COLD CHAIN COMPLIANCE

Webinars for Cold Chain Professionals

COMPLIANCE WEEK DAY 2: THE FUTURE OF REFRIGERANTS

STARTING AT 10:30AM

Supported by:

Ryan-Jayberg

Opteon™ Refrigerants

Chemours™

COLD CHAIN FEDERATION

- 190 COMPANIES REPRESENTED
- 450+ FACILITIES
- >30 MILLION M^3 STORAGE
- >30,000 REFRIGERATED TRAILERS
- c.20,000 EMPLOYEES

Leading the UK's Temperature Controlled Logistics Industry

Cold Move The Experts in Food Logistics
Reed Boardall
FreshLinc
THE ICE CO storage & logistics
Hunt's More than just Foodservice
Lineage
Buffaload Logistics & Facilities
AGRO Merchants Group
IBL Cold Stores
SPAR James Hall & Co. Ltd.
mcculla
Fowler Welch
Transkold London's Local Cold Storage Hub
brakes
PULLEYN
Chiltern Cold Storage Group Ltd
QK
Ardboe Coldstore Ltd.
MM Flowers
MORAN logistics
Sainsbury's
DFDS
oakland International
GXO Logistics at full potential
TESCO
healthcare at home
CALDERHEAD REFRIGERATED TRANSPORT & COLDSTORE
SOLSTOR UK LIMITED
Samworth Brothers Supply Chain
müller
McBURNEY REFRIGERATION A division of McBurney Transport Group Ltd
Mansfields A complete service in fresh produce
NAGEL-GROUP
HSH Coldstores
MAGNAVALE
gist
culina FOOD & DRINK LOGISTICS SPECIALISTS
ASDA
ACS&T LOGISTICS
NORISH Cold Storage
March Cold Stores
savage HAULAGE LTD
interfrigo leading the way in cold storage Cold Storage & Shipping Services
MB MARTINBROWER
EURO TUNNEL
PORT OF TILBURY LONDON
NEWCOLD ADVANCED COLD LOGISTICS

COLD CHAIN COMPLIANCE

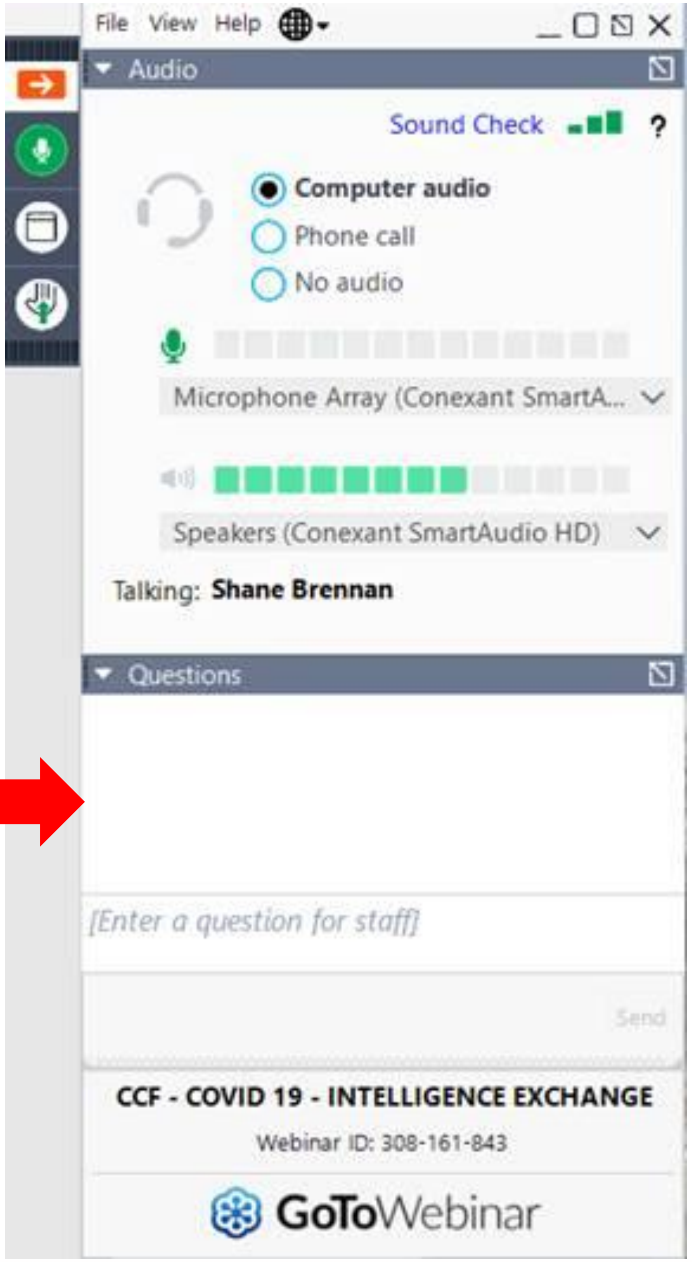
THE FUTURE OF REFRIGERANTS

SCHEDULE

COLD CHAIN FEDERATION

10:30 – 10:35	Introduction	
10:35 – 11:00	Future of Refrigerants: a policy update	BESA BUILDING ENGINEERING SERVICES ASSOCIATION
11:00 – 11:25	The evolution of low GWP refrigerants	Opteon Refrigerants Chemours
11:25 – 11:50	Adapting Refrigeration Systems for new refrigerants	Ryan-Jayberg
11:50 – 12:00	Discussion	

COLD CHAIN FEDERATION



THE FUTURE OF REFRIGERANTS: POLICY UPDATE

GRAEME FOX
HEAD OF TECHNICAL, BESA AND REFCOM

BESA
BUILDING ENGINEERING SERVICES ASSOCIATION

REFCOM®
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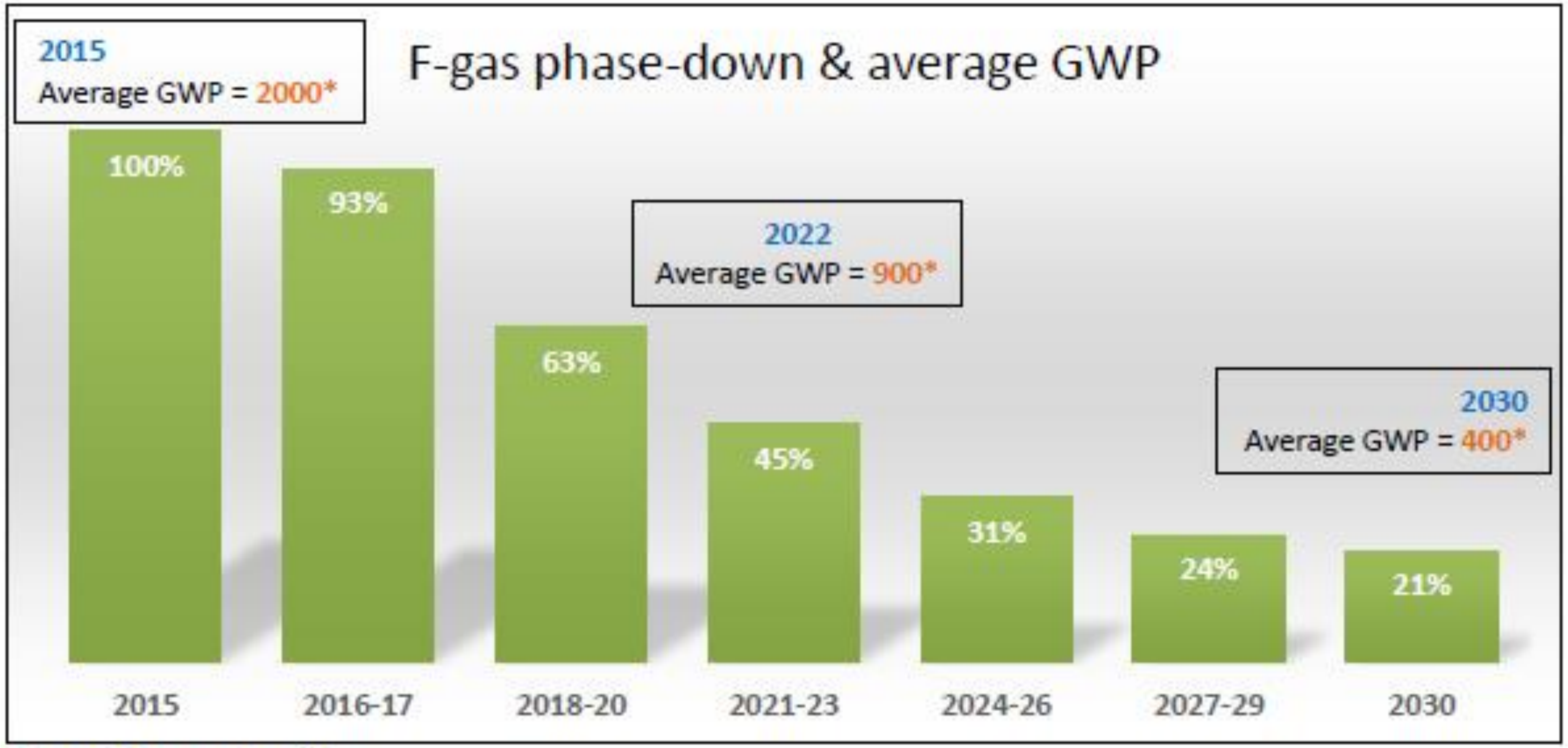
BESA
BUILDING ENGINEERING SERVICES ASSOCIATION

The Future of Refrigerants

Graeme Fox
Head of Technical
at
BESA and REFCOM

REFCOM
www.refcom.org.uk

The F-Gas Phase Down



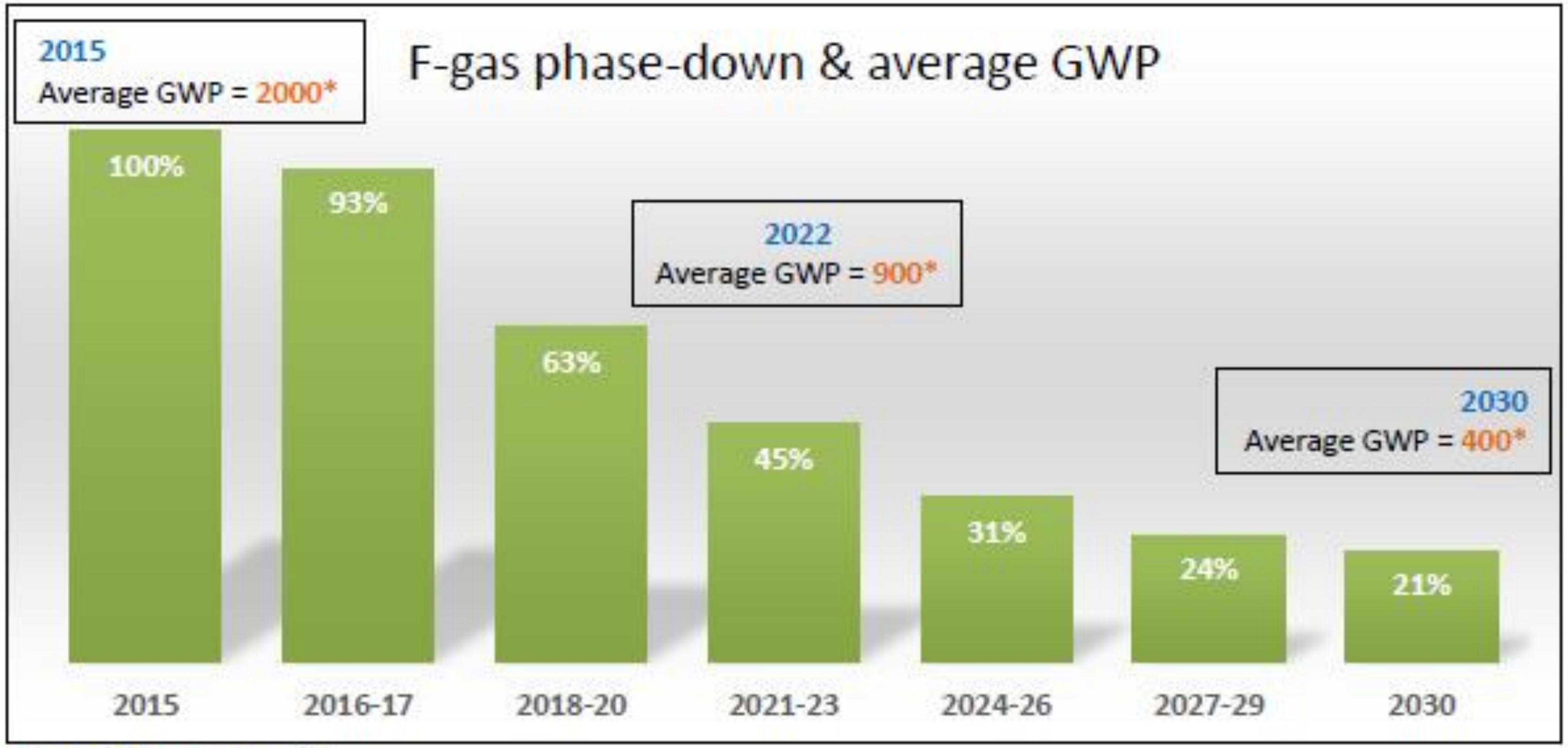
* Source: European Commission

Steps determined by CO_2 tonnes equivalent value.

Average GWP show the limitations our sector will face in the coming years.

We currently have half the gas available (in terms of CO_2 eq) than we did 6 years ago.

The F-Gas Phase Down



* Source: European Commission

The now familiar F-Gas Phase Down steps diagram:

What happens now we have left the EU?

How is the quota split?

GB Regulations rather than UK?

Virgin Refrigerant

From Northern Ireland to and from the UK
Requires QUOTA to move.

Essentially obtain your refrigerant and any item that CONTAINS refrigerant in Northern Ireland.

DO NOT transport between the UK and Ireland.

EC517/2014 revision proposals expected Q1/2 2022

- The pre-charged splits argument rearing up again?
- Upskilling / Re-training? Flammable refrigerant use.
- Illegal cylinders and imports not on quota?
- Will the UK follow suit or go further?

Who can the certification bodies give a certificate to?

Article 6

Company certificates

1. A certification body as referred to in Article 7 shall issue a certificate to a company for one or more of the activities referred to in Article 2(2) provided that it fulfils the following requirements:

(a) employment of natural persons certified in accordance with Article 3, for the activities requiring certification, in a sufficient number to cover the expected volume of activities,

(b) proof that the necessary tools and procedures are available to the natural persons engaged in activities for which certification is required.

2. The certificate shall contain at least the following:

(a) the name of the certification body, the full name of the holder, a certificate number, and the date of expiry if any,

(b) the activities which the holder of the certificate is entitled to perform, also specifying the maximum charge size, expressed in kilograms, of the equipment concerned,

(c) issuing date and issuer's signature.

All certification bodies are bound by implementing regulation 2067/2015 where it states in Article 6 that only companies who employ properly certified engineers / technicians can be given a valid company F-Gas certificate.

And F-Gas EC517/2014 Article 3 states that only certified people can carry out any installation, servicing, maintenance, repair or decommissioning work

4. Natural persons carrying out the tasks referred to in points (a) to (c) of Article 10(1) shall be certified in accordance with Article 10(4) and (7) and shall take precautionary measures to prevent leakage of fluorinated greenhouse gases.

Undertakings carrying out the installation, servicing, maintenance, repair or decommissioning of the equipment listed in points (a) to (d) of the Article 4(2) shall be certified in accordance with Article 10(6) and (7) and shall take precautionary measures to prevent leakage of fluorinated greenhouse gases.

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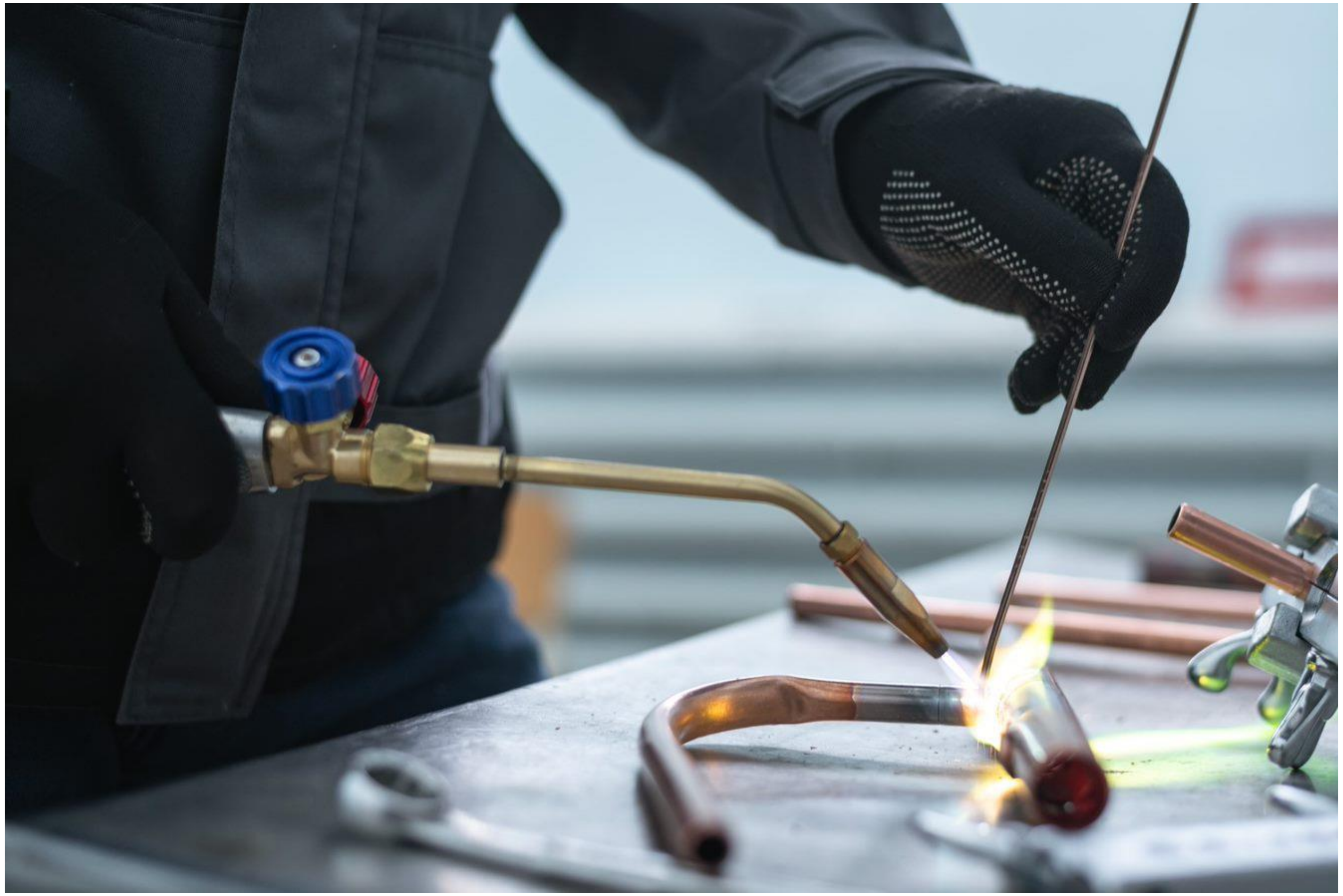
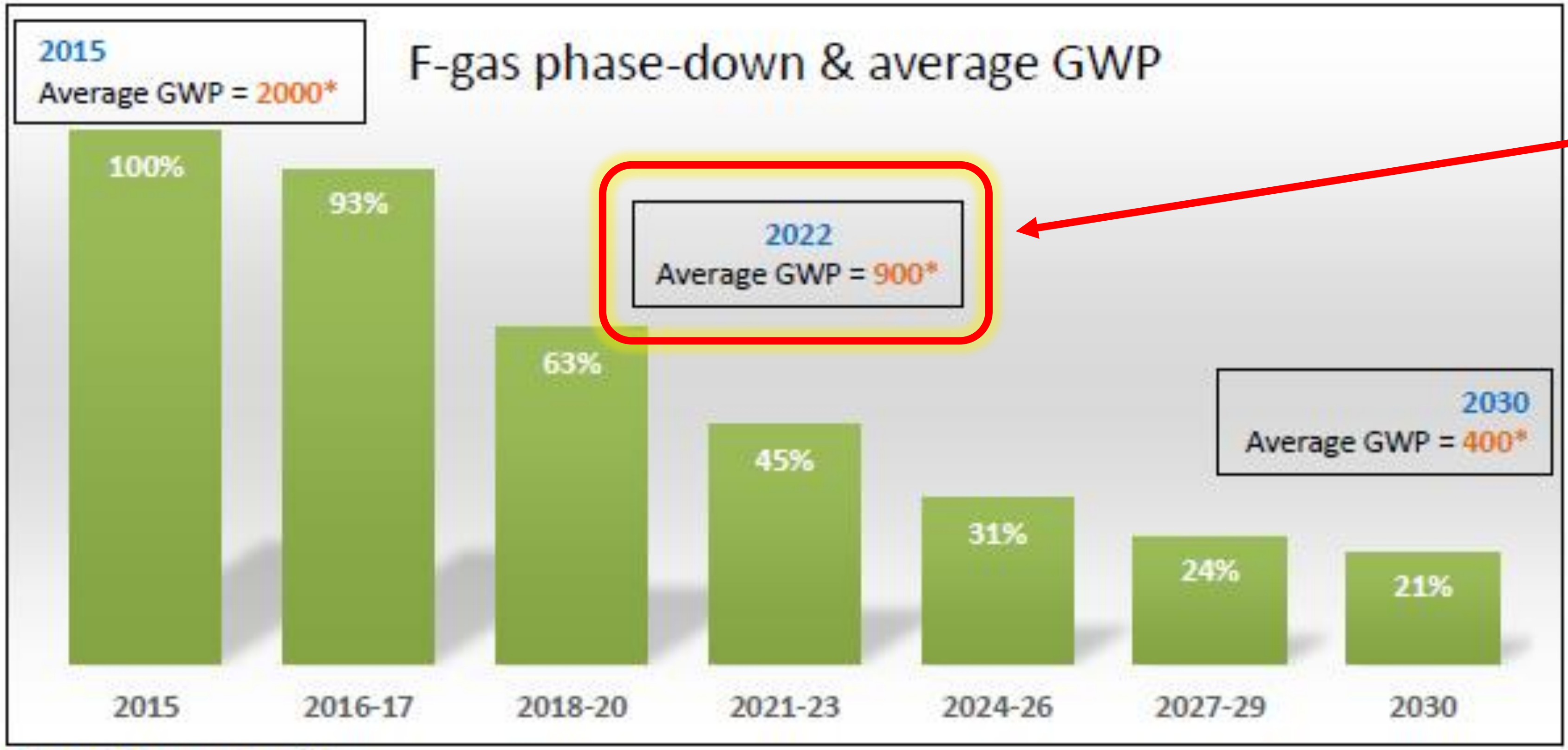
Are practical skills adequate?



Are practical skills adequate?

The F-Gas Phase Down

There is now 55% less refrigerant placed on market than in 2015



* Source: European Commission

We are now in a situation where the total refrigerant placed on the market annually has an average GWP of no more than 900 just to maintain the status quo.

Growth in the market creates a bigger problem.

If we increase the number of systems in use then that figure needs to be even lower!

Extract from EN378-1-2016 Annex E

406A	R-22/600a/142b (55/4/41)	±
407A	R-32/125/134a (20/40/40)	±
407B	R-32/125/134a (10/70/20)	±
407C	R-32/125/134a (23/25/52)	±
407D	R-32/125/134a (15/15/70)	±
407E	R-32/125/134a (25/15/60)	±
407F	R-32/125/134a (30/30/40)	±
408A	R-125/143a/22 (7/46/47)	±
409A	R-22/124/142b (60/25/15)	±
409B	R-22/124/142b (65/25/10)	±
410A	R-32/125 (50/50)	+

The 4-series of refrigerants that we want use as alternatives to 404A all contain R32 to some extent:

Between 10 and 30% for the commercial refrigeration alternatives….

Refrigerant Options: small to medium duty

Refrigerant Number	Toxicity	Flammability	GWP
32	A	2L	675
134A	A	1	1430
290	A	3	3
407C	A	1	1774
410A	A	1	2088
600	A	3	4
600a	A	3	3

Refrigerant Options: small to medium duty

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410A	A	1	2088
600	A	3	4
600a	A	3	3

High flammability make these unsuitable for building services

Strict limitations on charge size under EN378-2016

Refrigerant Options: small to medium duty

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134A	A	1	1430
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600	A	3	4
600a	A	3	3

Medium GWP make these unsustainable for smaller systems because of the need to limit average overall GWP in accordance with the phase down targets

Refrigerant Options: small to medium duty

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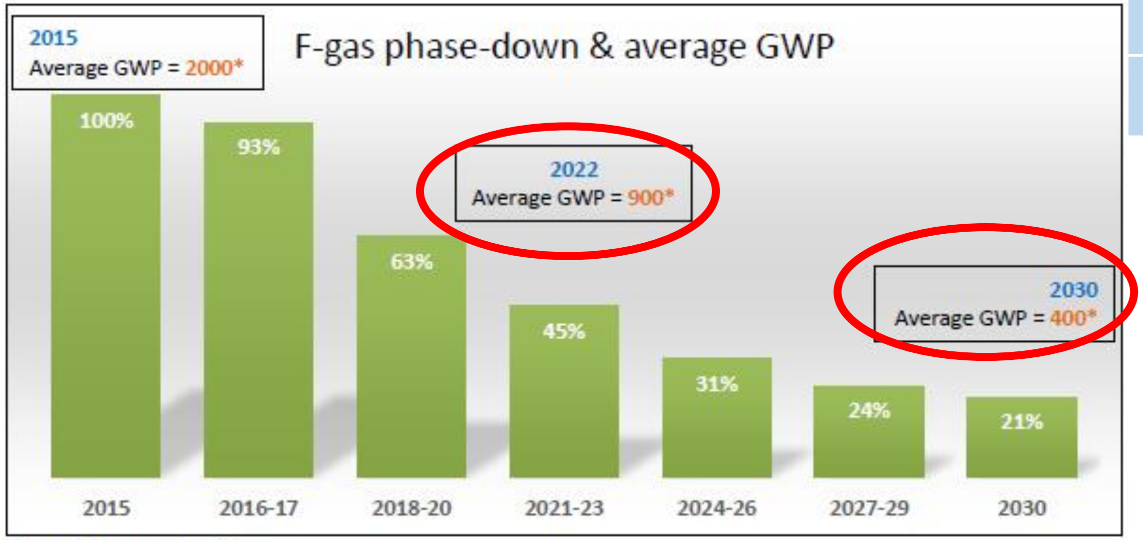
			3



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The only realistic (currently available) option for small to medium duty systems

Still 275 above the target average by 2030!

Refrigerant Options

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The only realistic (currently available) option for small to medium duty systems

Still 275 above the target average by 2030!

It is classed as “mildly flammable” A2L so there are still charge restrictions under EN378-2016

Thank you
Any questions?

Graeme Fox

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Graeme.fox@thebesa.com

LOW GWP REFRIGERANTS

MARK HUGHES
BUSINESS DEVELOPMENT MANAGER EMEA,
CHEMOURS THERMAL AND SPECIALIZED SOLUTIONS

Opteon™
Refrigerants

Chemours™

"Refrigerants ready now for the Future"- low GWP A2L refrigerants and their application

Mark Hughes MInstR

Business Development Manager EMEA

Chemours Thermal and Specialized Solutions

mark.hughes@chemours.com

The industry needs help!

Over the next few years, most new refrigeration systems installed in the UK will have a refrigerant that is either:

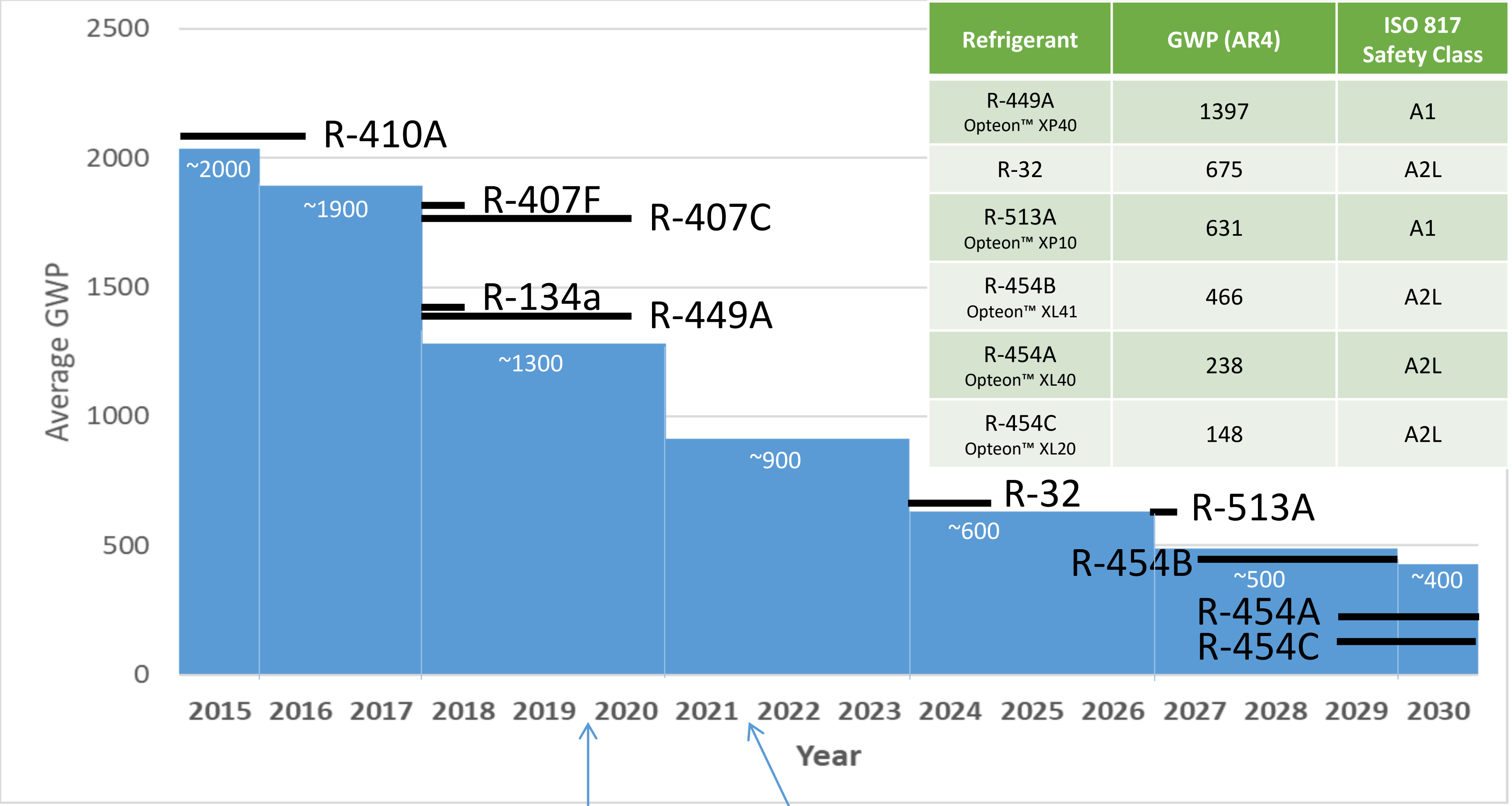
Explosive,

Toxic

Or

Flammable to some degree

Riding The Rapids – The Phase Down



Refrigerant	GWP (AR4)	ISO 817 Safety Class
R-449A Opteon™ XP40	1397	A1
R-32	675	A2L
R-513A Opteon™ XP10	631	A1
R-454B Opteon™ XL41	466	A2L
R-454A Opteon™ XL40	238	A2L
R-454C Opteon™ XL20	148	A2L

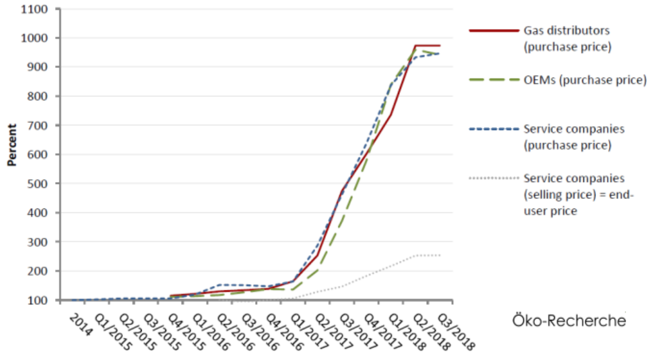
GWP Limits

	GWP Limit
New	2500
Service	2500 > 10kg 404A

	GWP Limit
New hermetic & new multi compressor commercial >40kW	150
Primary of cascade in new multi compressor commercial >40kW	1500

Market Drivers - Current product availability and price

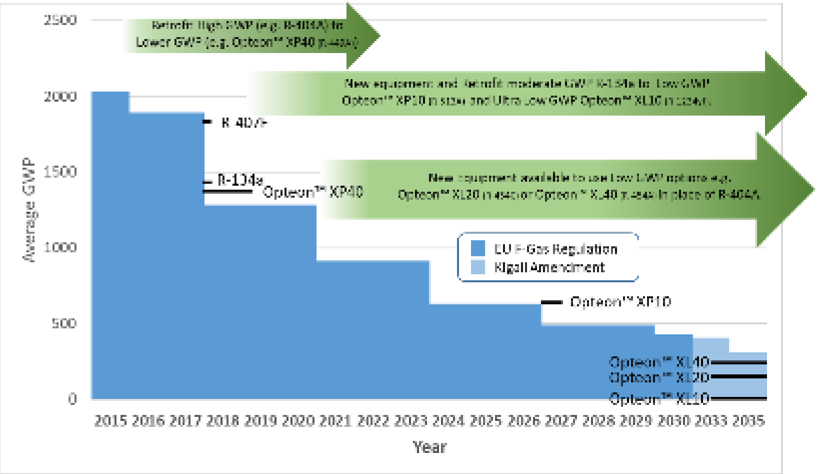
- 2018 showed what can happen when quota bites
- Virgin 404A ban started
- Reclaim 404A can be used but stocks required for whole of EU
- Replenish of Reclaim dependent on retrofit or replace existing systems
- many R404A systems have not been retrofitted or replaced yet
- 2021, 2024 major UK quota cuts – UK enforcement working



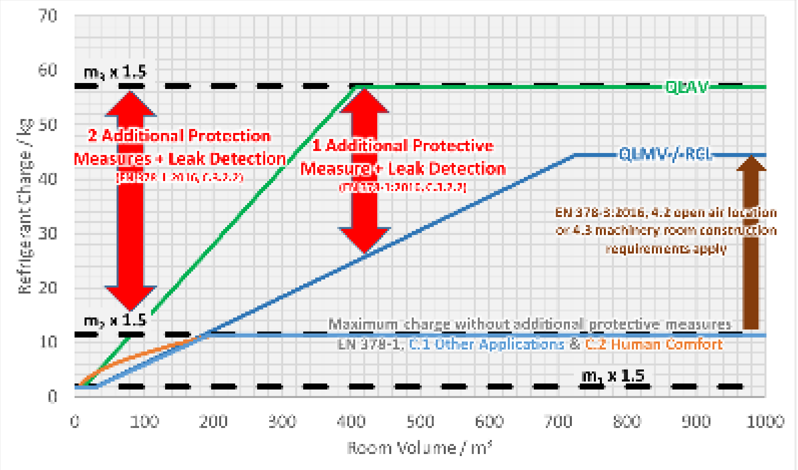
Öko-Recherche

Market Drivers – Sustainability & Safety in Use

- Sustainability
  - Secure solution for the future (F-Gas, Kigali)
  - Very low GWP products, once below 300 GWP the climate impact is all about energy performance.



- Safety in use
  - Proven safe to use
  - A2L Charge sizes >50kg allowed under EN378
  - Larger charge sizes possible with appropriate risk assessment

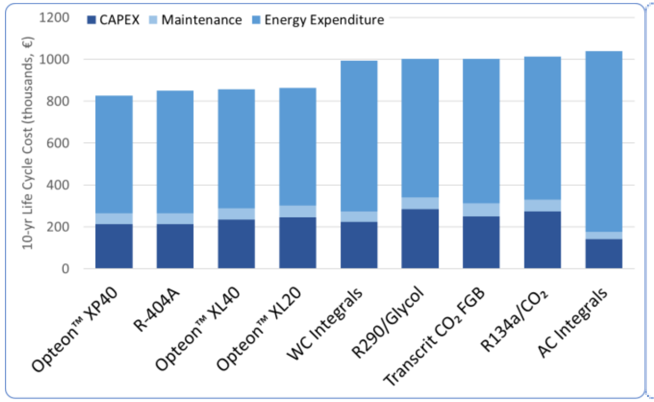


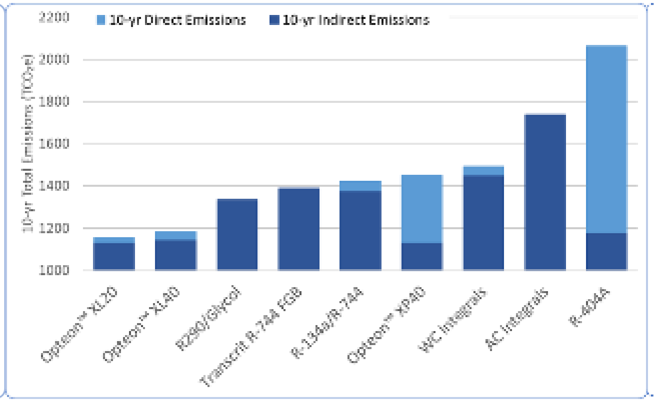
Public

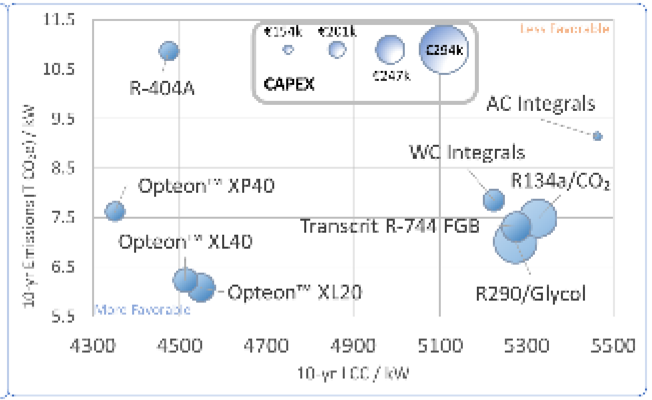
Market Drivers – CAPEX & Life Cycle Cost

The Phasedown will prevent the installation of High GWP Refrigerants.
For New Installs End Users Must Consider:

- Availability and cost (initial & ongoing) of new technology
- Energy performance – Energy efficiency is a key decision factor
- Ease of design, installation and maintenance
- Example – Cold storage







What Do I need from my New Refrigeration System?

Alternative technology choice will depend on a number of factors including:

Cost – Lower CAPEX, Lower OPEX, Lower 10-year Life Cycle Cost

Energy Efficiency – Lower Operating Costs, Lower Indirect Emissions

Reliability - Maximum System Availability, Lowest Impact to Trade

Safety - Lower Flammability, Lower Operating Pressures

Environmental Sustainability –Legislation Compliant / Lower Total Emissions

System Complexity – Ease of Installation, Ease of Maintenance, Lower Costs

Why should I choose A2L refrigerants?

Can so-called "naturals" be used to meet F-Gas and Kigali targets?

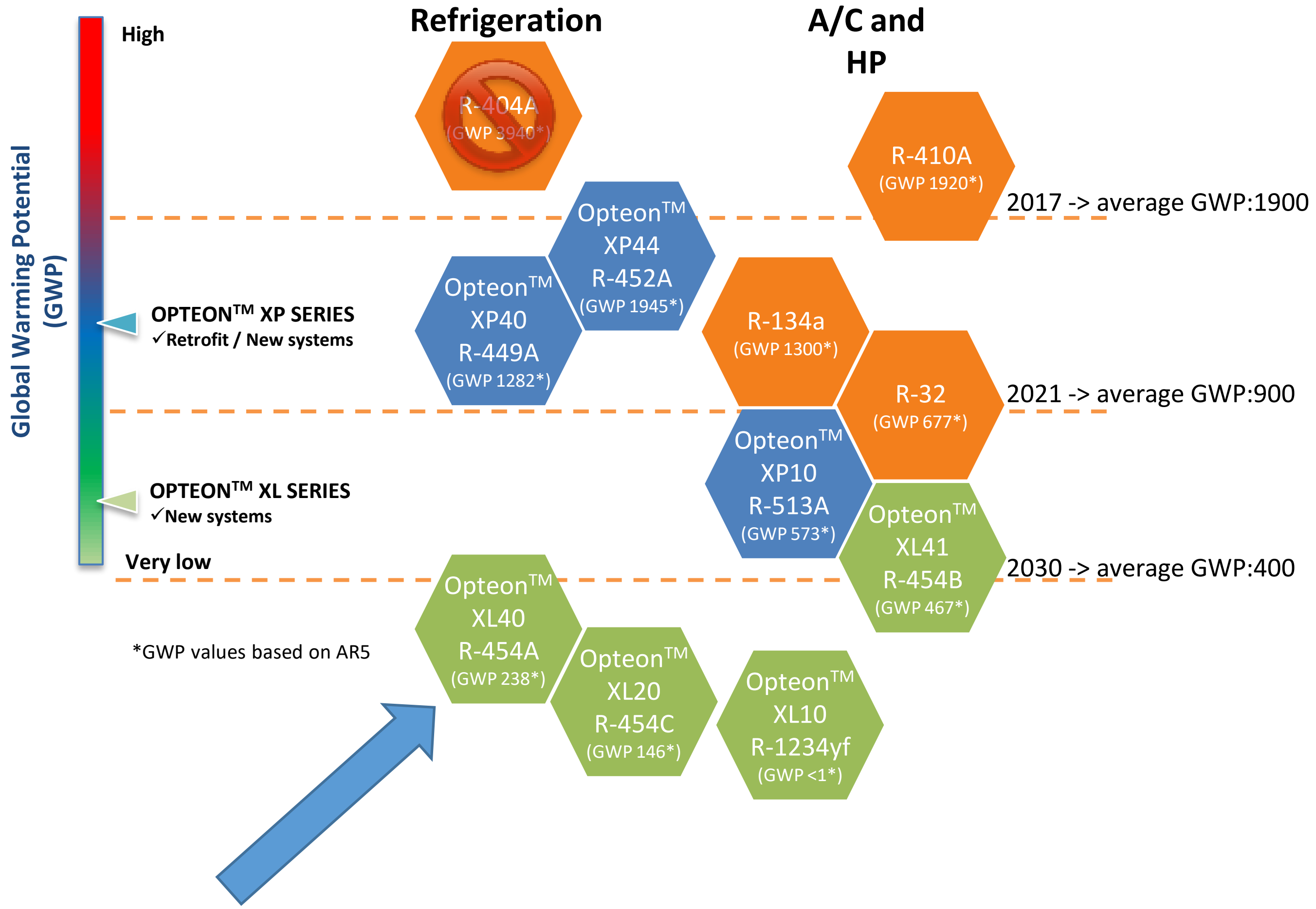
They are part of the solution YES……….but there are limits:

- Not possible/practical for retrofit, top-up of installed systems.
- Have constraints for range of new equipment use – safety, cost, codes/standards.
- Limited industry capacity & skilled contractors for installed base replacement suitable equipment.

"Natural" refrigerants	Use constraints	Market Use
CO_2	• New systems only. • Retrofit not possible (high pressure). • **Cost and efficiency compared to latest HFO blend technology.**	• Good choice for supermarket low T in cascade with HFC for med T – centralized systems
hydrocarbons	• New systems only. • Very small charge size only; retrofit not allowed (**highly flammable**; codes/standards).	• Common choice for hermetically sealed small refrigeration/freezing equipment. • Typically used with a glycol loop for larger applications
ammonia	• New systems only; retrofit not allowed (flammable, **toxicity**, codes/standards). • Non-public areas.	• Common for industrial refrigeration but not for all locations and smaller units

Lower GWP HFO blends are required

Phase down: Opteon™ XL portfolio



Refrigeration – Opteon™ XL Product Portfolio

Opteon™ XL, A2L low GWP solution vs. CO2 and propane

Refrigeration Applications

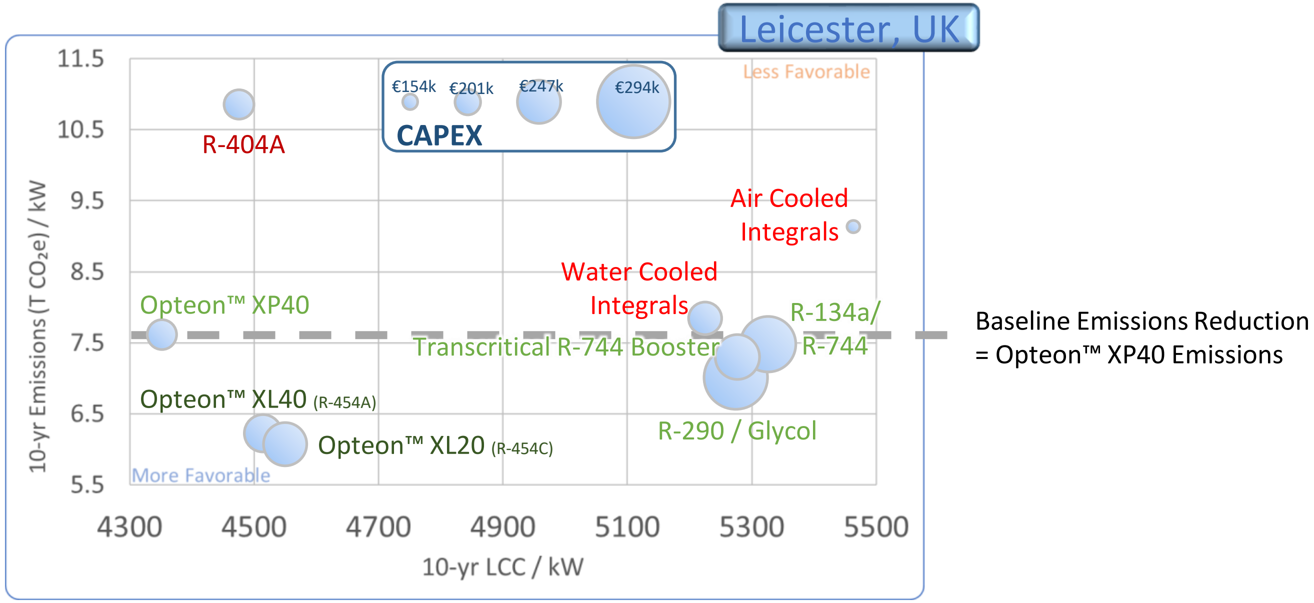



Opteon™ XL10 (R1234yf) GWP = 4 → Replaces R-134a

R454C Opteon™ XL20 GWP = 148 → Hermetic equipment and DX multi compressor Retail Refrigeration packs and condensing units

R454A Opteon™ XL40 GWP = 238 → Non-hermetic DX multi compressor Retail Refrigeration packs <40kW and all other non-hermetic, non-retail systems

Which Technology offers the Best Value for Money?
(Standard Supermarket, 2000m²)



- ✗ **AC & WC Integrals** - Highest emissions and High 10-yr LCC.
- ✗ **Transcritical R-744** System - Only 4% lower than baseline in the moderate UK climate at a High 10-yr LCC.
- ✗ **Secondary Loop Technologies** - Emissions 2-8% below baseline with increased 10-yr LCC of 21-22%. Highest CAPEX of all technologies.
- ✓ **Opteon™ XL Refrigerants** – Largest Emissions Reduction (18-20% less than baseline), Lowest 10-yr LCC (16-21% lower than other Low GWP options)

Applications - Retail

Commercial Refrigeration

- ASDA modular approach
- Small packs and condensing unit end users <40kW
- Chains of small supermarkets and convenience stores
- Large end users with small format stores – Local, Express, PFS
- Click and collect Cold stores
- A2L refrigerants proven to be safe in this application

Applications – Commercial non-retail

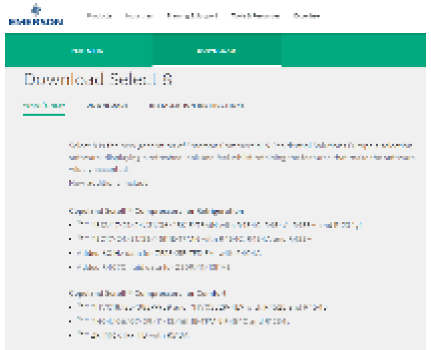
Cold stores

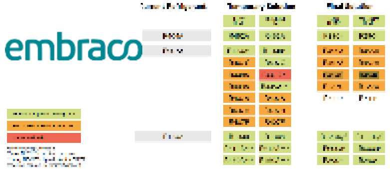
- Smaller facilities not suitable for ammonia and CO_2 is not efficient
- Condensing unit and small pack non-retail
- Food production, storage
- Can use >150 GWP
- Similar to traditional HFC technology but very low GWP – experienced installer/contractor friendly
- A2L refrigerants proven to be safe in this application

Component OEMs Progress for Refrigeration

Many Components for A2L including Opteon™ XL are now available from OEMs

Widespread Commercial availability through wholesale chain





Public

Public

Widespread adoption

A2Ls are already widely used for Air Conditioning

For Refrigeration

Numerous A2L systems
have already been installed in

Retail & Non-Retail

Commercial Refrigeration

MCE Store converted to **Opteon™ XL40** in January 2018

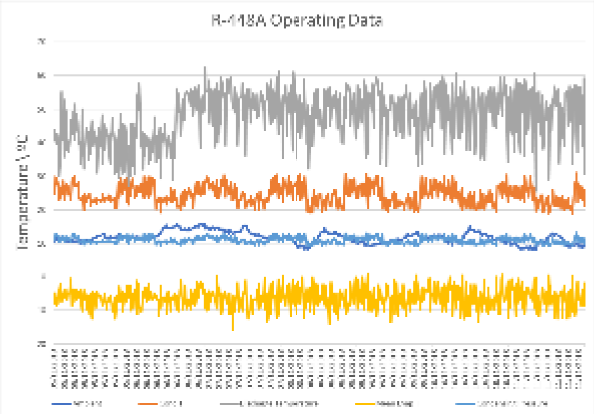
- Operated for 5 months with good system stability
- Indications of Good Energy Performance

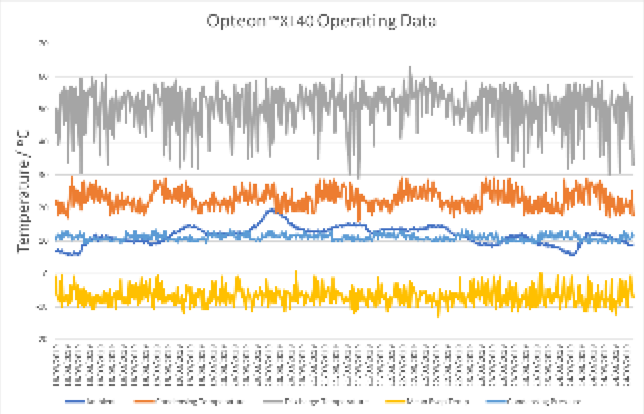
A2L Ready Pack Installed in New MCE August 2018

- Emerson Opteon™ XL40 approved Scroll Compressors
- Hubbard Pack
- Installed by City Building Engineering Services

System in a “Real” Store Installed October 2019

- F-Gas Compliant
- 94% Lower GWP than R-404A
- Improved Energy Efficiency over R-404A and R-448A
- Lower Capital and Maintenance Costs than CO_2 system





Opteon™ XL40 – Park Cake Bakeries, UK

Freeze Store (-18ºC)

Cold Store Dimensions: 24m x 11.9m x 6.4m

Capacity 360 Pallets

3 x Zanotti HCU5180B941J Condensing Units

Bitzer Compressor 4HE-18Y-40P, BSE 32 Oil

23 kg Refrigerant per Unit

Designed and installed by Dawson rentals

Dawson portable chill and freezer stores

moving from R449A to designs on Opteon™ XL40 R454A

Industrial Refrigeration – Technofroid, France

Opteon™ XL20

- Main Cold Room 401m² (3011m³ Volume)
  - Room temperature -25°C approx. (T_{evap} =-30°C, T_{Cond} = 45°C)
  - Two LT systems are used – 36 kg R-454C (per system)
  - Cooling capacity per system 25 kW
  - Each system is using a Bitzer compressor (6FE-44Y-40P)
  - Guntner evaporators (GHN 071.27/27)
  - Condensers A2L AF Energy (GCC-TNF-N25-Y)
  - EXV Carel E2V35

Opteon™ XL10

- Entrance 'Air-Lock' 57m²
  - Room temperature 5°C approx. (T_{evap} =-5°C, T_{Cond} = 45°C)
  - One MT system – 11kg Opteon™ XL10 (R-1234yf)
  - Cooling capacity 10 kW
  - Bitzer compressor (4DES-5Y-40P)
  - Guntner evaporator (GACC RX 040.1/2)
  - Condensers A2L AF Energy (GCC-P1-SHS-8E-1EC450)
  - EXV Carel E2V35

A heat recovery system is installed (in parallel to the condenser)

The heat is used to heat up the floor, for sanitary hot water and space heating for the employees. This recovery systems allows tax reductions according to the French laws SWEP plate water condensers are used for this system

UK Cold store activity - status

- Increasing number of cold store contractors working with A2L
- Long term solution compared to R449A or R452A for new install
- Experience with equipment and installation increasing
- Components available to manufacture A2L systems
- Many projects ongoing in produce and food storage around the UK
- Technical support available through distributors and wholesalers and direct from Chemours

Very Low GWP, Long Term, Sustainable Solutions

Opteon™ XL Refrigerants

“The sensible choice - right now”

Mark Hughes
Business Development Manager
Chemours Thermal and Specialized Solutions
mark.hughes@chemours.com

Opteon™

Chemours™

Public

Q & A

Thank you

Mark.hughes@chemours.com

ADAPTING REFRIGERATION SYSTEMS FOR CHANGING REFRIGERANTS

RICHARD PARR
ENGINEERING DIRECTOR, RYAN JAYBERG LTD

Ryan-Jayberg

Ryan-Jayberg

Refrigeration Design, Consultancy, Build & Service Company

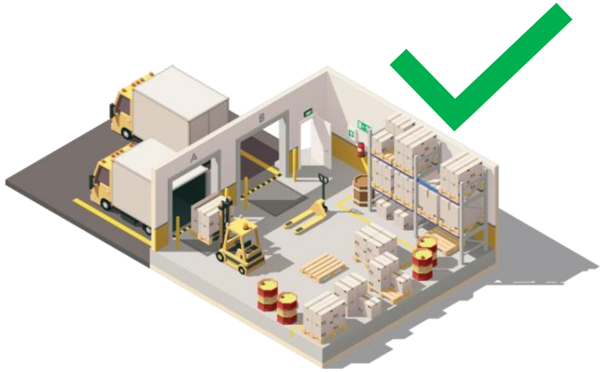
How refrigeration systems will need to evolve to be able to use lower GWP refrigerants and aid businesses reduce carbon emissions?

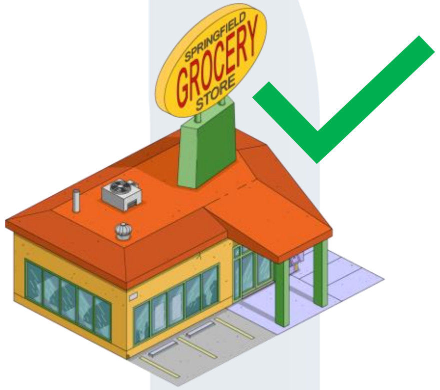
Ryan-Jayberg

About us

- 36 Years Trading- Independent privately owned company
- Refrigeration Solutions & Services
- Our HQ is in London with regional offices, Gloucester, Swansea, Southampton
- Our ethos is to deliver our services with integrity & efficiency forming long term partnerships with our clients.
- Passionate in low carbon technologies, their integration within the built environment & our vision is to provide clean, green refrigeration, cooling HVAC & Heat Pump technologies so we reduce our clients carbon footprint.

What do we do?





Cradle to Grave Services-
Consult, Design, Build, Maintain, Measure & Improve.

CLIMADESIGN Ryan-Jayberg

Ryan-Jayberg

We have come full circle?

1800's - 1929

Mechanical refrigeration used natural refrigerants. Nearly all the first-generation refrigerants were flammable, toxic or both and some were also highly reactive.

1930's-1940's

CFCs & HCFCs (Chlorofluorocarbon's, Hydrochlorofluorocarbon's) refrigerants were developed. What wasn't known at the time is that CFCs deplete the ozone layer, this was established in 1970's

1987

Montreal protocol signed. Phase out and eventual ban of CFCs & HCFCs due to their ODP were replaced with HFCs (Hydrofluorocarbon's).

2016

Kigali Agreement signed in 2016 to reduce use of HFCs, especially high GWP refrigerants due to their effect on the climate (global warming impact).

Now

We are back to natural refrigerants? (Co2, Ammonia, Hydrocarbons) and the new generation of developed low GWP refrigerants HFO's (HydroFluoroOlefin).

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Low GWP Refrigerants

What are they?

There are over 160 single compound and blended refrigerants listed, but this easily gets narrowed down to 20-30 "available" refrigerants.

To protect against changing regulation we typically always advise the lowest GWP refrigerant be prioritised on the basis **BOTH safety** and **efficiency** measures can be satisfied for your specific application.

Refrigeration selection continually debated since commercialisation of refrigerant technology. Impact decisions-

- Environmental/ legal obligations,
- Safety requirements (Pressure, Toxicity, Flammability),
- Efficiency and thermodynamic cycle
- Material compatibility
- Availability- components
- Competency/ expertise- pre & post construction

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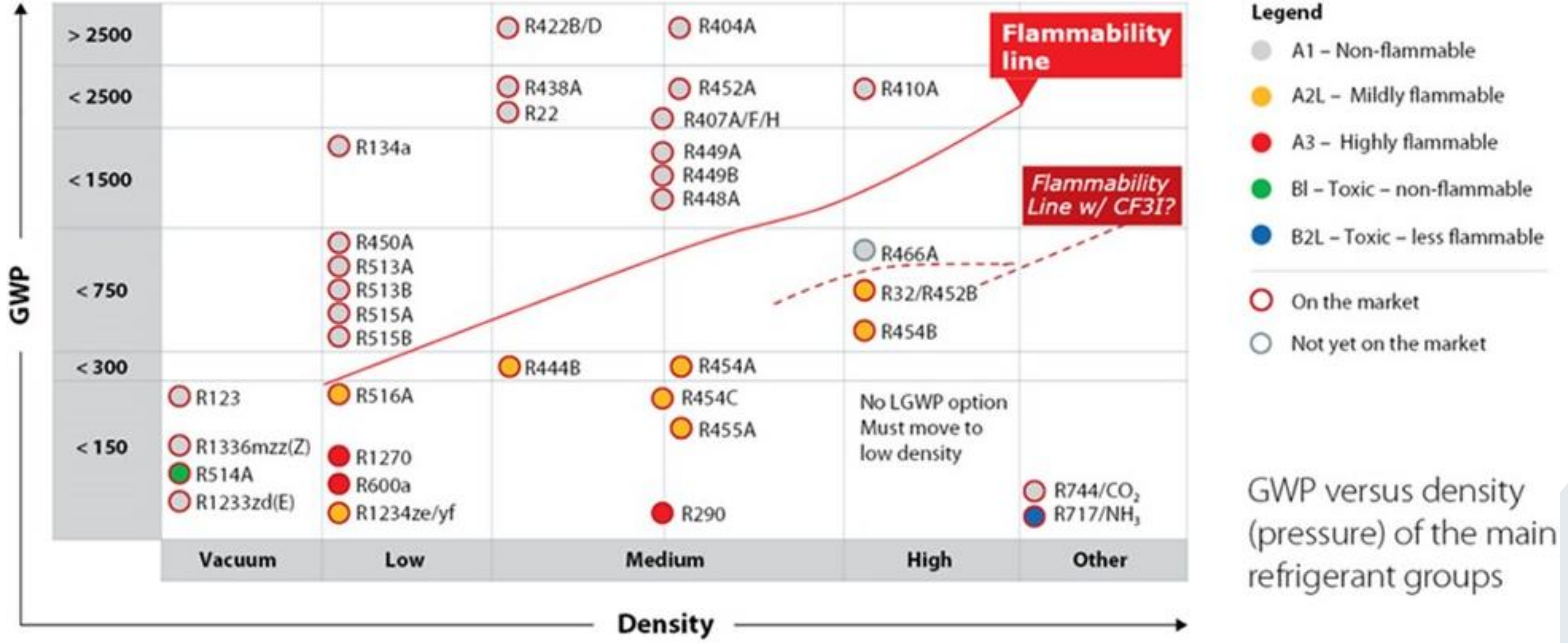
Low GWP Refrigerants

With lower GWP refrigerants there is a trade-off between a lower GWP and flammability. Most of the "current" refrigerants have no simple low-GWP drop-in solutions-



Source Danfoss

BS EN 378:1 Table C1 – gives guidance where toxicity is dominant hazard (R717, R744)

Table C2- gives guidance where flammability is the dominant hazard (HC and A2Ls)

HFO's- A2L and HC's A3 Refrigerants

Clients and system designers must ensure safety;-

1) Sources of ignition on or close to leaked refrigerant cannot ignite leaked refrigerant. Leaked refrigerant can stagnate causing damage/ danger to property or people. Gas detection & ventilation will likely be required.

2) Refrigerant that leaks into a room/space must not pose an explosion risk. Charge sizes have to be limited. This includes assessment of all spaces including where refrigerant pipework may pass not simply where plant or evaporators maybe located.

These refrigerants will/ are being used in small close coupled condensing units & sealed systems such as mono blocks. Outdoor items such as water chiller's/ heat pumps already adopt these refrigerants using multiple smaller refrigerant circuits to limit charge sizes.

Although BS EN 378 differentiates between types of flammable refrigerants, other regulations & standards apply-

- **DSEAR applies to handling flammable refrigerants**
- **ATEX 95 applies.**

These refrigerants can offer energy savings vs older HFC refrigerants- Safe design, risk assessment and management is an essential requirement.

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The new generation- low GWP Refrigerants

Future systems need to be risk accessed to manage/ eliminate Toxicity & Flammability aspects that come with low GWP refrigerants.

Existing facilities using older higher GWP HFCs need to consider new/ additional requirements.

Restrictions on use and maximum charge sizes must be understood. This is impacted by;-

- Location of equipment, is it an occupied space or external?
- Above or below ground?
- Who has access to the area, public- unrestricted or authorised access?

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Ammonia (R-717) Refrigeration Systems

Used in large scale industrial operations and is very efficient for both refrigeration & heating applications. This is an established efficient natural refrigerant that will play significant part in the future of large industrial systems.

Ammonia R-717

PROS OF AMMONIA SYSTEMS:

- Natural and environmentally friendly- GWP 0
- Energy efficient
- Good heat transfer rates
- Lots of development into low charge systems to improve safety
- Low material/ refrigerant price

CONS OF AMMONIA SYSTEMS:

- A leak could injure or kill someone in rare cases- (Toxic & Flammable in certain quantities). Odour is sign of leakage.
- Usually used in warehouses and spaces with less personnel- reduce exposure (not used in public areas)

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CO_2 (R-744) Refrigeration Systems

CO_2 was used in refrigerant systems in 1800's. Industry moved away from CO_2 towards synthetic refrigerants. Since phase down in FGases CO_2 has been adopted widely especially in the commercial sector & in cooler climates.

PROS OF CO_2 SYSTEMS:

- Non-corrosive; non flammable; low toxicity (A1 refrigerant)*
- Natural and environmentally friendly
- Efficient at low temperatures
- Required equipment takes up less physical space. Volumetric cooling capacity is between 5 and 8 times that of HFCs, reducing the required compressor displacement and pipe size.
- Good heat recovery opportunities for hot water users
- Lots of development/ technology- Transcritical Booster Systems

CONS OF CO_2 SYSTEMS:

- Critical point- Larger energy user in high ambient
- High discharge temperatures so two stage compression for low temperature systems
- Requires specially designed components & compressors due to high pressure
- Leak detection systems required as In high concentrations Co_2 can cause asphyxiation. Leak detection/ alarm systems are recommended to monitor PPM levels in enclosed spaces

Unfortunately there is no single refrigerant that gets a green light across the board-

Refrigerant/ Generic Type	Class	Flammability	Inhalation	Pressure	Efficiency in High Ambients	Cost of Refrigerant	System Cost	Key Hazards
R744 (C02)	**A1**	Non Flammable	Asphyxiant- Low Toxicity	High	Low- critical pt 31degC	Lower	Higher	Asphyxiant, High operating pressures, dry ice cause freeze burns
R717 (Ammonia)	**B2L**	Low Flammability	Toxic	Lower	Higher	Lower	Higher	Asphyxiant, Toxic, low flammability, dry ice cause freeze burns
HFO's (R1234ze)	**A2L**	Low Flammability	Asphyxiant	Similar to HFC's	Similar to HFC's	Higher but HFCs PD impact	Higher	Asphyxiant, low flammability, dry ice cause freeze burns
HC (R600a, R290, R1270)	**A3**	Highly Flammable	Asphyxiant	Similar to HFC's	Higher	Lower	Higher	Asphyxiant, high flammability, dry ice cause freeze burns

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There is no single perfect refrigerant that is all things to all users. The Coldchain will be made up of multiple

	Standalone Units	Condensing Units	Centralised Plant	Distributed/ Industrial
	Micro Systems	Small Systems	Medium Systems	Large Systems
Duty	<2 Kw	2-40Kw	40-500Kw	500 to 1000's
Typical refrigerant Charge	0.1-0.5Kg	1-50Kg	30-250Kg	250Kg +
Low GWP Refrigerant	HC	HFO's & Co2 (R744)	Co2 (R744)	Ammonia (R717)
Indicative Photo of Plant				

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CO2 (R-744) Refrigeration Systems

Equipment is designed to achieve a nominal design point, which is the peak cooling load during the hottest expected ambient conditions. This design point can be considered as the “worst case” load condition. In reality, most systems spend very few hours per year close to this design point.

Source Real Alternatives

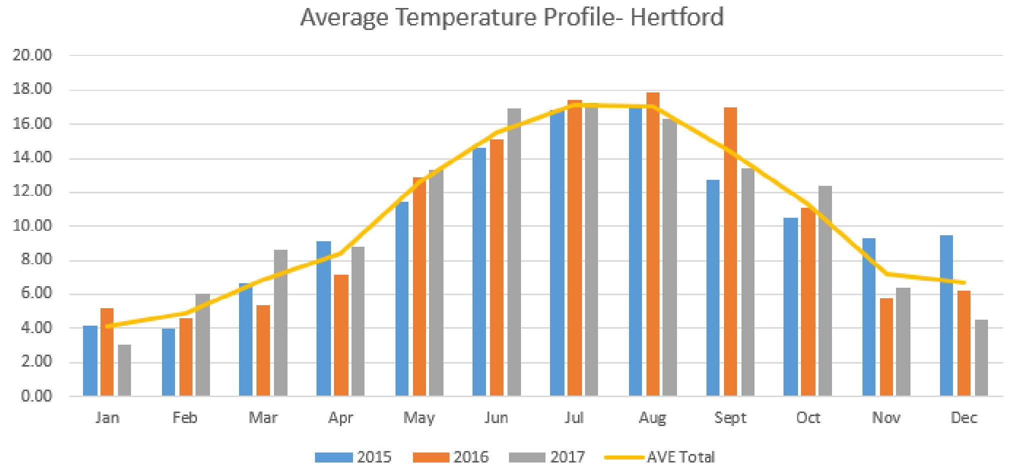
Refrigerant	Saturation temperature at 0 bar g,◦C	Required displacement m^3/h	COP	Discharge temperature, ◦C	Compression ratio [a]
R404A	-46	14.84	2.94	57	3.82
R744	-78	3.88	1.75 [c]	114	3.42
R717	-33	14.3	3.27	152	4.82
R32 [b]	-52	9.65	3.17	99.5	3.77
R1234ze [b]	-19	35.14	3.28	52	4.54
R600a	-12	47.13	3.26	51	4.40
R290	-42	17.35	3.18	59	3.61
R1270	-48	14.3	3.17	67	3.53

Table 5, performance comparison

a. Compression ratio is the discharge pressure divided by the suction pressure, both in bar abs
b. Data from Refprop
c. All the COPs given in this table are theoretical COP of the refrigeration cycle. R744 operates above the critical point at the reference cycle, in practice the COP will be higher than shown in the simple comparison above.

The comparison has been estimated at the following conditions:

- Cooling capacity, 10kW
- Evaporating temperature, -10°C
- Condensing temperature, 35°C (R744 is trans critical and has a gas cooler exit temperature of 35°C)
- Useful superheat, 5K
- Subcooling, 2K
- Pressure losses are equivalent to 0.5K
- Isentropic efficiency, 0.7 or 70%



Co2 Transcritical Run Hours- Above 25degC – 1-2% of total annual hours

To reduce your carbon emissions look at the operation over the calendar year. Compare seasonal performance not just peak design performance.

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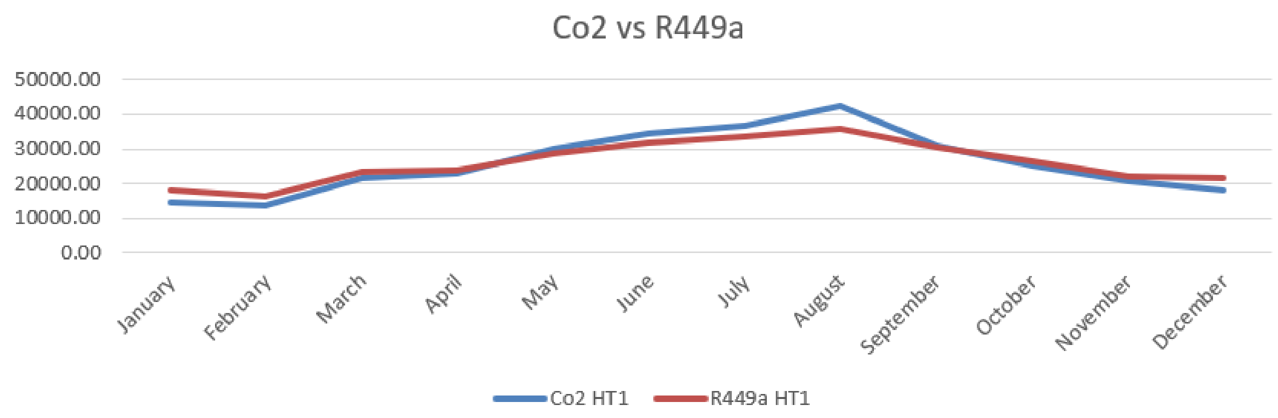
CO_2 (R-744) Refrigeration Systems

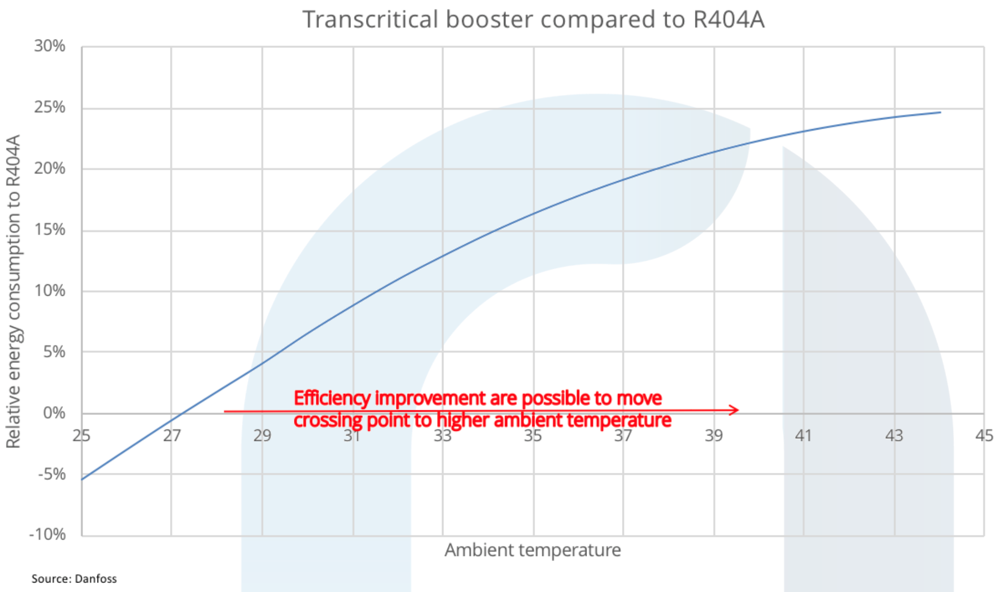
Chilled Store Facility & Dispatch- Case Study
A recent client was going to procure R449a systems, we were the only contractor to offer/ return a Co2 Transcritical solution/ system.
They asked why? On their website they had recently made a commitment to reduce carbon emissions. As part of the tender process pro's, con's and comparisons were requested.



CO2	Run Cost at 0.14p/kwh		TEWI (tonne Co2)
HT1	£	35,610.91	954.15
HT2	£	35,610.91	954.15
Total	£	71,221.82	1,908.30
R449a	**Run Cost at 0.14p/kwh**		**TEWI (tonne Co2)**
HT1	£	35,995.56	1448.54
HT2	£	35,995.56	1448.54
Total	£	71,991.12	2,897.08
Variance	**-£**	**769.30**	**-988.79**
		-1.07%	**-34.13%**

As a minimum run costs comparable over the calendar year, even though Co2 uses more energy in peak summer ambient
Direct emissions significant saving due to reduced GWP
Life-cycle reductions over life of the chill store facility

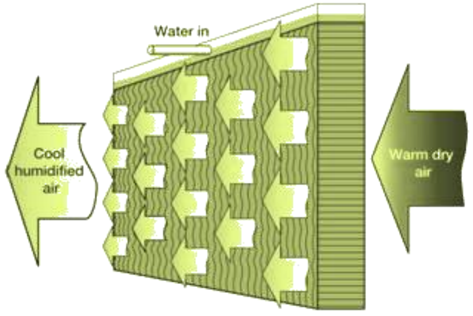
CO2 (R-744) Refrigeration Systems

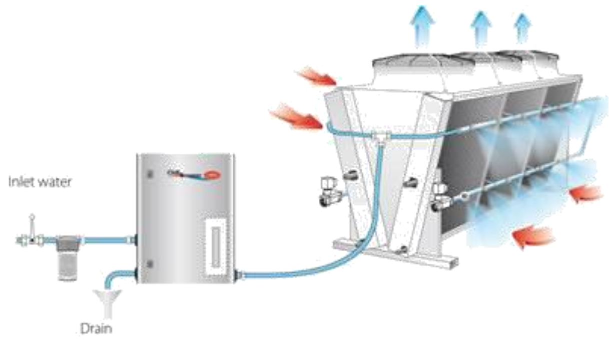


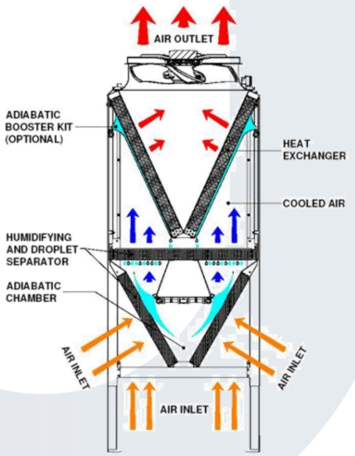
Optimising Efficiency and reducing carbon emissions in Co2 Transcritical Systems

Indirect:

Adiabatic systems/ Spay system- reduce air on temperatures to gas cooler equipment.







Full analysis required as there are some draw backs including water treatment, fin treatment and additional maintenance costs.

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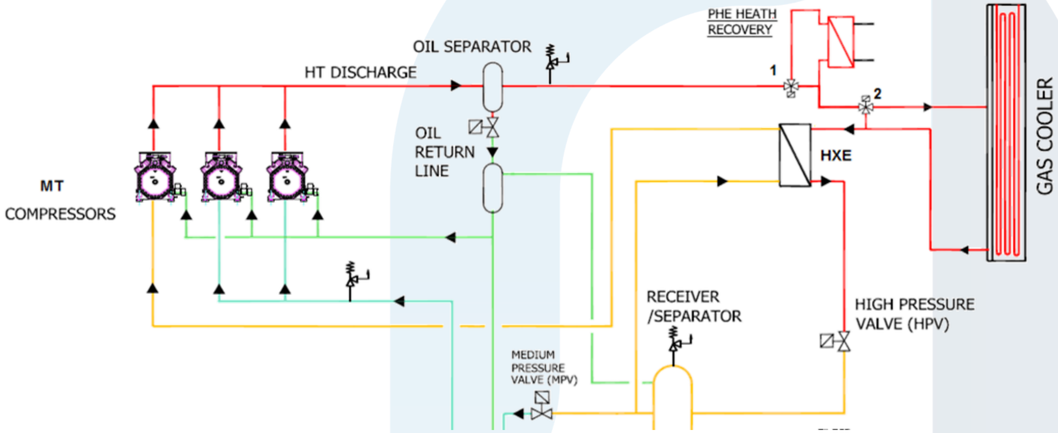
CO_2 (R-744) Refrigeration Systems

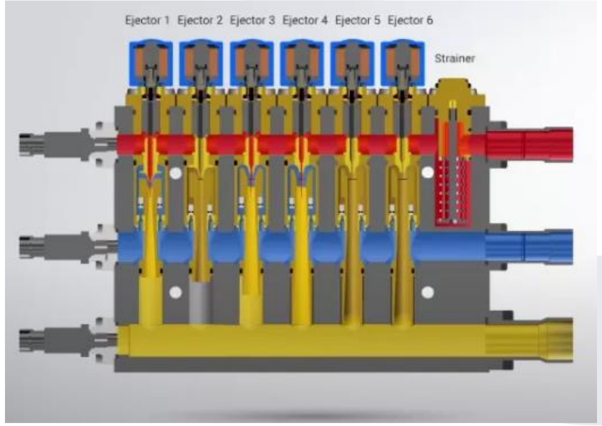
Case Study-**Optimising** Efficiency and reducing carbon emissions in Co2 Transcritical Systems-

Direct:

Parallel compression- Use a compressor to "re-cycle" the higher un-useful flash gas at a higher efficiency than the operation of the main compressors. 10% Saving Opportunities

Multi Ejector Technology- Vapour & Liquid Ejectors within Co2 systems when combined with parallel compression are now reaching the market offering 10-20% Saving Opportunities





Source SCM Frigo/ Danfoss

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CO2 (R-744) Refrigeration Systems

Case Study-**Integrated** Systems- Heat Recovery

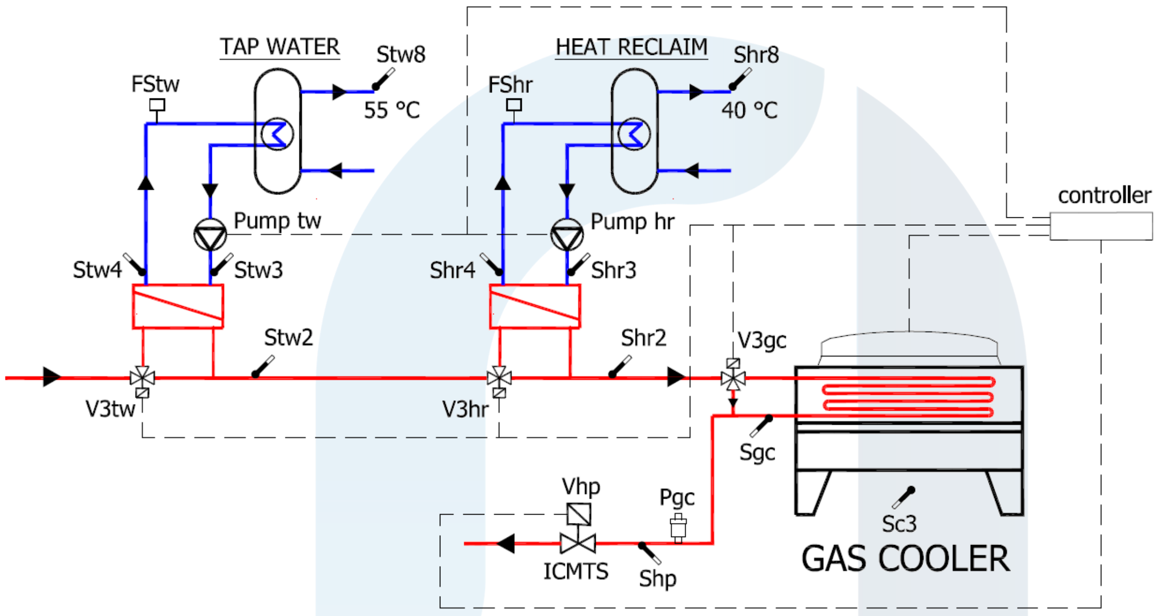
Why are we throwing heat away if it can be used elsewhere in the facility and or used by others. To be truly carbon neutral and reduce emissions heat needs to be recovered?

Integration of heating & cooling system key priority.

Don't just look at refrigeration/ cooling demands what are your heating demands?

Energy balance and thermal model, consider-

- Hot Water
- Space heating requirements
- Underfloor heating requirements
- Thermal/ Energy Storage
- Load shifting from peak tariff times



Heat Reclaim realized in 4 stages:

Stage 1: Activate HR. Valve 1 open. (V3hr)

Stage 2: Raise the system pressure. With the increasing of the heating demand. The head pressure is increased consequently.

Stage 3: Stop gas cooler fans.
To allow the increasing of the heating load the gas cooler fans are stopped.

Stage 4: By-pass gas cooler.
In this way the HR exchanger becomes a total heat recovery and heating load is maximum

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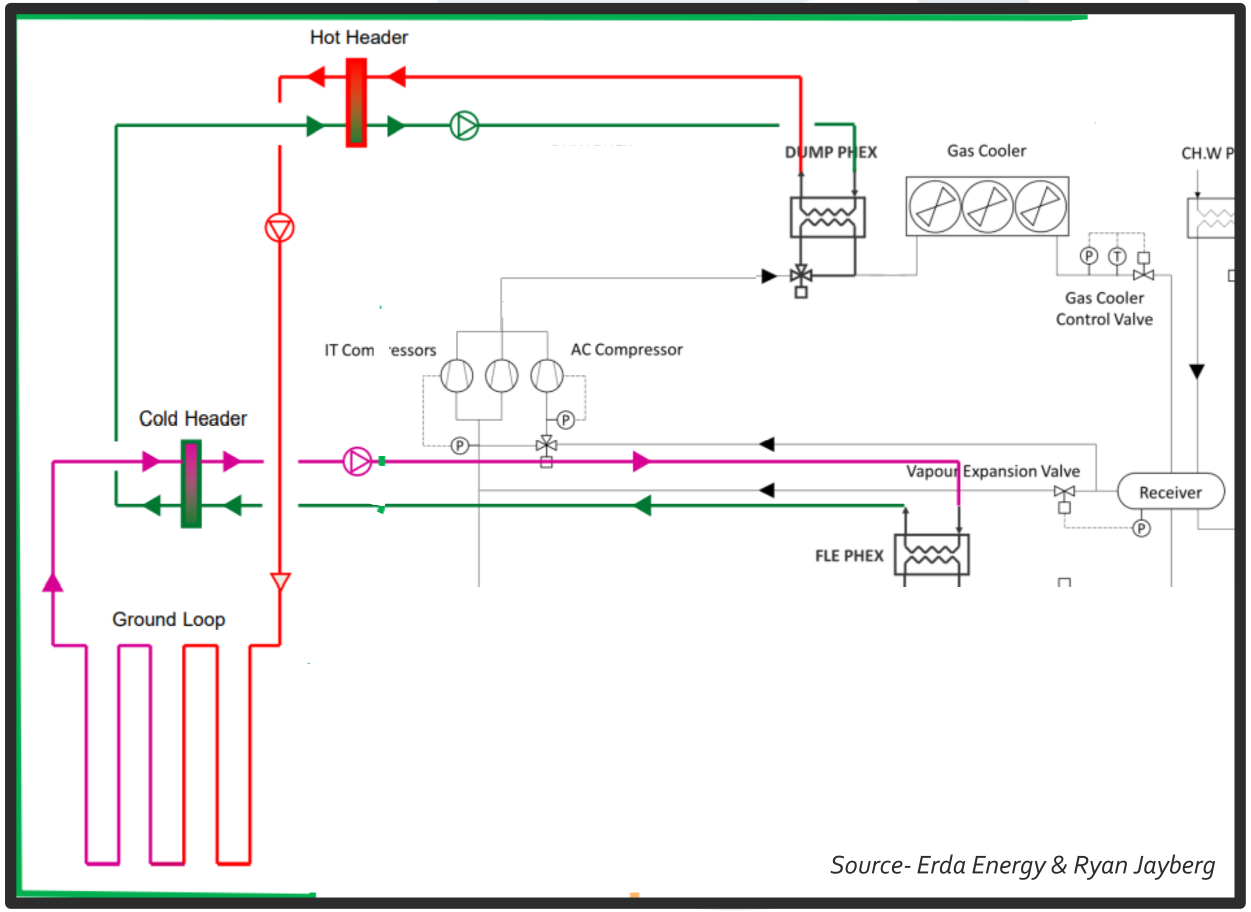
CO_2 (R-744) Refrigeration Systems

Case Study-**Integrated** Systems- Ground Coupled Systems to reduce carbon emissions.

Utilise the ground as a battery to store thermal energy.

Use water as the condensing/ cooling medium in peak summer months to avoid transcritical operation (when the ground is cooler than the air)

Remove the heat from the ground during winter months using water to water heat pump for heating demands.



Source- Erda Energy & Ryan Jayberg

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No matter the refrigerant- Safe, Efficient & Sustainable Refrigeration Design

Leak Reduction- Irrespective of the refrigerant it is important & a LEGAL requirement that leaks are minimised

- Safety - all refrigerants are asphyxiants, many of the alternatives are flammable and R717 is toxic
- Energy/ performance-leaking system has less capacity and consumes more power than a fully charged
- Cost- Cost associated with refrigerant replacement, reliability and minimise consequential losses;
- Carbon- Direct effect on climate change – some of the alternatives have a significant global warming potential;
  Indirect CO_2 emissions associated with additional power consumption

So:-

- ✓ Minimise the number of joints;
- ✓ Minimise the number of components;
- ✓ Close couple the system; keeping the refrigerant quantity as low as possible: refrigerant that is not in the system cannot leak
- ✓ Minimise the number of access points to the system and locate them where they are most useful;
- ✓ Avoid using Schrader valves, but if an access valve is absolutely necessary use a ball valve with a flare connector (and ensure it is capped when not in use);
- ✓ Ensure pipe is correctly clamped and vibration transmission is eliminated;
- ✓ Provide information:- the location of access points on the isometric drawing in the plant room;
- ✓ Design in ease of service to aid leak detection and other vital maintenance activities.

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No matter the refrigerant- Safe, Efficient & Sustainable Refrigeration Design

Technical Considerations- Think and ask about good practice, optimization & integration?

- Avoid assumptions, tendency will always to be cautious and over design. Agree a brief and a specification.
- Building/ Coldroom fabric/ Door Air ingress- reduce heat gains. Minimise refrigeration & cooling requirements/ loads.
- Minimise pressure drop's in refrigeration pipework design
- Minimise pipe routes, avoid setting, unnecessary joints, bends
- Can delta T- temperature difference's across heat exchangers be reduced, this will involve larger heat exchangers/ evaporators using more raw material at an increased capital cost but their will be a payback in operation. Rule of thumb for every 1DegC the evaporating temperature can be raised= 3% saving in plant energy consumption.
- Grouping of evaporator loads, multiple system temperatures to avoid running multiple evaporators at the lowest evaporating condition.
- Ensure compressor plant sizing consider not only maximum design loads but ability to match minimum/ part load operating conditions.
- Smart Controls such as- Floating suction setpoints and optimization via intelligent electronic control system
- Internet-of-Things- Smart Technology coming to the market
- Can electric defrost/ heating systems be replaced with hot gas, glycol reclaimed from the refrigeration process.
- Automatic leak detection and leak tightness

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No matter the refrigerant- Safe, Efficient & Sustainable Refrigeration Design

Regulatory Considerations/ Incentives- Informed decision making?

- ✓ Rules for minimum performance including energy efficiency regulations. ECO Labelling of products.
- ✓ Recycling & waste targets
- ✓ Check for grants, government incentives such as capital allowances to aid financing of higher cost options for ultimately more energy efficient solutions
- ✓ CDM- Ensure equipment can be maintained easily to maximise energy efficiency
- ✓ Adhere and comply with Regulations, PED, PSSR etc.
- ✓ Follow standards & apply guidelines and good practice.

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Efficient & Sustainable Refrigeration Design- look beyond TEWI?

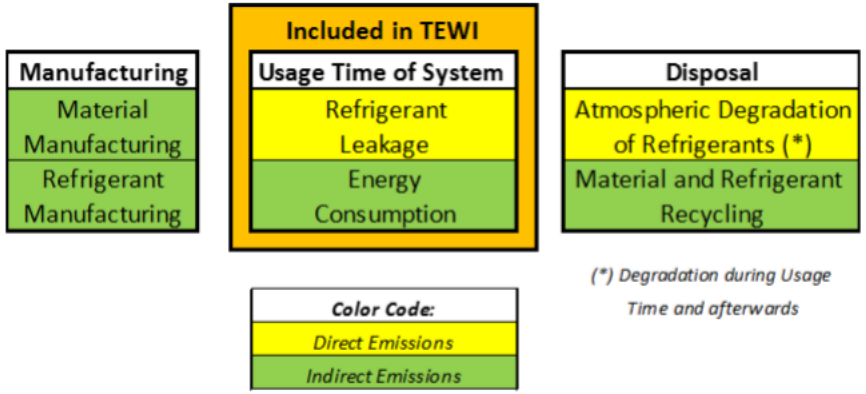

Figure 5.1: LCCP vs. TEWI Comparison

Life Cycle Climate Performance (LCCP)

- Typically refrigeration designers are familiar with TEWI (Total Equivalent Warming Impact) to review refrigeration systems. This looks at both direct (refrigerant charge/ leakage) and indirect (electrical consumption from running) emissions of Co2 of a system.

- The key variance with LCCP is this calculation method also looks at energy embodied in product materials, greenhouse gas emissions during chemical manufacturing, and end of life disposal of the unit.

- As GWP's of refrigerants get lower, coupled with the UK electricity grid becoming greener (more reliant on renewables) LCCP will become a more accurate way of accessing refrigeration systems for

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Summary

- There is no single perfect low GWP refrigerant
- When moving to low GWP refrigerants you must consider safety. (Toxicity & Flammability)- Risk Assessment for the application.
- When replacing legacy higher GWP refrigerants/ systems- consider the lowest GWP refrigerant for your application based on measured/ balanced approach around life cycle.
- Consider natural refrigerants, R717 and R744
- Adopt latest technology to maximise opportunities to reduce energy
- Remember **good practice**, **leak reduction, optimization & integration**

"We have made a firm commitment to assist our clients in reducing their carbon footprint to provide a sustainable pathway for now & future generations. Our services & ideas, using low carbon refrigeration technologies will help build clean and green buildings and systems."

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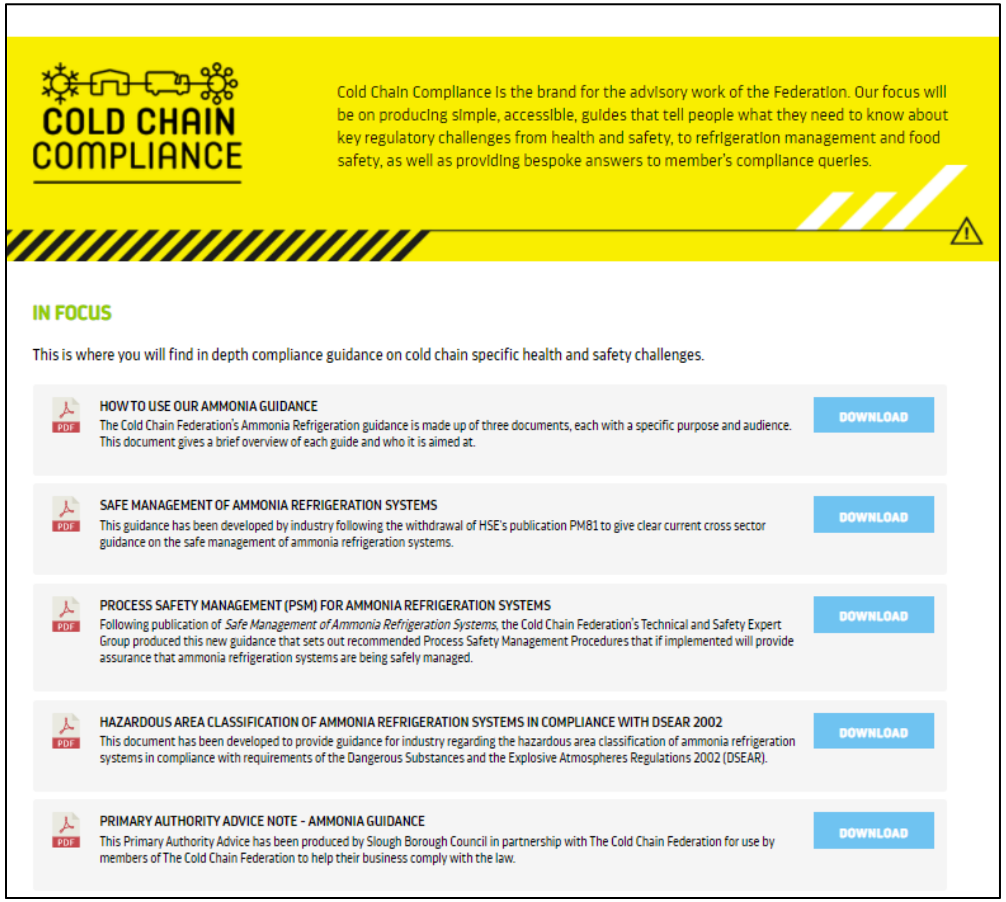
QUESTIONS & DISCUSSION

GUIDANCE



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