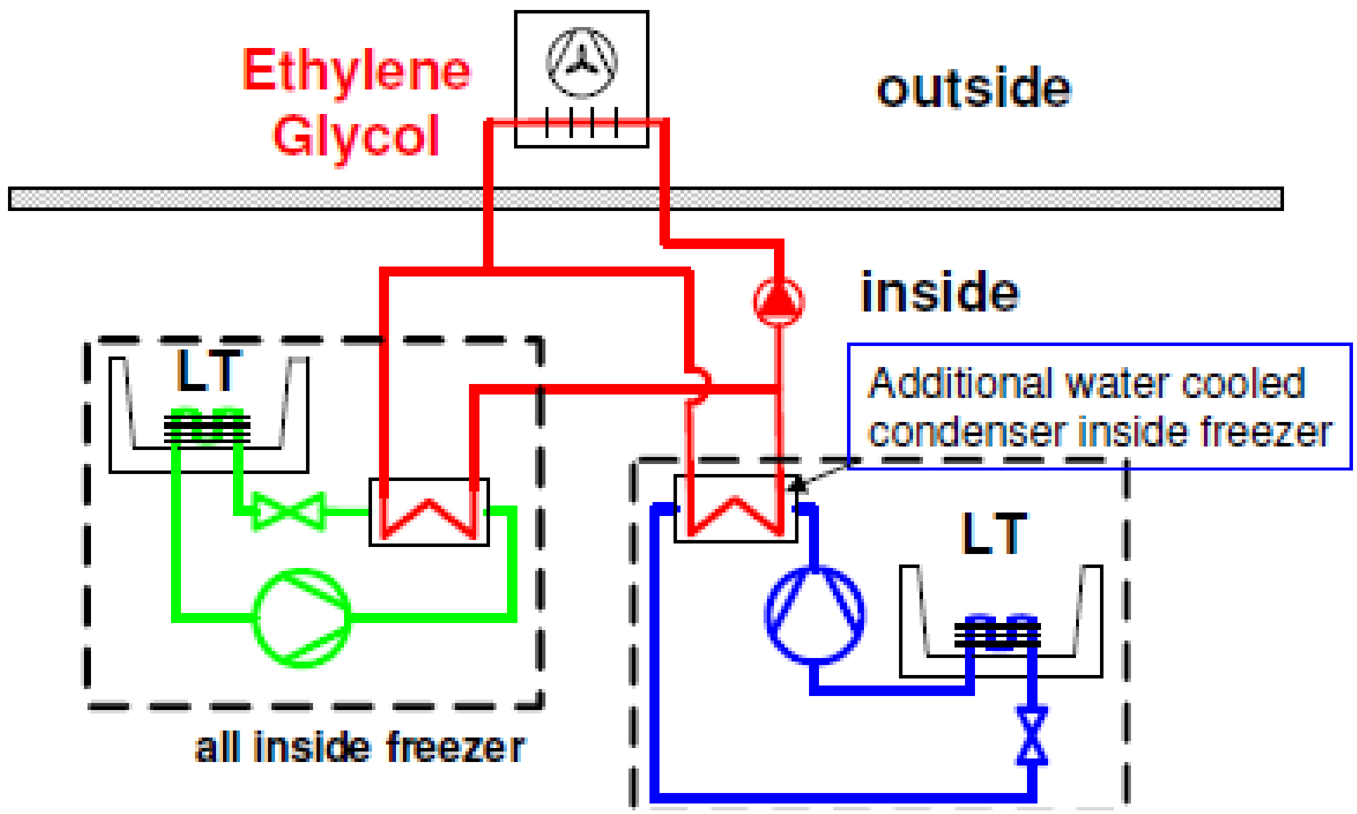


4. Examples of TOs – Commercial refrigeration (centralised systems)

- Example of
  - Supermarket installation
  - water cooled packs

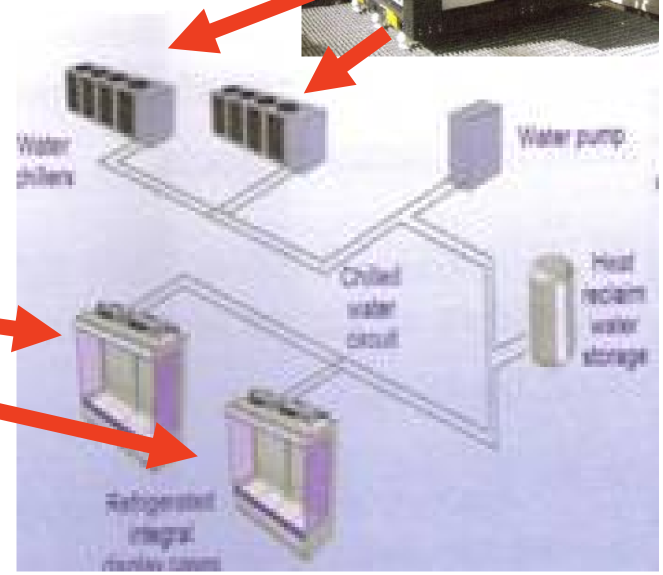
4. Examples of TOs – Commercial refrigeration (centralised systems)

- Indirect circuit with integral condensing units



4. Examples of TOs – Commercial refrigeration (centralised systems)

- Waitrose supermarket (UK)
  - All new installations to use HCs
- Safety aspects
  - Designed to EN 378
  - Charge size of cabinets up to 500g
  - Charge size of chiller ~ 5 kg per circuit
- System based on chilled water-circuit, removing heat from water-cooled condensing units in display cases



4. Examples of Technical Options (TOs)

Sub-sector	*System type*	*Technical options*
Industrial refrigeration	***Stand-alone (FPCS)***	***HC 600a, HC 290***

4. Examples of TOs – Industrial refrigeration (stand-alone) – [food processing and cold storage]

- Professional food and drinks preparation equipment
  - Shake sundae machine
  - Post-mix beverage machine
  - Juice dispenser
- Ice makers
- Cold storage
  - Meat freezers and chilled produce rooms






4. Examples of TOs – Industrial refrigeration (stand-alone) – [food processing and cold storage]

- Williams refrigeration
  - Commercial stand-alone cabinets
  - (also supplied with R134a and R404A)
- Safety aspects
  - Designed to EN 378
  - Charge size up to 150 g of R290
- Cost of R290 systems same as HFC products
- Energy consumption
  - R290 gives 15% lower kWh/24h than HFC option
- R290 provides lower noise levels, operates efficiently up to +43°C ambient

4. Examples of TOs – Industrial refrigeration (stand-alone) – [food processing and cold storage]

- Foster Refrigerator
  - Commercial stand-alone cabinets
- Safety aspects
  - Designed to EN 60335-2-89
  - Charge size up to 150 g of R290
- Cost of R290 systems same as HFC products
- Energy consumption
  - R290 gives 15% lower kWh/24h than R134a/R404A option

temperatures & capacities

Dimensions (w x d x h) mm	700 x 700 x 1780	700 x 800 x 1780	700 x 800 x 2080	700 x 840 x 2070	820 x 700 x 2080	1440 x 800 x 1780	1440 x 800 x 2080
	S 400	G 500	G 600	G 600 U	B 600	G 1100	G 1350
nett capacity (litres)	400	500	600	600	600	1100	1350
refrigerator (+1°/+4°C)	EPRO S 400 H	EPRO G 500 H	EPRO G 600 H	EPRO G 600 HU	EPRO B 600 H	EPRO G 1100 H	EPRO G 1350 H
freezer (-18°/-21°C)	EPRO S 400 L	EPRO G 500 L	EPRO G 600 L	EPRO G 600 LU	EPRO B 600 L	EPRO G 1100 L	EPRO G 1350 L

4. Examples of TOs – Industrial refrigeration (stand-alone) – [food processing and cold storage]

- Gram refrigeration
  - Commercial stand-alone cabinets; R290 is standard
- Safety aspects
  - Designed to EN 60335-2-89
  - Charge size up to 150 g of R290 and R600a
- Cost of R290 systems same as HFC products
- R290 has lower energy consumption than HFC options

		PLUS 600			PLUS 660			PLUS 1270			PLUS 1400		
		K	M	F	K	M	F	K	M	F	K	M	F
Temperature range	°C	+2/+12	-5/+12	-25/-5	+2/+12	-5/+12	-25/-5	+2/+12	-5/+12	-25/-5	+2/+12	-5/+12	-25/-5
Refrigeration capacity at -10/+45°C	Watt	389			389			946			946		
Refrigeration capacity at -25/+45°C	Watt			475			475			950			950

		TWIN 600			TWIN 660			EURO 500			MIDI 425			MIDI 625		
		K	M	F	K	M	F	K	M	F	K	M	F	K	M	F
Temperature range	°C	+2/+12	-5/+12	-25/-5	+2/+12	-5/+12	-25/-5	+2/+12	-5/+12	-25/-5	+2/+12	-5/+12	-25/-5	+2/+12	-5/+12	-25/-5
Refrigeration capacity at -10/+45°C	Watt	389			389			389			389			389		
Refrigeration capacity at -25/+45°C	Watt			475			475			475			374			475

4. Examples of TOs

<table>
<tr><th>Sub-sector</th><th>System type</th><th>Technical options</th></tr>
<tr><td rowspan="3">Industrial refrigeration</td><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Centralised systems (FPCS)</td><td>Low-GWP + liquid secondary
Low-GWP + CO2 secondary
Low-GWP + CO2 cascade</td></tr>
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4. Examples of TOs – Industrial refrigeration (centralised) – [food processing and cold storage]

- System concepts similar to commercial refrigeration – centralised supermarket systems
  - Refer to supermarket equipment
- Example of cold storage and food process facility
  - Bank of R290 chillers feeding cold storage facility

4. Examples of Technical Options (TOs)

Sub-sector	*System type*	*Technical options*
Transport Refrigeration	***Refrigerated trucks/trailers***	***HC 290/HC 1270*** ***R744 (CO2)***

4. Examples of TOs – Transport refrigeration

- Refrigerated trucks and trailers
  - Available with R290 and R744
- Reefer containers will be available with R744

5. Refrigerant implication on efficiency– Introduction

- Refrigerant implication on efficiency
  - The issue of refrigerant selection impact on system efficiency is often raised
  - The subject is very involved and normally required extensive discussion
  - Here a brief overview is provided

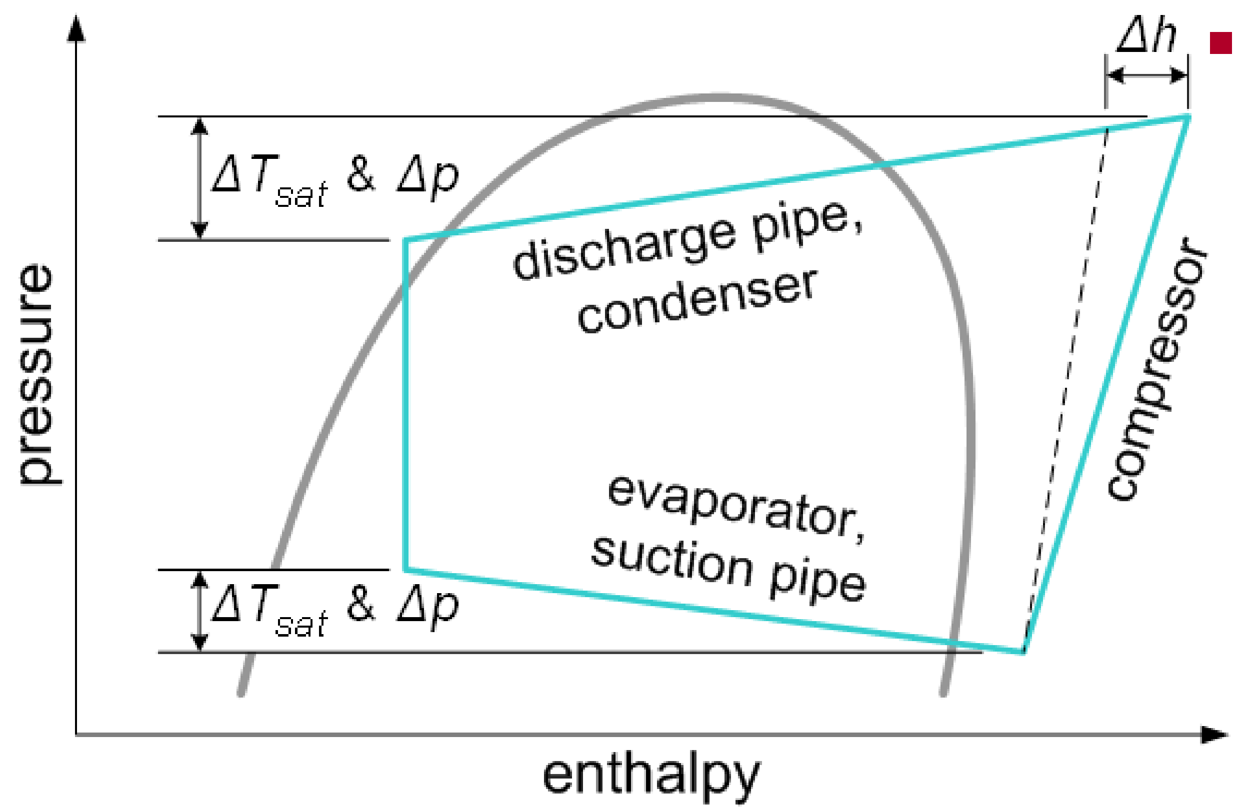
5. Refrigerant implication on efficiency

- System energy consumption very important
  - —Typically accounts for 60 – 90% of greenhouse gas emissions of a system
- Energy consumption is related to a number of factors:
  - —System heat load (capacity)
  - —Ancillary components; electric motors for fans/pumps, controls
  - —Parasitic energy from lighting, resistance and defrost heaters
  - —Motor efficiency and mechanical losses within the compressor
  - —External conditions, eg, heat sink and heat source temperatures
- Also related to design of cycle components and thermophysical properties of refrigerants

5. Refrigerant implication on efficiency

- Both component design and refrigerant properties required to achieve high efficiency
- For a given cycle (T_{cold} = 0 ℃, T_{hot} = 35 ℃)
  - "ideal" cycle – no pressure drops, no ΔTs, etc – COP = 3.4
  - With losses in pipework and heat exchanger, COP = 1.5
- Virtually impossible to reach "ideal" situation, but with correct design of components, there is a higher potential with natural refrigerants, then with HFCs

5. Refrigerant implication on efficiency



- Desirable to have good heat transfer and low pressure drop in evaporator and condenser

- Preferred properties
  - Low liquid and vapour viscosities
  - High liquid specific heat
  - High liquid and vapour thermal conductivities
  - High latent heat
  - Small temperature glide

5. Refrigerant implication on efficiency

Refrigerant	Critical temp. (°C)	Liquid viscosity (Pa s $\times 10^6$)	Vapour viscosity (Pa s $\times 10^6$)	Liquid sp. heat (kJ/kg K)	Liq thermal cond (W/m K)	Latent heat (kJ/kg)
R-22	96.1	216	11.4	1.17	0.095	205
R-134a	101.1	267	10.7	1.34	0.092	199
R-404A	72.0	179	11.0	1.39	0.073	166
R-407C	86.0	211	11.3	1.42	0.096	210
R-410A	71.4	161	12.2	1.52	0.103	221
R-717	132.3	170	9.1	4.62	0.559	1262
R-290	96.7	126	7.4	2.49	0.106	375
R-1270	92.4	121	7.8	2.44	0.126	378
R-744	31.0	99	14.8	2.54	0.110	231

5. Refrigerant implication on efficiency

- Example of split air conditioners
  - Comparison of R22 and R290 in studies published in journals
  - All show improvements, range from 2 – 20%

Study	Improvement
Chinnaraj et al, 2010	4 – 7%
Devotta et al, 2005	up to 8%
Jin et al, 2012	4 – 12%
Li et al, 2010	10 – 15%
Lin et al, 2010	4 – 12%
Liu, 2007	10 – 20%
Padalkar et al, 2010	up to 14%
Park and Jung, 2008	up to 11%

Study	Improvement
Park et al, 2007	up to 2%
Wang et al, 2004	12 – 19%
Xiao et al, 2006	up to 12%
Xiao et al, 2009	up to 10%
Xu et al, 2011	7%
Yan, 1999	up to 10%
Zhang et al, 2002	up to 12%
Zhou & Zhang, 2010	up to 9%

6. Reducing energy use – introduction

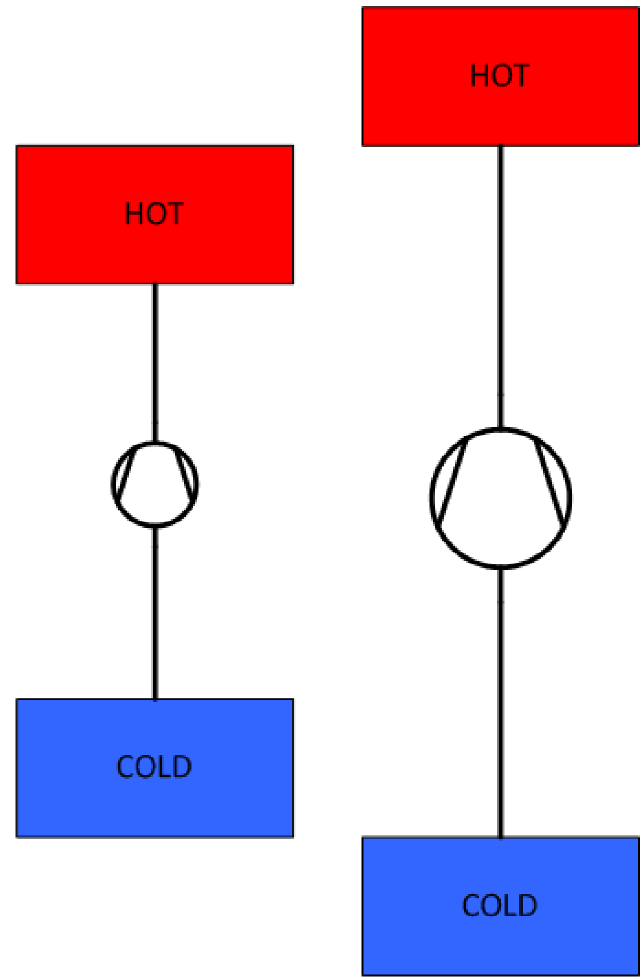
- Reducing energy use
  - Although in Costa Rica, emissions arising from electricity production is extremely low
  - From global warming gas emissions perspective, reducing energy use is less significant (than refrigerants)
  - However, useful to reduce energy use for economic reasons
  - Brief overview of options

6. Reducing energy use – introduction

- Three fundamental contributors to efficiency
  - Refrigeration cycle
  - Parasitic losses
  - Transient effects
- Also take into account cooling demand (heat load)
  - Less heat absorbed = less energy
- Many of the elements that contribute to efficiency and energy use are interrelated
- List some practical options for how to achieve better efficiency and lower energy use

6. Reducing energy use – Refrigeration cycle

- Principally the way that the machine creates cold
  - Temperature lift
  - Temperature of the cold refrigerant
  - Temperature of the hot refrigerant
  - Selection of refrigerant circuitry
  - Pressure losses within pipework
  - Properties of refrigerant (type)
  - Oil type
- Essential to focus on component selection and circuit design



6. Reducing energy use – Refrigeration cycle – improvement examples

Optimise system balancing	+++
Refrigerant charge size; critical/non-critical charge	+++
Larger evaporator/condenser surface area; improved surface texture	+++
Optimise evaporator/condenser circuitry	++
Forced vs. natural convection evaporator/condenser	++
Clean evaporator/condenser (surface treatment)	+
Minimise superheat	++
Flooded evaporator	++
Reduce piping pressure losses	++
Optimise sub-cooling	+

6. Reducing energy use – Refrigeration cycle – improvement examples

Selection of compressor with optimum capacity	++
Alternative refrigerants, pure vs. mixtures	++
Use of liquid-suction heat exchanger (some refrigerants)	+
Selection of optimal lubricant	+
Use of oil separator	+
Alternative cooling cycles (e.g., Lorenz, Stirling, etc)	+++
Two, multi-stage system (e.g., for LT)	++
Improved air flow over product	+
Integrated evaporator shelving	+

6. Reducing energy use – Parasitic losses

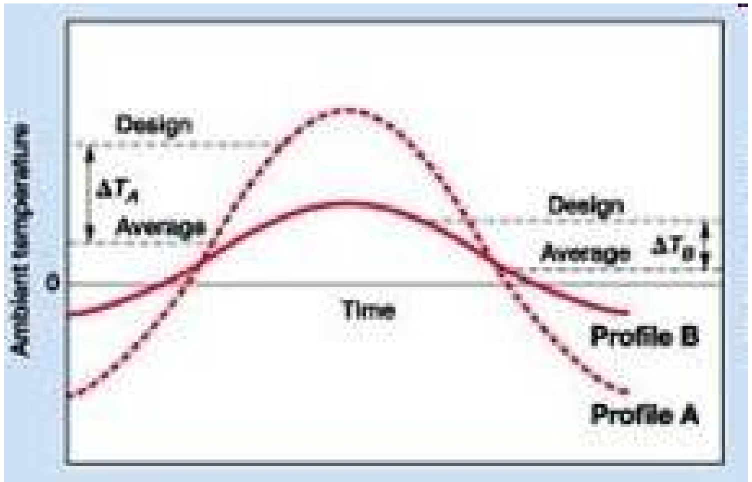
- "Parasitic" losses typically related to ancillary components, e.g.,
  - Defrost heaters
  - Lighting
  - Trim heaters
  - Fans
  - Pumps
- All 'sort of' necessary to achieve the cold, but can normally be reduced

6. Reducing energy use – Parasitic losses – improvement examples

More efficient compressors (incl. alternative compressor types, start/run methods)	+++
More efficient fan motors (e.g., ECMs)	++
More efficient fan design (higher fan blade efficiency)	+
Variable-/dual-speed fans	+
Discharge heat heaters instead of resistance heaters	+
Forced vs. natural convection evaporator/condenser	+
Off-cycle defrosting	++
Hot gas, cool gas, reverse cycle defrost	+
Low power lighting (LEDs, etc), electronic ballasts for fluorescents	++

6. Reducing energy use – Transient effects

- Transient or dynamic losses due to behaviour of the machine at non-design conditions
  - Changes in ambient conditions
  - Changes in heat load
  - Compressor starting
  - Pressure equalisation
- Often 'hidden' potential for improvement

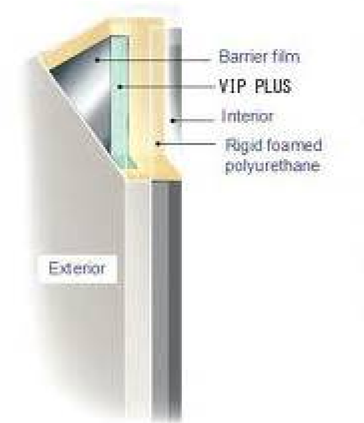


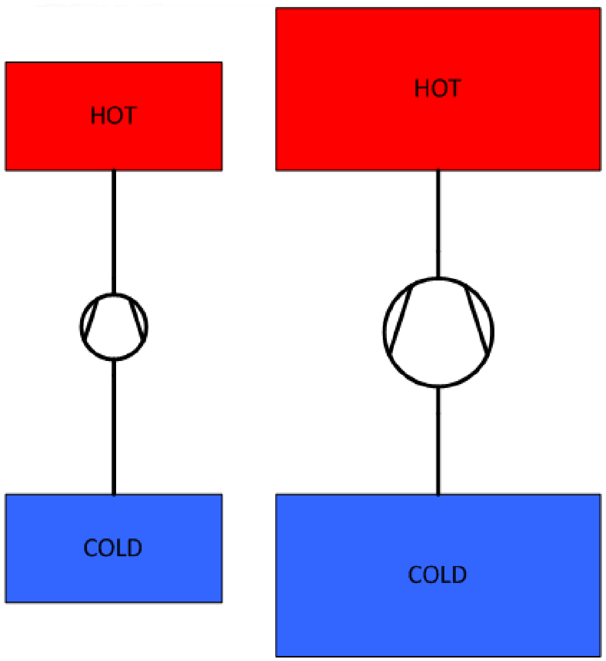
6. Reducing energy use – Transient effects – improvement examples

Variable-speed compressors	+++
Variable-capacity compressors	+++
Adaptive/optimised electronic control	+++
Expansion valve instead of capillary tube	+++
Floating head pressure control	++
Flow regulation valves (for multi-evaporator systems)	+
Phase-change materials within cold box, condenser	++
Off-cycle migration valve (prevent pressure equalisation)	+
Two, multi-compressors	++

6. Reducing energy use – Cooling demand

- Not directly related to efficiency, but can reduce energy use
  - Quality of insulation
  - Amount of infiltration
  - Solar gain
  - Electrical loads
  - Product temperature
  - Use patterns
- A greater cooling demand (heat load) increases energy consumption





6. Reducing energy use – Cooling demand – improvement examples

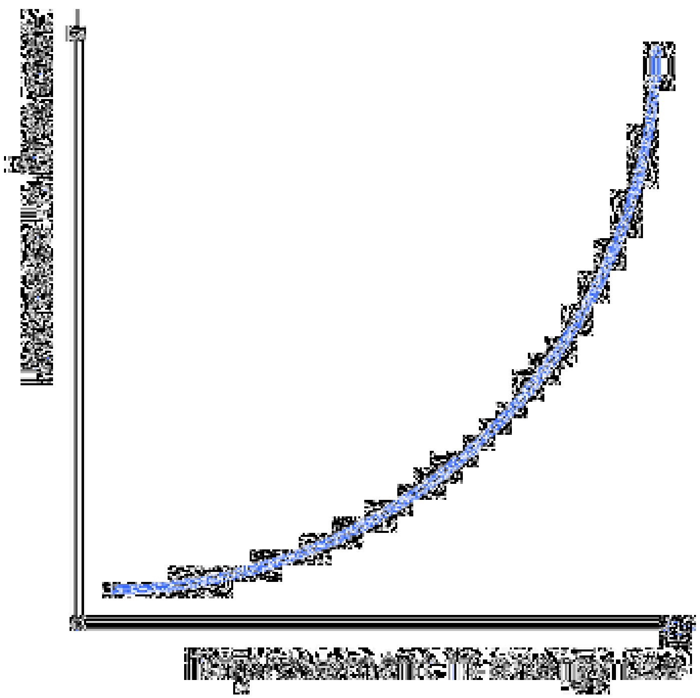
Increase cabinet insulation	++
Better quality insulation (vacuum insulation panels, gas panels, alternative foams)	++
Increase door insulation	+
Decrease door leakage (better gaskets)	+
Use of night blinds	++
Glass door/lid	+++
Adaptive defrosting	++
Off-cycle defrosting	++
Hot gas/reverse cycle defrost	+

6. Reducing energy use – Cooling demand – improvement examples

Low power lighting (LEDs, etc), choice of ballasts for fluorescents	++
External lighting	++
Adaptive lighting	+
Reduce IR gain (reflective glass, etc)	++
Improve anti-sweat trim heaters / dew point control	+
Reduce internal volume	+

6. Reducing energy use – Integration of measures

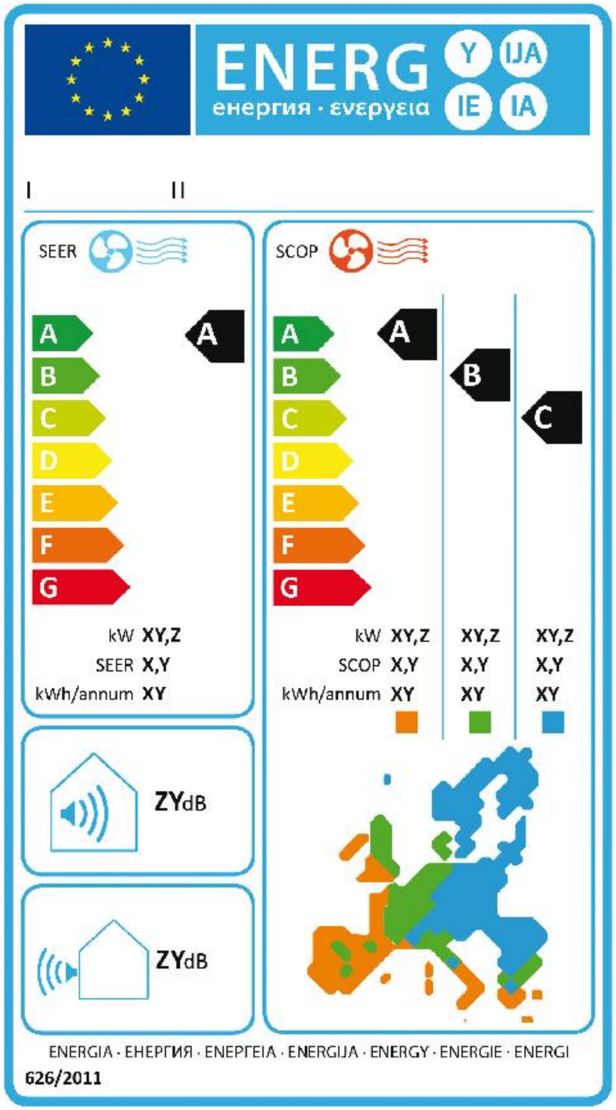
- Benefit of above measures rarely additive
  - Typically for each additional measure, effectiveness lessens
- Eventually, adding more and more features simply adds cost
  - Must determine most cost-effective set of options
- Important to first analyse current design to determine most effective measures



6. Reducing energy use – implementation

- Means of imposing reduction in energy
- Options
  - Energy labelling

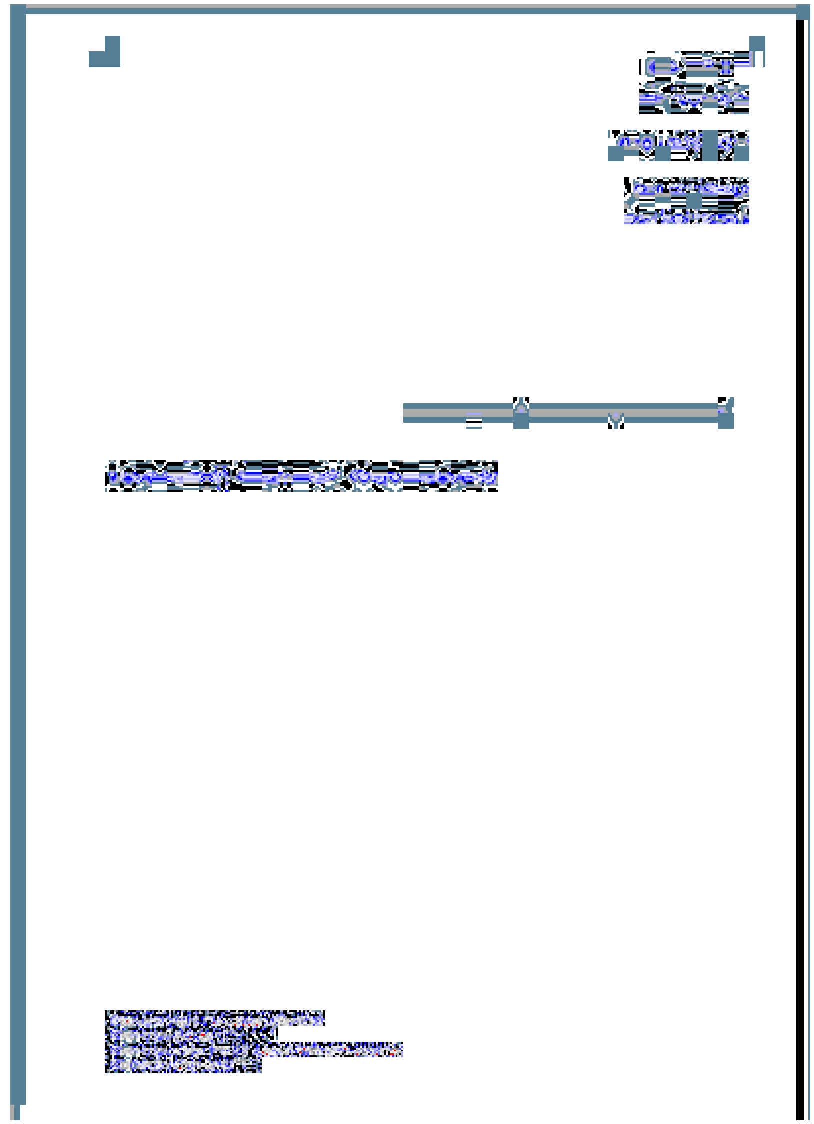
Energy Efficiency Class	SEER	SCOP
A+++	SEER ≥ 8,50	SCOP ≥ 5,10
A++	6,10 ≤ SEER < 8,50	4,60 ≤ SCOP < 5,10
A+	5,60 ≤ SEER < 6,10	4,00 ≤ SCOP < 4,60
A	5,10 ≤ SEER < 5,60	3,40 ≤ SCOP < 4,00
B	4,60 ≤ SEER < 5,10	3,10 ≤ SCOP < 3,40
C	4,10 ≤ SEER < 4,60	2,80 ≤ SCOP < 3,10
D	3,60 ≤ SEER < 4,10	2,50 ≤ SCOP < 2,80
E	3,10 ≤ SEER < 3,60	2,20 ≤ SCOP < 2,50
F	2,60 ≤ SEER < 3,10	1,90 ≤ SCOP < 2,20



6. Reducing energy use – implementation

- Means of imposing reduction in energy
- Options
  - Minimum efficiency rules
  - Test standards

Capacity	GWP	Air conditioners, except double and single duct type		Double duct Air conditioners		Single duct air conditioners	
		SEER	SCOP	EER	COP	EER	COP
< 6 kW	>150	4.60	3.80	2.60	2.60	2.60	2.04
< 6 kW	<150	4.14	3.42	2.34	2.34	2.34	1.84
6 - 12 kW	>150	4.30	3.80	2.60	2.60	2.60	2.04
6 - 12 kW	<150	3.87	3.42	2.34	2.34	2.34	1.84



7. Concluding remarks…

- Concluding remarks…
  - What next?

7. Concluding remarks…

- Due to environmental issues, many major multi-national corporations adopting natural refrigerants
  - —Want to improve environmental profile
  - —Need to reduce environmental impact
  - —Anticipation of future environmental regulations
  - —Increasing number of multi-nationals implementing natural refrigerants world-wide, e.g., Refrigerants, Naturally! initiative, Consumer Goods Forum, etc
- All have HFC-free polices; result in wide use naturals

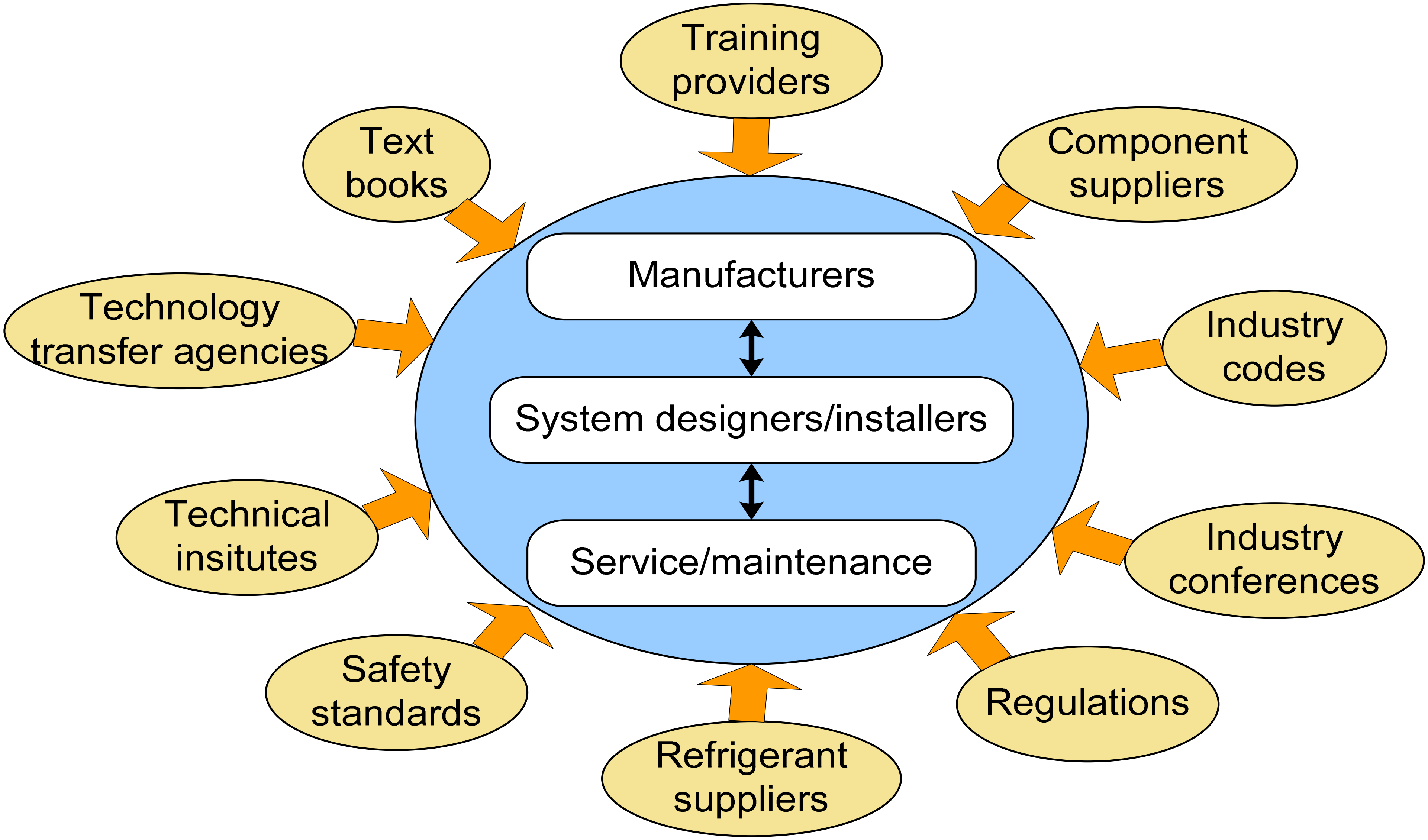
7. Concluding remarks…

- If Costa Rica wants to achieve massive reduction in refrigerant-related global warming emissions (i.e., HCFCs, HFCs, etc)
  - It is possible to adopt widespread use of natural refrigerants
  - However, the country but must be determined and work at it
- Most activities and developments for natural refrigerants is in Europe
  - North and South America are lagging
  - Other Central American and Caribbean countries interested in progressing natural refrigerants – should try to collaborate!
- Many regions planning to phase down HFCs but long time

7. Concluding remarks…

- Any activities should be sensitive to sub-sectors and equipment types
  - Some sectors easier to tackle than others (self-contained systems, mass-produced)
- Should set up implementation plan
- Must act fast to reach the 2021 target
- Need legislation and strong agreements to compel the market
  - Max GWP quotas, GWP-related tax (or deposit scheme), etc
- Technical training should be a high priority
- Sensible to tackle on a regional levels

7. Concluding remarks...



Thank you for your attention