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FME FORSKNINGS-SENTER FOR MILJØVENNLIG ENERGI
Norges forskningsråd

Why natural working fluids are a smart choice for energy efficient heat pumps and refrigeration units

Armin Hafner

NWF a smart choice: Content

- **Introduction**
  - Kigali Amendment of the Montreal protocol and EU F gas directive
- **Working fluid options**
  - HFC's
  - Natural working fluids (NWF)
- **HSE (Health Safety Environment)**
- **Energy Efficiency**
  - NWF units versus non-NWF units
- **Summary**

Significance of refrigerant choice: Introduction

Kigali Amendment of the Montreal protocol and EU F gas directive (517/2014)

UNITED NATIONS ENVIRONMENT PROGRAMME

Programme des Nations Unies pour l'environnement | Programa de las Naciones Unidas para el Medio Ambiente
Программа Организации Объединенных Наций по окружающей среде | برنامج الأمم المتحدة للبيئة
联合国环境规划署

UNEP

Table 1: Phase-down schedule for HFCs in Article 5 and non-Article 5 parties

	A5 parties (developing countries) - *Group 1*	**A5 parties (developing countries)** - *Group 2*	**Non-A5 parties (developed countries)**
Baseline formula	Average HFC consumption levels for 2020-2022 + 65% of hydrochlorofluorocarbon (HCFC) baseline	Average HFC consumption levels for 2024-2026 + 65% of HCFC baseline	Average HFC consumption levels for 2011-2013 + 15% of HCFC baseline*
Freeze	2024	2028	-
1st step	2029 – 10%	2032 – 10%	2019 – 10%
2nd step	2035 – 30%	2037 – 20%	2024 – 40%
3rd step	2040 – 50%	2042 – 30%	2029 – 70%
4th step			2034 – 80%
Plateau	2045 – 80%	2047 – 85%	2036 – 85%

* For Belarus, Russian Federation, Kazakhstan, Tajikistan, Uzbekistan, 25% HCFC component of baseline and different initial two steps (1) 5% reduction in 2020 and (2) 35% reduction in 2025

Photo: Torgrim Asphjell, Miljødirektoratet

Source: Kigali_Amendment_Factsheet1.pdf

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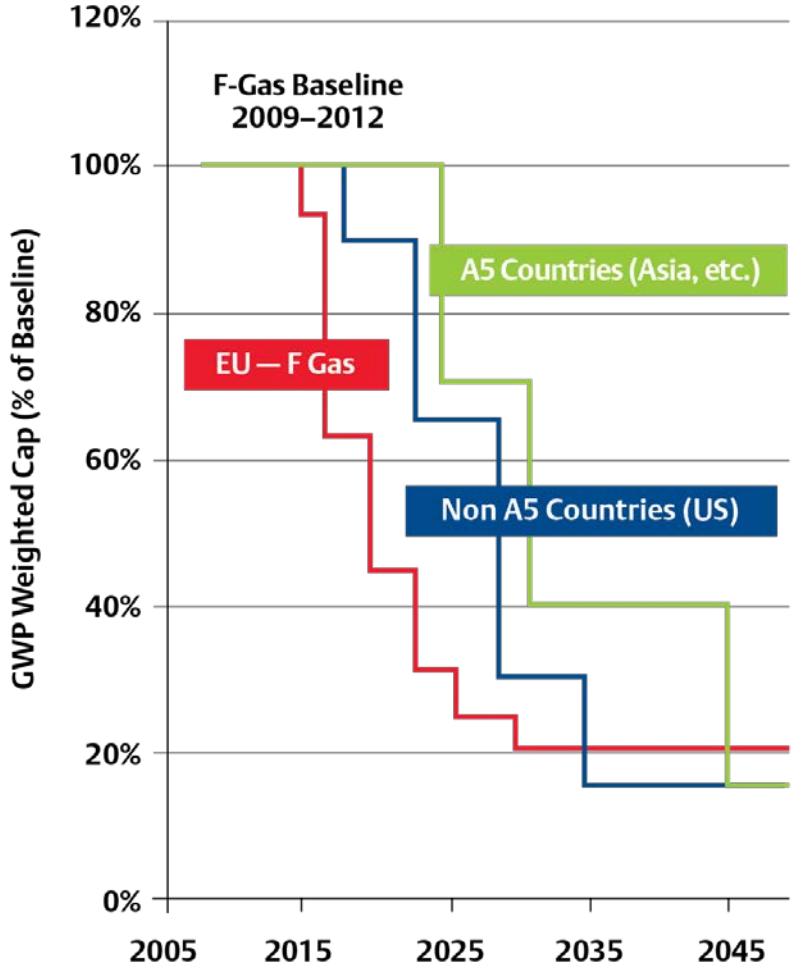
Significance of refrigerant choice: Introduction

Kigali Amendment of the Montreal protocol and **EU F gas directive (517/2014)**

REGULATION (EU) No 517/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 16 April 2014
on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006

Years	Percentage to calculate the maximum quantity of hydrofluorocarbons to be placed on the market and corresponding quotas
2015	100 %
2016–17	93 %
2018–20	63 %
2021–23	45 %
2024–26	31 %
2027–29	24 %
2030	21 %

Source: https://eur-lex.europa.eu/legal-content



Significance of refrigerant choice: Introduction

F-gas regulation in Norway

English Sámegiella

Om Miljødirektoratet | Presse | Kontakt oss

Skriv inn søkeordet her SØK

MILJØ-DIREKTORATET

TJENESTER OG VERKTØY | TEMA | AKTUELT | PUBLIKASJONER | REGELVERK | HØRINGER

Du er her: Miljødirektoratet - Forside / Tjenester og verktøy / Veileder / Forskrift om fluorholdige klimagasser

MILJØDIREKTORATET - FORSIDE

Tjenester og verktøy

Veileder

Forskrift om fluorholdige klimagasser

Relevant lovverk

Sertifisering av personell og foretak

Informasjon til kuldebransjen (inkl.

Forskrift om fluorholdige klimagasser

EUs forordning nr. 517/2014 om visse fluorholdige klimagasser, samt tilhørende underforordninger er nå implementert i produktforskriften paragraf 6a-1.

23.06.2013| Endret 05.02.2019

Veileder Forordning Forskrift

GÅ TIL LOVDATA

For å innfri Norges forpliktelse under Montrealprotokollen, er det også innført import- og eksportkontroll av HFK i bulk fra 2019 (6a-2). Vedlegget til forskriften angir nedfasingsplanen for import av HFKer i bulk.

Kategori

Veileder

Forordning

Forskrift

Relaterte lenker

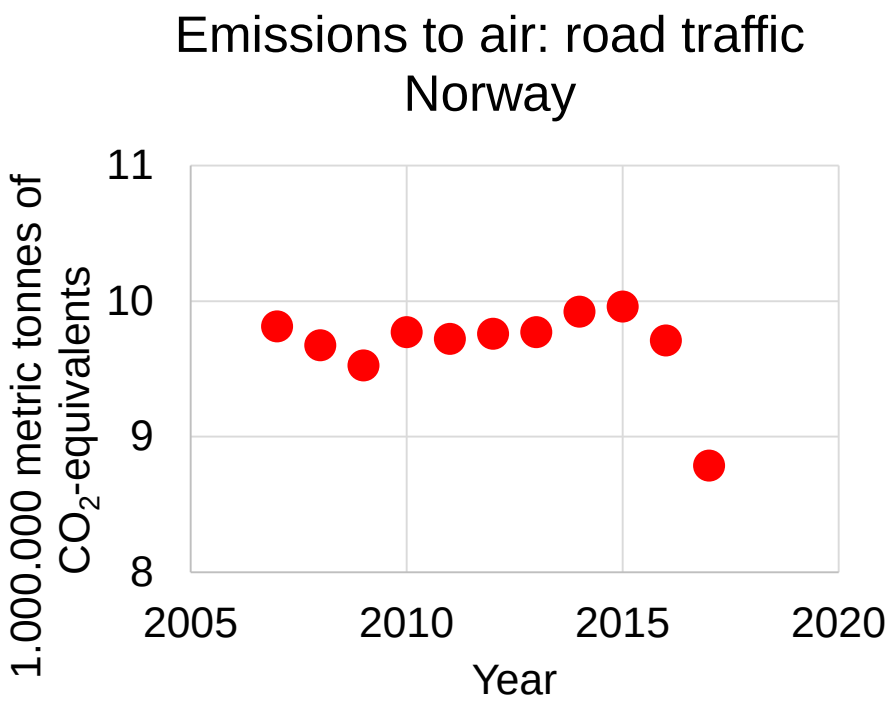
Høyring om skjerpa krav til fluorhaldige klimagassar (2016/5504)

Reguleringa av HFK-gass i kuldeanlegg vert innskjerpa

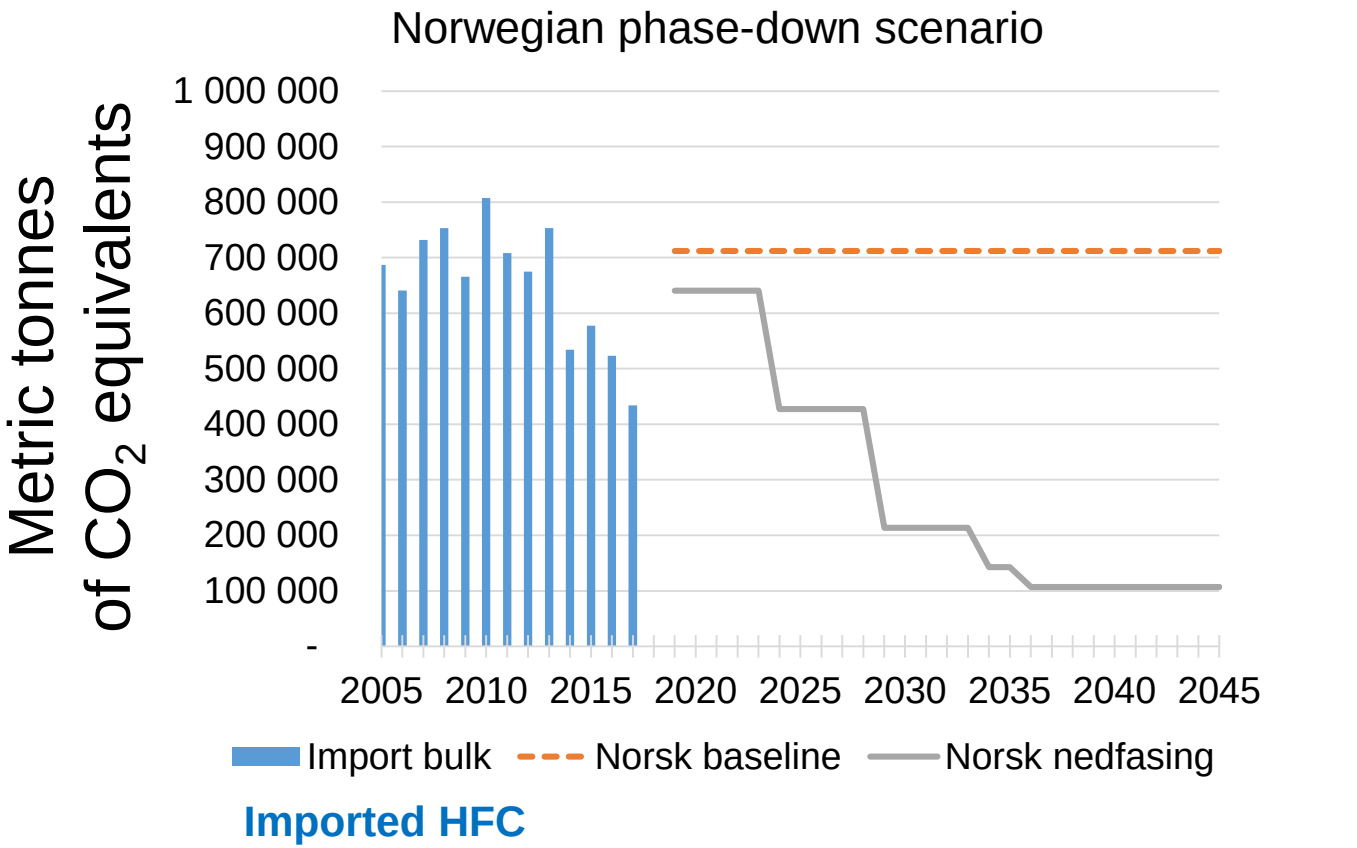
Source: http://tema.miljodirektoratet.no/no/Tjenester-og-verktoy/Veileder/EU-forordningen-om-fluorholdige-klimagasser/

NWF a smart choice: Introduction

Emissions versus quotas



Source: ssb.no



Imported HFC

Source: miljødirektoratet.no

Working fluid options

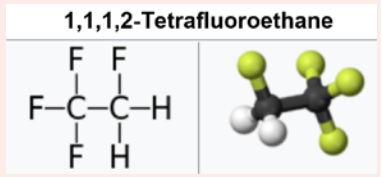
» **Business as usual** until 2020 and then usage of recycled gas until 2030;
- Availability/cost of the gas and equipment
- Future ban of service and maintenance
- Stricter leak detection and refrigerant recovery processes

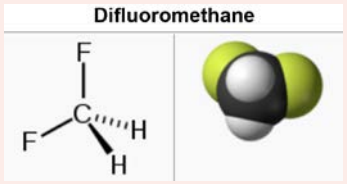
» Convert/retrofit with **new synthetic low-GWP refrigerants;**
- **Total environmental impact un-known**, future regulation?
- HSE (Health Safety Environment)
- Cost of the refrigerant?

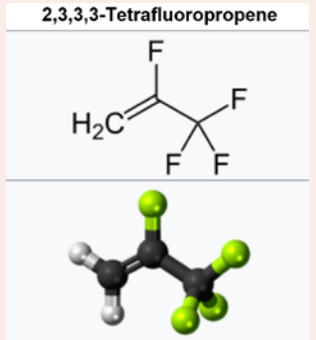
» **Natural Refrigerant** business orientation.
- **Long term solution**
- **Investment cost no longer higher than traditional HFC**

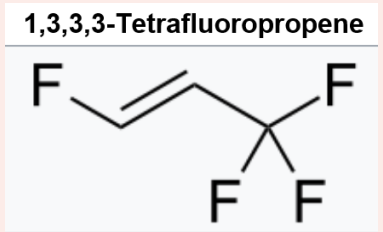
Working fluid options: HFCs

1,1,1,2-Tetra flouroethane	Blends….	Difluoro-methane	2,3,3,3-Tetra-flouropropene	1,3,3,3-Tetra-flouropropene
R134a	R410A, R404A	R32	R1234yf	R1234ze
• GWP 1430 • Industrial refrigeration • …	• GWP > 2500 • Taken from the market in Europe • New low-GWP blends are proposed on a weekly base	• GWP 675 • Split AC and HP units • …	• 11 days lifetime in atmosphere • Mobile AC systems	• Short lifetime in atmosphere • Chiller applications • …
• High GWP • next phase out candidate	• Unsecure future supply • **Energy efficiency ?**	• Intermediate refrigerant • Flammable	• Flammable • **Toxic decom-position products** • **High cost**	• Flammable • **Toxic decom-position products** • **High cost**









Working fluid options: NWFs

Hydrocarbons (Propan, Butan…)	Ammonia	Water (Steam)	Carbon dioxide CO_2	Air
R290, R600, …	R717	R718	R744	R729
• Domestic refrigeration • Split AC and HP units • Light commercial refrigeration • High temperature heat pumps • Chiller units • …	• Industrial refrigeration • Industrial heat pumps • …	• High temp-erature heat pumps • …	• Hot water heat pumps • Commercial refrigeration • Transport refrigeration • …	• Low temperature refrigeration • Transport refrigeration • …
• High energy performance • Globally available • Flammable	• High energy performance • Globally available • Applied since 130 years	• Low density • Requires very large volume flow rates	• High energy performance • Globally available	• Low density • Requires large volume flow rates, • High energy performance at low ref. temps: >-50°C

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HSE (Health Safety Environment)

R 1234yf & R 1234ze

SAFETY DATA SHEET Chemours

Opteon™ YF (R-1234yf) Refrigerant

2,3,3,3-Tetrafluoropropene

Danger

H220 Extremely flammable gas.

Hazardous combustion products

Hydrogen fluoride
Fluorine compounds
Carbon oxides

Version 8.1 Revision Date: 03/26/2019

Solstice® ZE Refrigerant (R-1234ze(E))

000000016095 Honeywell

Version 2.9 Revision Date 12.03.2019

trans-1,3,3,3-Tetrafluoroprop-1-ene

Lower explosion limit	:	No LEL and UEL was assigned at standard testing conditions, 20°C. Exhibits flame limits at temperatures in excess of 28° C.
Upper explosion limit	:	No LEL and UEL was assigned at standard testing conditions, 20°C. Exhibits flame limits at temperatures in excess of 28° C.

Fire may cause evolution of:
Hydrogen fluoride
Carbon oxides
Carbonyl halides
Halogenated compounds

HSE (Health Safety Environment)

ASHRAE-Nummer	Formel	Name	CAS-Nummer
R-1216	C3F6	Hexafluorpropen	116-15-4
R-1225ye	C3HF5	1,2,3,3,3-Pentafluorpropen	5528-43-8
R-1225zc	C3HF5	1,1,3,3,3-Pentafluorpropen	690-27-7
R-1234ye(E)	C3H2F4	1,1,2,3-Tetrafluor-2-propen	115781-19-6
R-1234ye(Z)	C3H2F4	1,1,2,3-Tetrafluor-2-propen	730993-62-1
R-1234yf	C3H2F4	2,3,3,3-Tetrafluorpropen	754-12-1
R-1234ze(E)	C3H2F4	1,3,3,3-Tetrafluorpropen	29118-24-9
R-1243zf	C3H3F3	3,3,3-Trifluorpropen	677-21-4
R-1270	C3H6	Propen (Earlier: Propylen)	115-07-1

R1234yf

~~A2L~~ => B2L


G 3191 A

Seite 457

GEMEINSAMES MINISTERIALBLATT

des Bundesministeriums für Wirtschaft und Energie / des Auswärtigen Amtes / des Bundesministeriums des Innern
des Bundesministeriums der Finanzen / des Bundesministeriums für Arbeit und Soziales
des Bundesministeriums für Ernährung und Landwirtschaft / des Bundesministeriums der Verteidigung
des Bundesministeriums für Familie, Senioren, Frauen und Jugend / des Bundesministeriums für Gesundheit
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des Bundesministeriums für Bildung und Forschung / des Bundesministeriums für Reaktorsicherheit
und Entwicklung / der Beauftragten der Bundesregierung für Kultur und Medien

HERAUSGEGEBEN VOM BUNDESMINISTERIUM DES INNERN

Nr. 24

Berlin, den 24. Juni 2016

ISSN 0939-4729

67. Jahrgang

rt.-Nr. 56396624

Substance:	2,3,3,3-Tetrafluorpropene
CAS No.:	754-12-1

	Limit value - Eight hours		Limit value - Short term	
	ppm	mg/m³	ppm	mg/m³
Germany (AGS)	200	950	400 (1)	1900 (1
Germany (DFG)	200	940	400(1)	1880 (1

	Remarks
Germany (AGS)	(1) 15 minutes average value
Germany (DFG)	(1) 15 minutes average value

This means that 2,3,3,3-Tetrafluorpropene (R1234yf) is a B2L substance

Ammonia is also classified as B2L

HF

TLV (Threshold Limit Value) = 3 ppm

IDLH (Immediately dangerous to life or health) = 30ppm

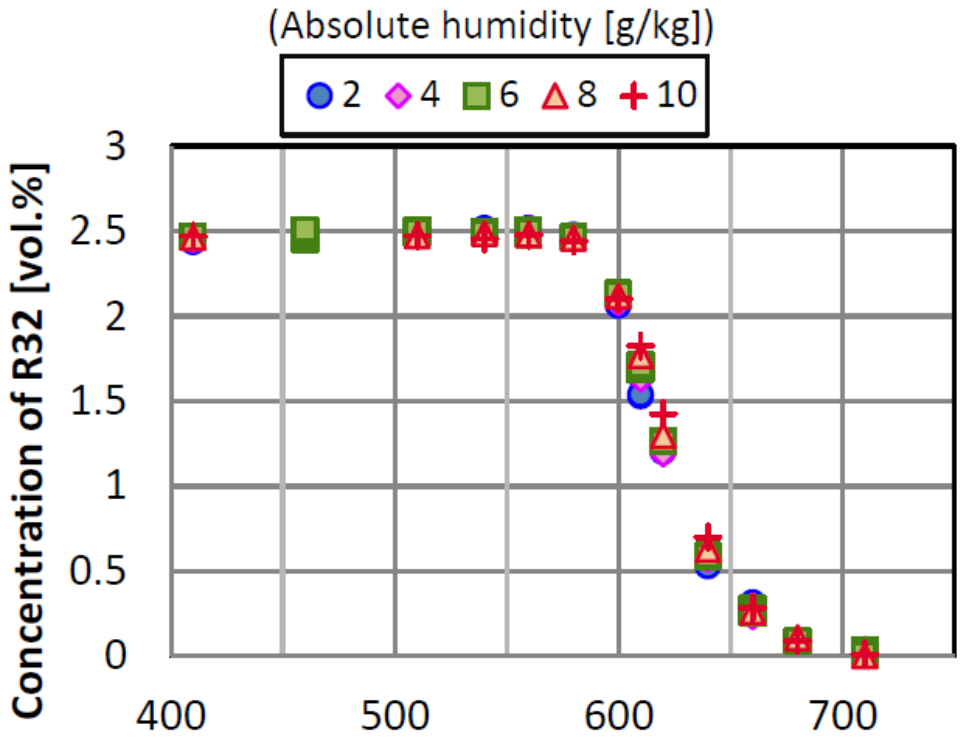

Fig. 2-38 Concentration of R32 versus heater temperature
(Total flow rate of 200 ml/min;
2.5 vol. % R32 with air; Inconel 600 tube)

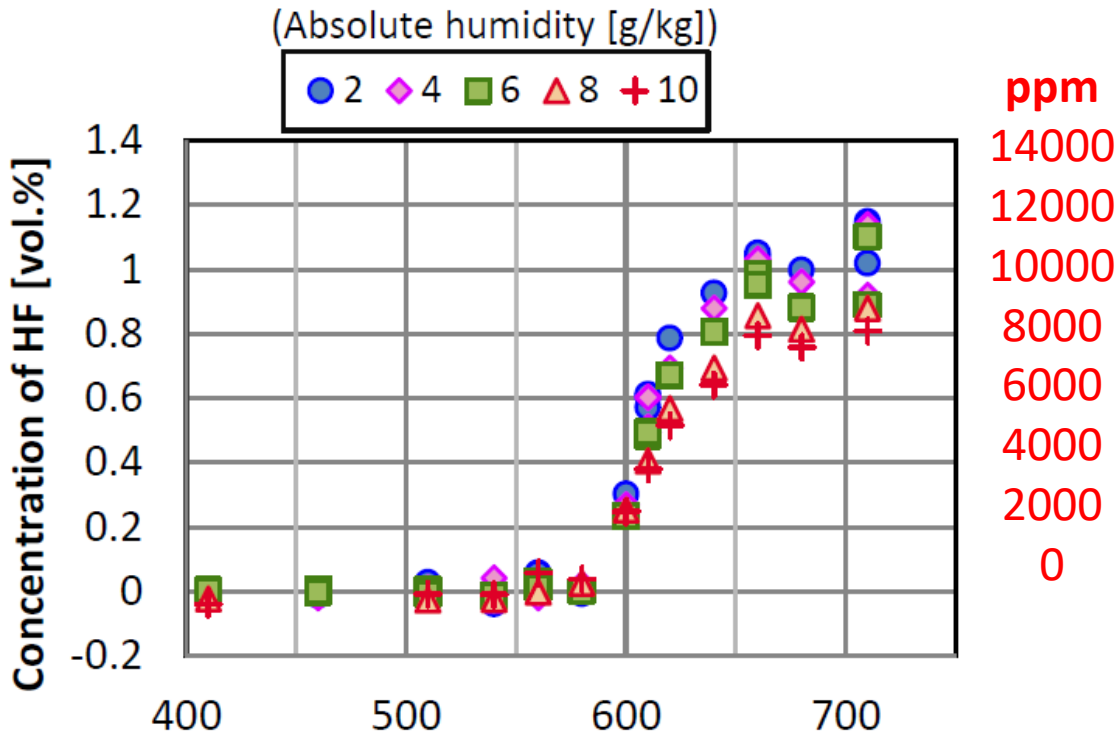

Fig. 2-39 Concentration of HF versus heater temperature
(Total flow rate of 200 ml/min;
2.5 vol. % R32 with air; Inconel 600 tube)

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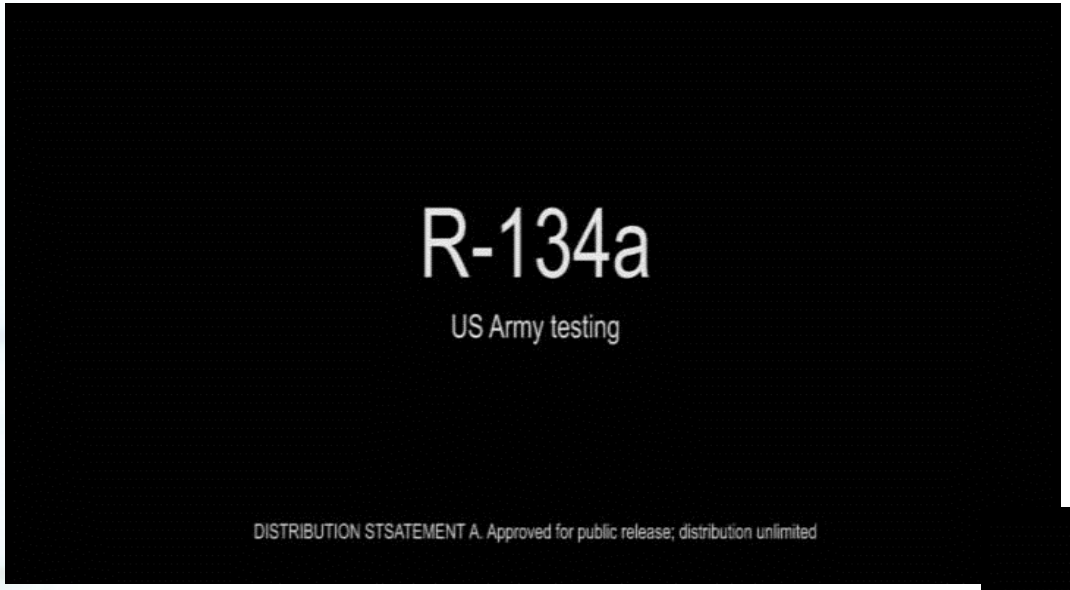
Risk Assessment of Mildly Flammable Refrigerants, JSRAE report 2016, http://www.jsrae.or.jp/committee/binensei/final_report_2016r1_en.pdf

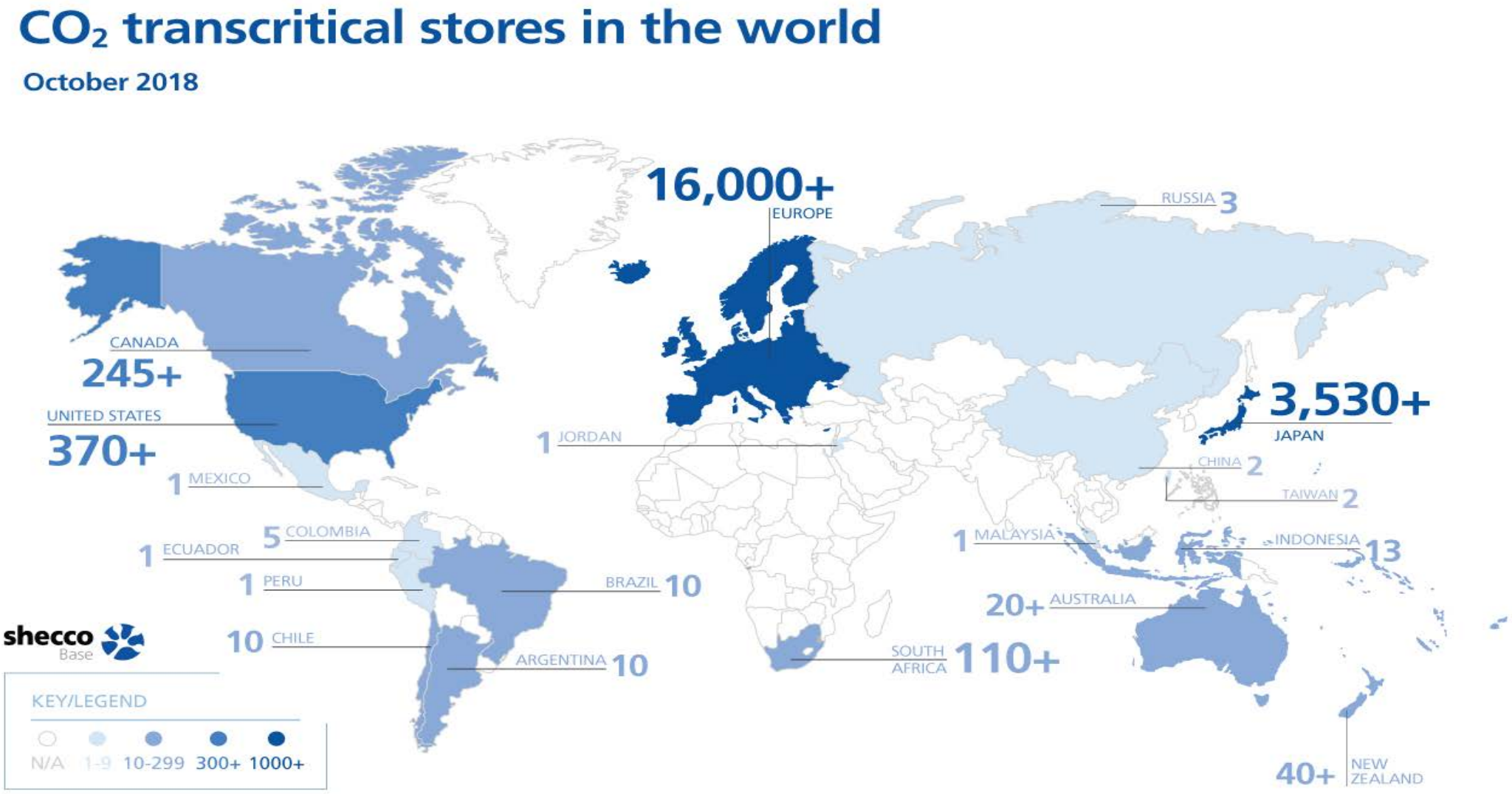
R-134a versus R-1234yf



R-1234yf:
Now applied in MAC

R-134a:
High GWP
Previously applied in MAC

Energy Efficiency – Example: Commercial refrigeration



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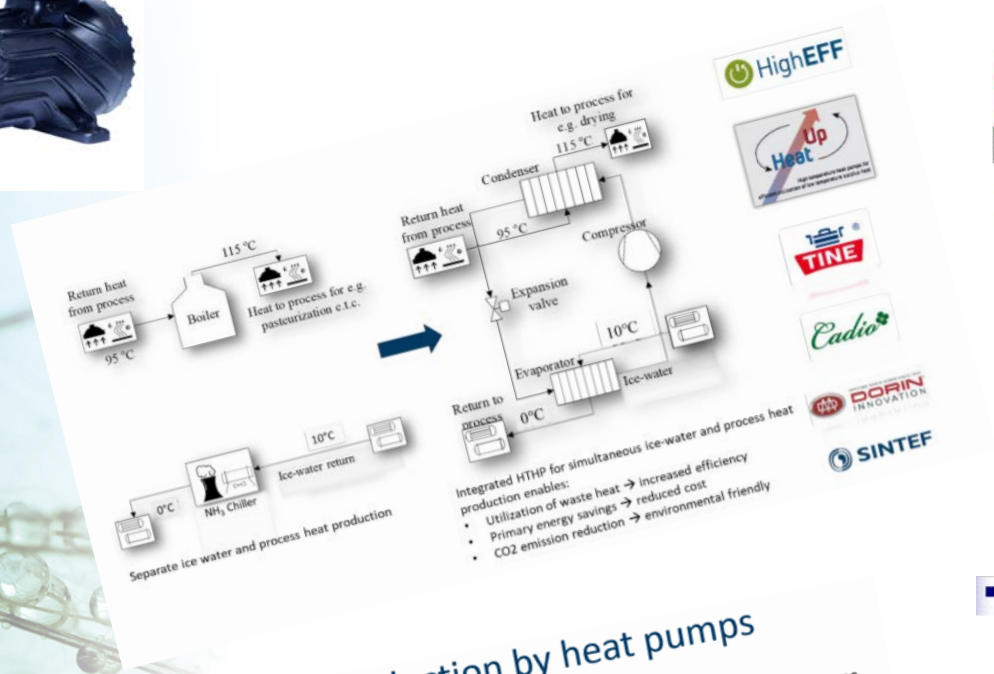
Example CO_2 commercial refrigeration

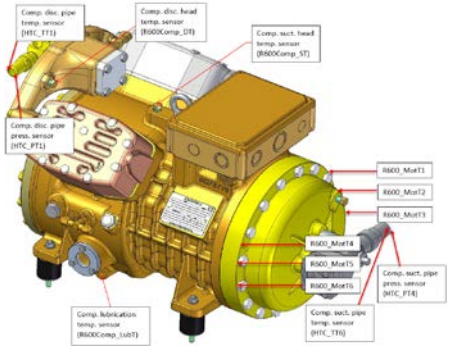
https://www.unido.org/news/climate-friendly-supermarket-refrigeration-installed-jordan

Feedback from the vendor:

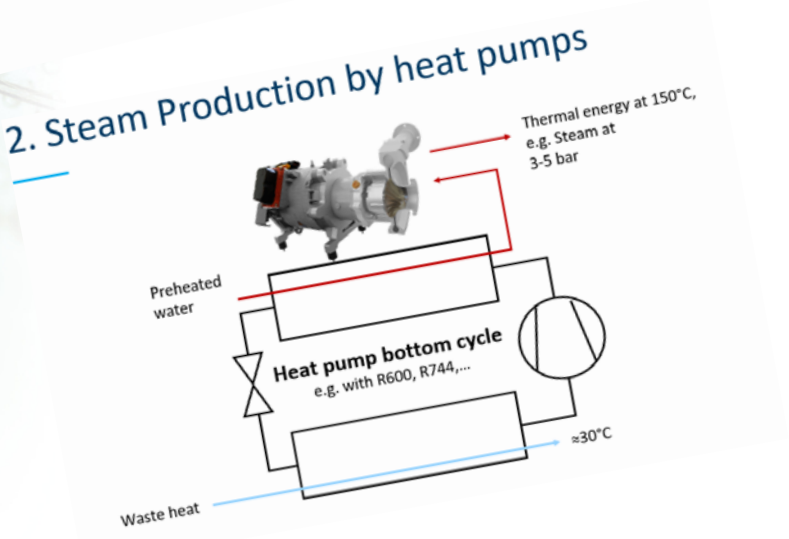
- After 12 months: Zero maintenance visit.
- **Energy demand reduced by more than 30%** compare with the same standard (& age) HFC system.
- Our customer has inform us that since we have installed the CO_2 System in his store he has **zero food wastage** due the stable temperature in the cabinets and **no failure in the system or cabinets**.

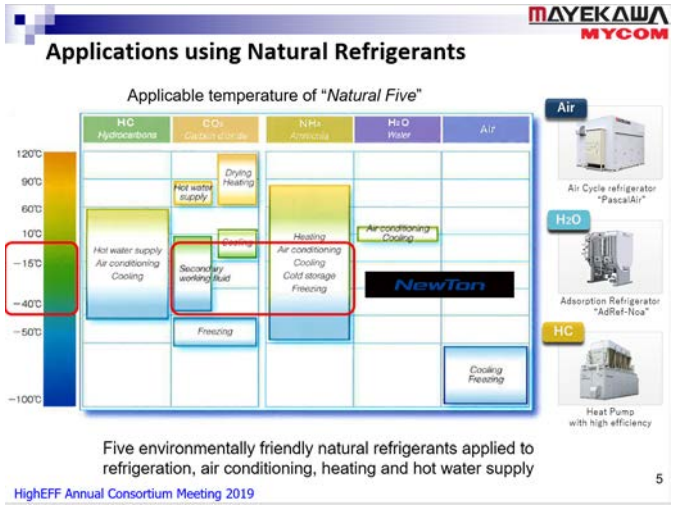
Examples of utilizing NWF within HighEFF





OFFICINE MARIO DORIN SINCE 1918
DORIN INNOVATION





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NWF a smart choice: Summary

Natural working fluids are:

- future proof **global alternative refrigerants**
- **Energy efficient replacements** for synthetic fluids **with significant environmental impacts**
- **safe investments** when applied in refrigeration & heat pumping equipment

Take home massage:

When you order your next refrigeration / heat pumping units:

- Specify the Refrigerant: → Natural working fluid.
  - Not only low GWP fluid

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Questions are welcome!

Q & A