Greener Reefers - introducing climate and environmentally friendly maritime cooling containers

OZONE COOL ZONE

30 Nov–12 Dec
COP28 UAE

Side Event
Sunday, 10th of December 2023, 2:00 - 3:00 pm (GST/UTC+4)
Ozone to Cool Zone (Montreal Protocol Pavilion)

german cooperation
DEUTSCHE ZUSAMMENARBEIT

The Federal Government

IKI INTERNATIONAL CLIMATE INITIATIVE

Implemented by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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Sunday, 10th December 2023, 2:00 pm – 3:00 pm (GST/UTC+4) | Ozone to Cool Zone (Montreal Protocol Pavilion)

Opening (5')	Philipp Denzinger, GIZ Proklima
Environmental impact and mitigation potential of greener reefers (10')	Philipp Denzinger, GIZ Proklima
How to transition to sustainable reefers (10')	Otto Schacht, Kühne Foundation
Energy efficient and climate friendly refrigeration systems (10')	Kristina Norne Widell, SINTEF
Q & A (10´)	Everyone

Our Speakers

Moderator: Philipp Denzinger, GIZ Proklima

Philipp Denzinger

GIZ Proklima

Otto Schacht

Kühne Foundation

Kristina Norne Widell

SINTEF

Environmental impact and mitigation potential of greener reefers

Philipp Denzinger, GIZ Proklima

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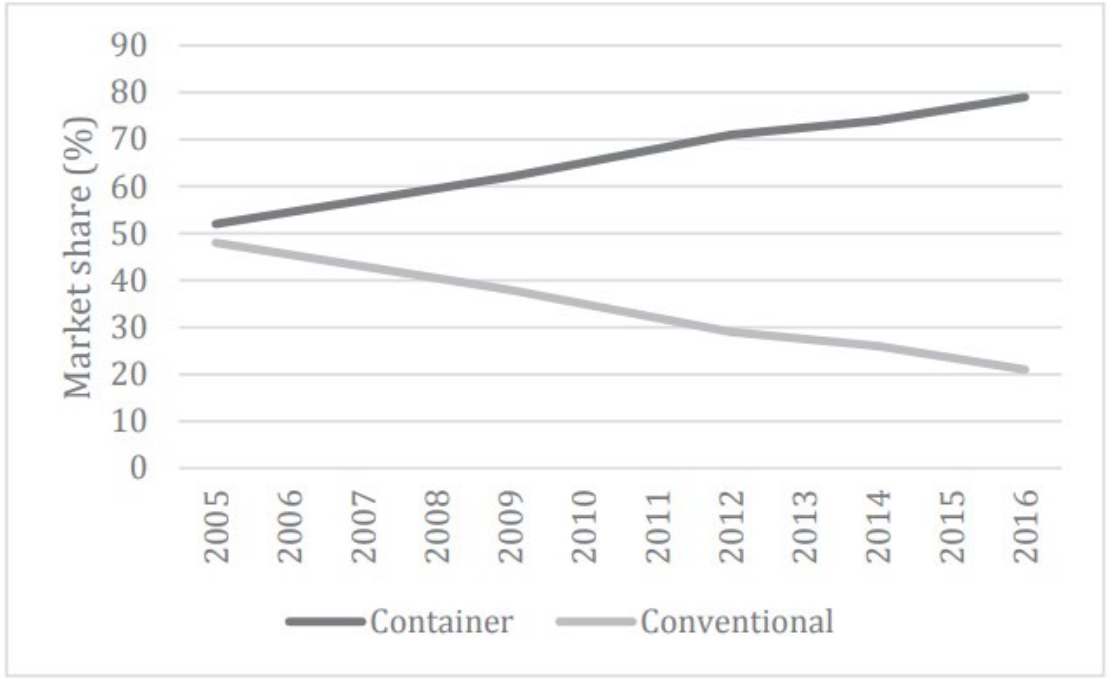
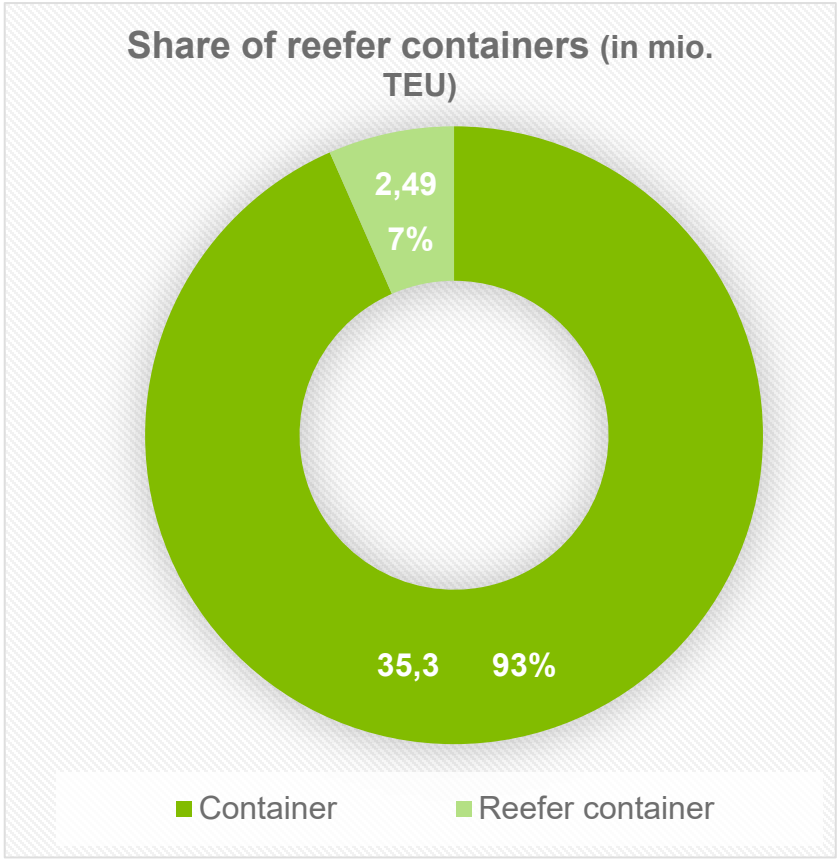
Background: Refrigerated Containers *Reefers*

- 2.49 million reefers in 2018 with a growth rate between 7,5% to 13% up to 2030.
- Market share of reefer containers vs reefer ships has increased steadily to 80% and it is expected to keep growing.





Sources: International Maritime Organization, 2022: Fourth IMO GHG Study 2020 Executive Summary & World Shipping Council, 2020

Sources: IMO, “Fourth IMO Greenhouse Gas study”, 2020.
E. Złoczowska, “Maritime Containers Refrigeration Plant Faults Survey”, 2018.
B. Castelein, H. Geerlings, and R. Van Duin, “The reefer container market and academic research: A review study,” 2020.
L. J. S. Lukasse et al., “Perspectives on the evolution of reefer containers for transporting fresh produce”, 2023.

Background: GHG emissions from container vessels

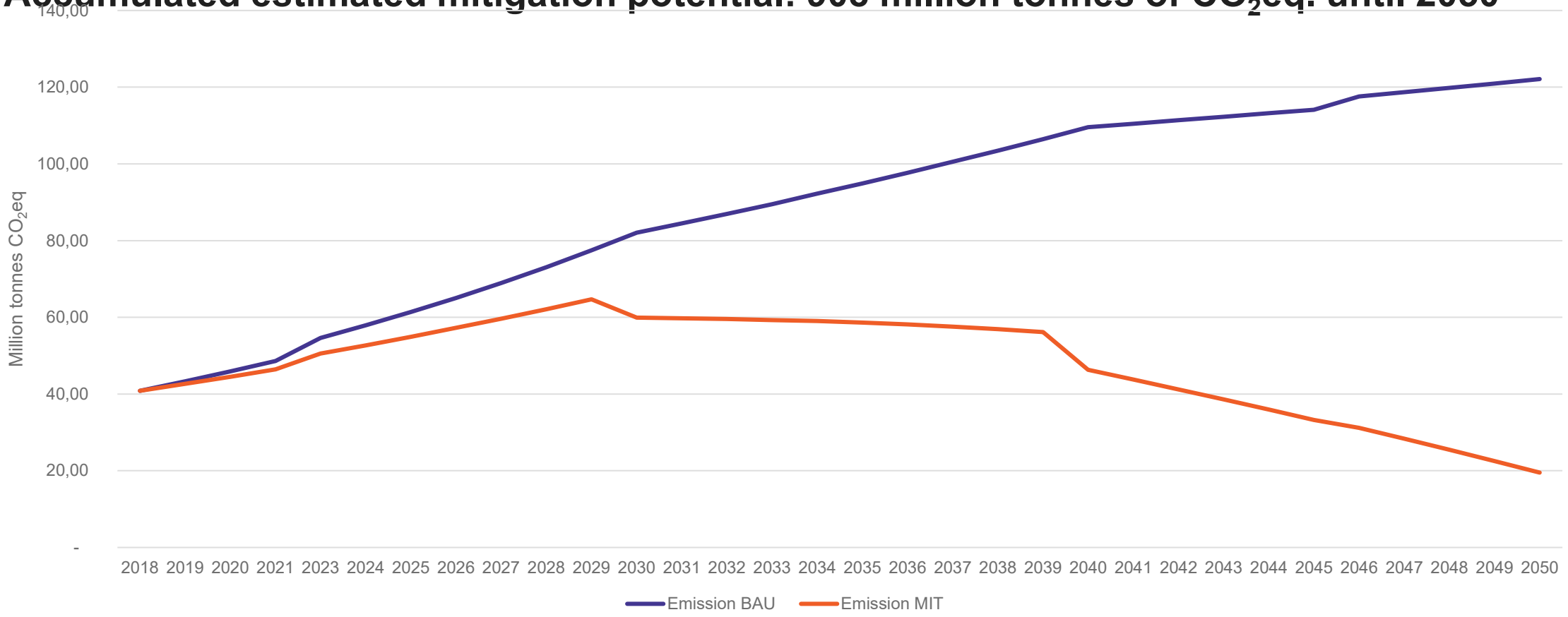
Size category	Unit	Number of vessels			Avg. DWT (tonnes)	Avg. main engine power (kW)	Avg. design speed (kn)	Avg. days at sea*	Avg. days international*	Avg. days in SECA*	Avg. SOG at sea* (kn)	Avg. distance sailed* (nm)	Median AER	Avg. consumption (kt)*			Total GHG emissions (in million tonnes CO_2e)	Total CO_2 emissions (in million tonnes)
		Type 1 and 2	Type 3	Type 4										Main	Aux.	Boiler		
0-999	teu	861	165	1	8,438	5,077	16.0	196	163	43	11.8	55,998	23.9	2.6	0.7	0.4	10.2	10.0
1000-1999	teu	1,271	0	0	19,051	12,083	19.0	210	270	30	13.4	68,141	17.2	5.1	1.5	0.4	28.5	28.0
2000-2999	teu	668	0	0	34,894	20,630	21.1	220	275	24	14.2	75,381	11.4	7.9	1.5	0.6	21.2	20.9
3000-4999	teu	815	0	0	52,372	34,559	23.1	246	271	29	14.7	87,456	10.3	12.7	2.4	0.5	40.1	39.4
5000-7999	teu	561	0	0	74,661	52,566	24.6	258	280	39	15.7	97,500	9.8	20.3	2.4	0.5	41.3	40.7
8000-11999	teu	623	0	0	110,782	57,901	23.9	261	301	38	16.3	102,600	8.3	26.4	2.9	0.5	58.8	57.9
12000-14499	teu	227	0	0	149,023	61,231	23.8	246	297	33	16.3	96,501	6.8	27.2	3.3	0.6	22.3	22.0
14500-19999	teu	101	0	0	179,871	60,202	20.2	250	309	51	16.5	99,770	5.4	26.7	3.7	0.6	9.9	9.7
20000-+	teu	44	0	0	195,615	60,210	20.3	210	292	43	16.3	82,534	5.3	21.0	3.6	0.9	3.5	3.5

Total annual emissions: 236 million tonnes of CO_2eq. in 2018

IMO, “Fourth IMO Greenhouse Gas study”, 2020.

Estimated indirect Reefer emissions (BAU) & mitigation potential (MIT)

Annual estimated indirect emissions in 2018: 41 million tonnes of CO_2eq.
Estimated BAU scenario (including small energy efficiency improvements)
Accumulated estimated mitigation potential: 908 million tonnes of CO_2eq. until 2050



Sources: IMO, “Fourth IMO Greenhouse Gas study”, 2020.
A. K. Vuppaladadiyam et al., “Progress in the development and use of refrigerants and unintended environmental consequences”, 2022.
E. Złoczowska, “ASSESSMENT OF THE ENVIRONMENTAL IMPACT OF REFRIGERATED CONTAINERS TRANSPORTED BY SEA”, 2018.
UNEP, “The Potential to Improve the Energy Efficiency of Refrigeration, Air Conditioning, and Heat Pumps”, 2018.

Direct emissions from Reefers

- Refrigerant emissions have been increasing in recent years
- Mainly due to an increase in number of reefer containers
- According to IMO (2020) in 2018 direct emissions of reefers are 4 million tonnes of of CO_2eq. (AR4)
- Direct emissions according to AR6 GWP values, would be 4.86 million tonnes of CO_2eq.

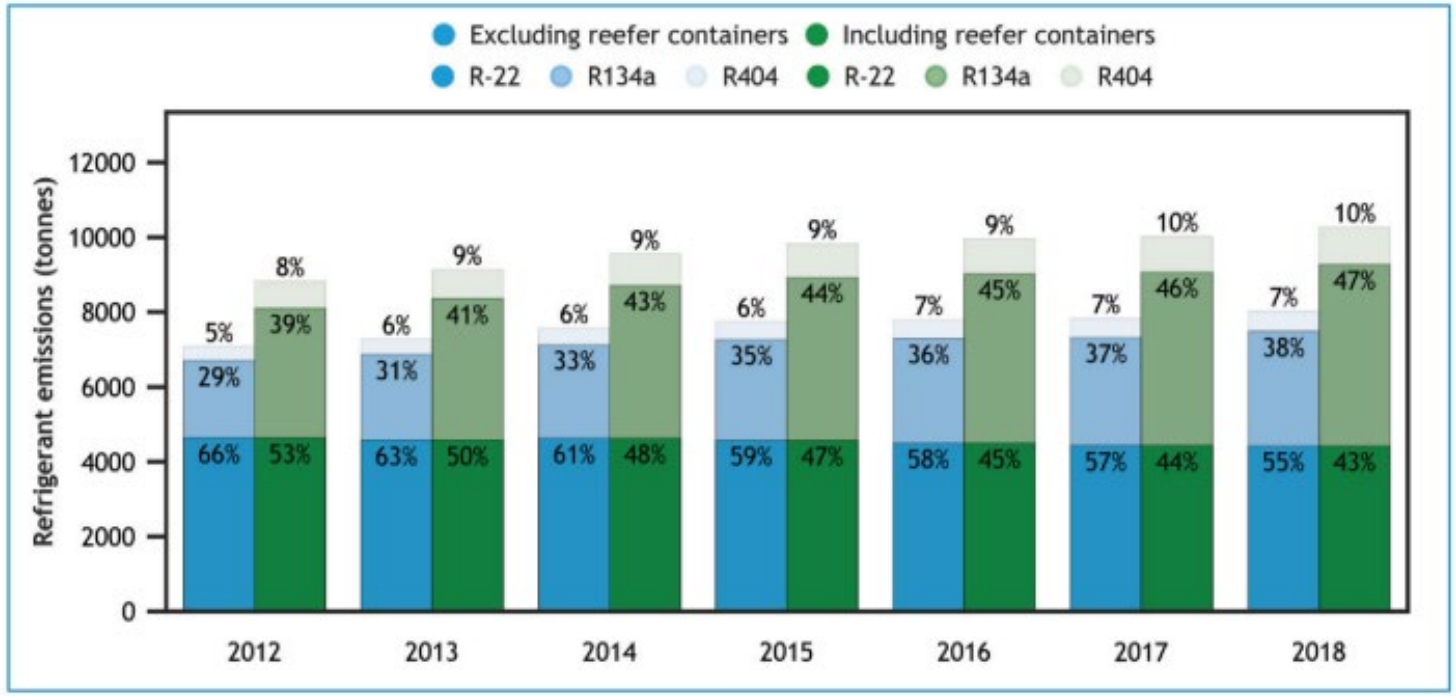


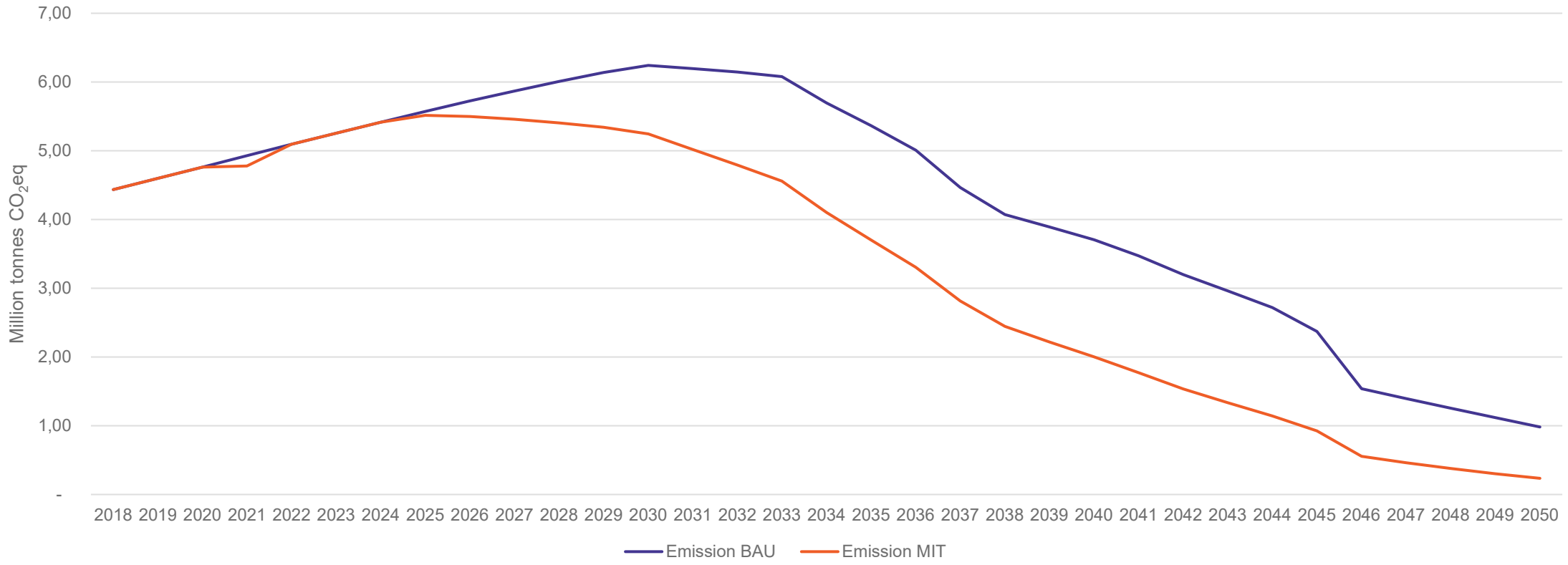
Figure 60 – *Estimated refrigerant emissions of the global fleet, showing both totals when including and excluding reefer containers*

Source: International Maritime Organization, 2022: Fourth IMO GHG Study 2020 Full Report, p82

Sources: IMO, "Fourth IMO Greenhouse Gas study", 2020.
A. K. Vuppaladadiyam et al., "Progress in the development and use of refrigerants and unintended environmental consequences", 2022.
E. Złoczowska, "ASSESSMENT OF THE ENVIRONMENTAL IMPACT OF REFRIGERATED CONTAINERS TRANSPORTED BY SEA", 2018.
UNEP, "The Potential to Improve the Energy Efficiency of Refrigeration, Air Conditioning, and Heat Pumps", 2018.

Estimated direct Reefer emissions (BAU) & mitigation potential (MIT)

Annual estimated direct emissions in 2018: 4.8 million tonnes of CO_2eq
Estimated BAU scenario: including low GWP HFCs and HFOs (
Accumulated estimated mitigation potential: 32 million tonnes of CO_2eq until 2050 (moving gradually to natural refrigerants)



Sources: IMO, “Fourth IMO Greenhouse Gas study”, 2020.
A. K. Vuppaladadiyam et al., “Progress in the development and use of refrigerants and unintended environmental consequences”, 2022.
E. Złoczowska, “ASSESSMENT OF THE ENVIRONMENTAL IMPACT OF REFRIGERATED CONTAINERS TRANSPORTED BY SEA”, 2018.
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Background: Refrigerants available for potential use in Reefers

Refrigerant	Type	Alternative for	GWP 20	GWP 100	PFAS	TFA
R23	HFC		12400	14600	No	No
R404A	HFC blend		7208	4728	Yes	Up to 20% R134a (4%), up to 10% R143a (52%)
R452A	HFC/HFO blend	R404A	4303	2292	Yes	Up to 100% R1234yf (30%)
R473A	HFC/HFO/CO_2 blend	R23	1915	1835	Yes (R125)	No
R134a	HFC		4140	1530	Yes	Up to 20% R134a (100%)
R32	HFC		2690	771	No	No
R513A	HFC/HFO blend	R134a	1823	673	Yes	Up to 20% R134a (44%), up to 100% R1234yf (56%)
R454A	HFC/HFO blend	R404A	1037	270	Yes	Up to 100% R1234yf (65%)
R1234yf	HFO	R134a / R513A	1.81	0.501	Yes	Up to R1234yf (100%)
R744	Natural (CO_2)		1	1	No	No
R290	Natural (Propane)		0.072	0.02	No	No

Per- and polyfluoroalkyl substances (PFAS) are a large class of synthetic chemicals that increasingly detected as environmental pollutants and linked to negative effects on human health. **Trifluoroacetic acid (TFA)** is an ultra short chain type of PFAS, commonly found in the breakdown of f-gases.

Sources: IPCC, 2021: 6th Assessment Report of the IPCC (Table 7.SM.7).
Behringer, D. et al. 2021: Persistent degradation products of halogenated refrigerants and blowing agents in the environment, Final report.
Certain HFCs and HFOs Are in PFAS Group that Five EU Countries Intend to Restrict - R744

Background: Political Context for *Reefers* Today

Kigali Amendment

- The **Kigali Amendment** under the Montreal Protocol phases down HFCs (e.g., R-134a, R-404A, R-32) on a global scale up to 2047.

UNFCCC process

- **Paris Agreement: Global temperature to limit the increase to 1.5 °C**
- Establishment of the **National Determined Contributions**
- **COP 28: Cooling Pledge**

IMO Strategy 2023

- Reduction of the total annual GHG emissions from international shipping by **20%-30% by 2030**
- By **70%-80% by 2040** compared to 2008.
- **Net zero** by or around **2050**

EU F Gas Regulation and REACH

- **Limiting the total amount** of F-gases (HFCs) that can be sold
- **Banning the use of F-gases** for reefers from 2029 onwards (tbc)
- **Proposal for restriction on PFAS under REACH**

Sources:
The Kigali Amendment (2016): The amendment to the Montreal Protocol agreed by the Twenty-Eighth Meeting of the Parties
2023 IMO Strategy on Reduction of GHG Emissions from Ships
The Paris Agreement | UNFCCC
EU legislation to control F-gases (europa.eu)

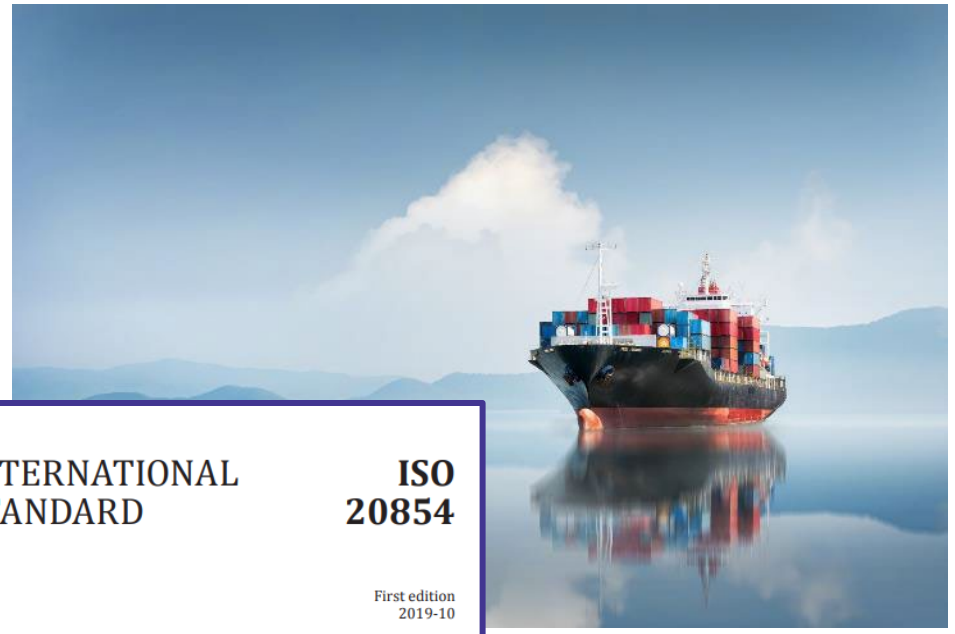
Definition of Greener Reefers

Greener Reefers are highly energy efficient refrigerated maritime containers that use **natural refrigerants** and blowing agents with ultra-low climate impact with **less than 11 GWP** value and do not contain f-gases and are **PFAS-free.**

Reefer containers. © GIZ Proklima

Natural refrigerants are the future

- **Only two natural options exist that fulfil the sustainable criteria of Greener Reefers:**
  - CO2 (already exists)
  - R290 (requires demonstration)
- R290 shows excellent thermodynamic properties (high critical temperature, low freezing temperature, high thermal conductivity, and low viscosity)
- R290 provides excellent energy efficiency at mid temperature applications (~0°C) and low temperature (~-20°C)
- Risks of R290 when used in marine container environment is higher from when used on land
- R290 is flammable and therefore requires risk mitigation measures (higher costs) and certified technicians. However, an ISO 20854 (2019) safety standard already exists
- Relevant regulations (IMO) also need to be aligned to use R290 on ships



Source Microsoft Picture


INTERNATIONAL STANDARD

ISO 20854

First edition
2019-10

Thermal containers — Safety standard for refrigerating systems using flammable refrigerants — Requirements for design and operation

Sources: S. Minetto, F. Fabris, C. Маринетти, and A. Rossetti, “A review on present and forthcoming opportunities with natural working fluids in transport refrigeration”, 2023.
A. K. Vuppaladadiyam et al., “Progress in the development and use of refrigerants and unintended environmental consequences”, 2022.

Greener Reefers Project

Comissioned by

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

based on a decision of the German Bundestag

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PROKLIMA NATURALLY COOL

Project Duration April 2023 until April 2026

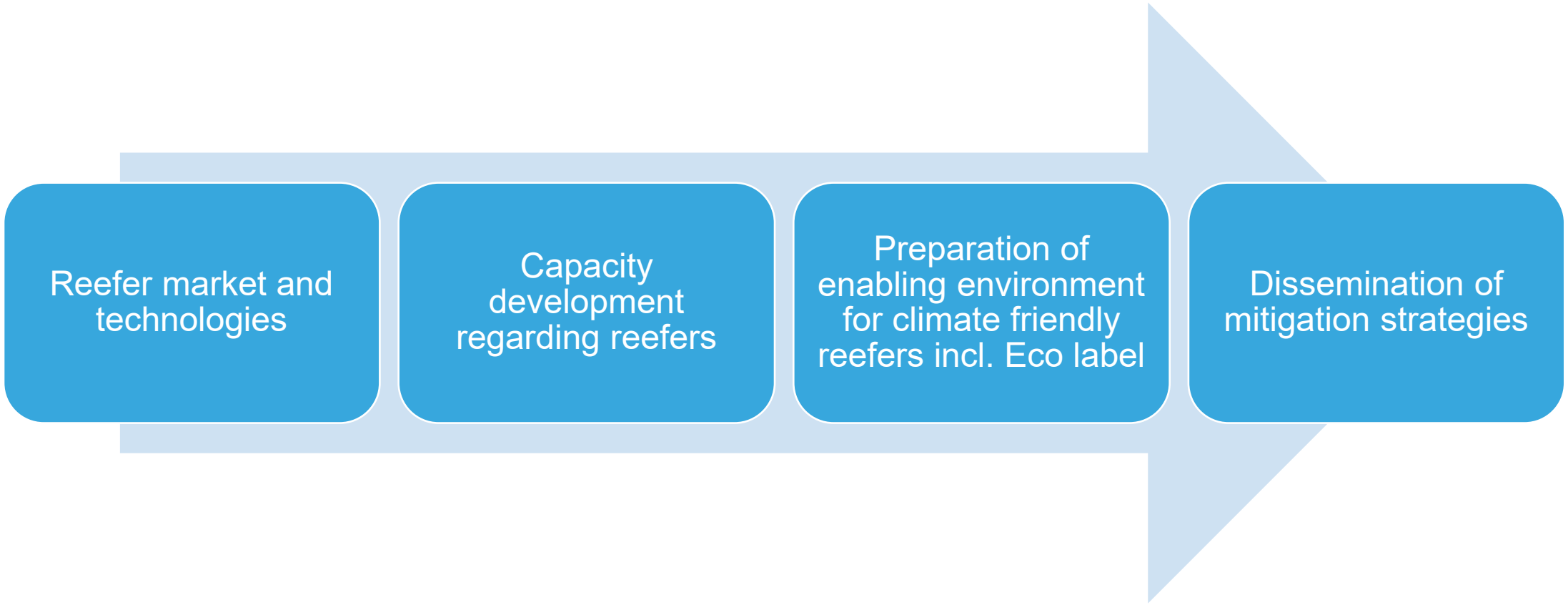
Project Budget EUR 2.900.000

Source Microsoft Picture

Greener Reefers Project

- **Stakeholders:**
  - Maritime organisations addressing climate change
  - Shipping industry: container manufactures, shipping lines, port terminals
  - Research institutions
  - Training institutions
  - Representatives of IMO, Montreal Protocol, UNFCCC
- **Partner countries:**
  - Costa Rica (Ministry of Environment and Energy, Ministry of Public Education, National Institute for Learning)
  - South Africa (Department of Forestry, Fisheries and the Environment)

Outputs of the Greener Reefers Project



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Do you want to be part or support the Greener Reefers Project?

If so please contact us!

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www.green-cooling-initiative.org

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How to transition to sustainable reefers

Otto Schacht, Kühne Foundation

How to catalyze the transition to sustainable reefers?

- **Wholistic perspective**
  - Refrigerants
  - Box design
  - Temperature protocols
  - Load factors

- **Cost** – but “costs” need to be put into broader perspective (cost per unit cargo, cost to consumer, relative to other climate costs)

- **Communication**
  - Do cargo owners know about high GWP of current refrigerants?
  - Do they know about the “forever chemicals”?
  - Be transparent

Source MSC

How to catalyze the transition to sustainable reefers?

- **Broad Alliance**
  - Manufacturers, logistics service providers, shipping lines
  - + Cargo owners, consumers
  - + Certification bodies
  - + Training agencies

- **Take care of the secondary effects**
  - Recycling of containers (techniques, business models etc.)
  - End of life management of refrigerants

Looking ahead to the low carbon society of 2050

- **Reefer demand in a changing climate?**
  - More extreme temperatures
  - Longer seasons
- **Mode shift from high carbon aviation?**
- **Different trade flows**
  - More trade in low carbon products
  - Different routes

….the low carbon society of 2050 will be very different from that of today – **get ready** - its only 26 years away

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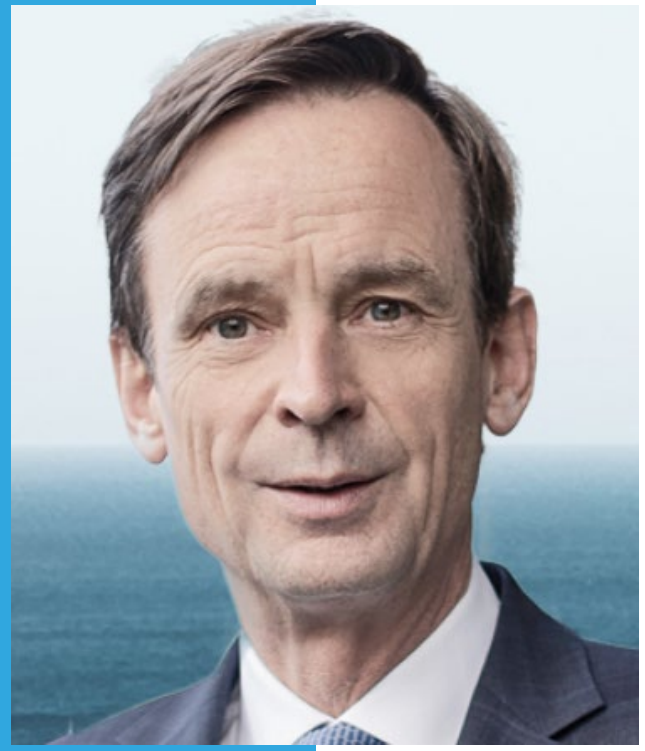

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KÜHNE-STIFTUNG

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Energy efficient and climate friendly refrigeration systems

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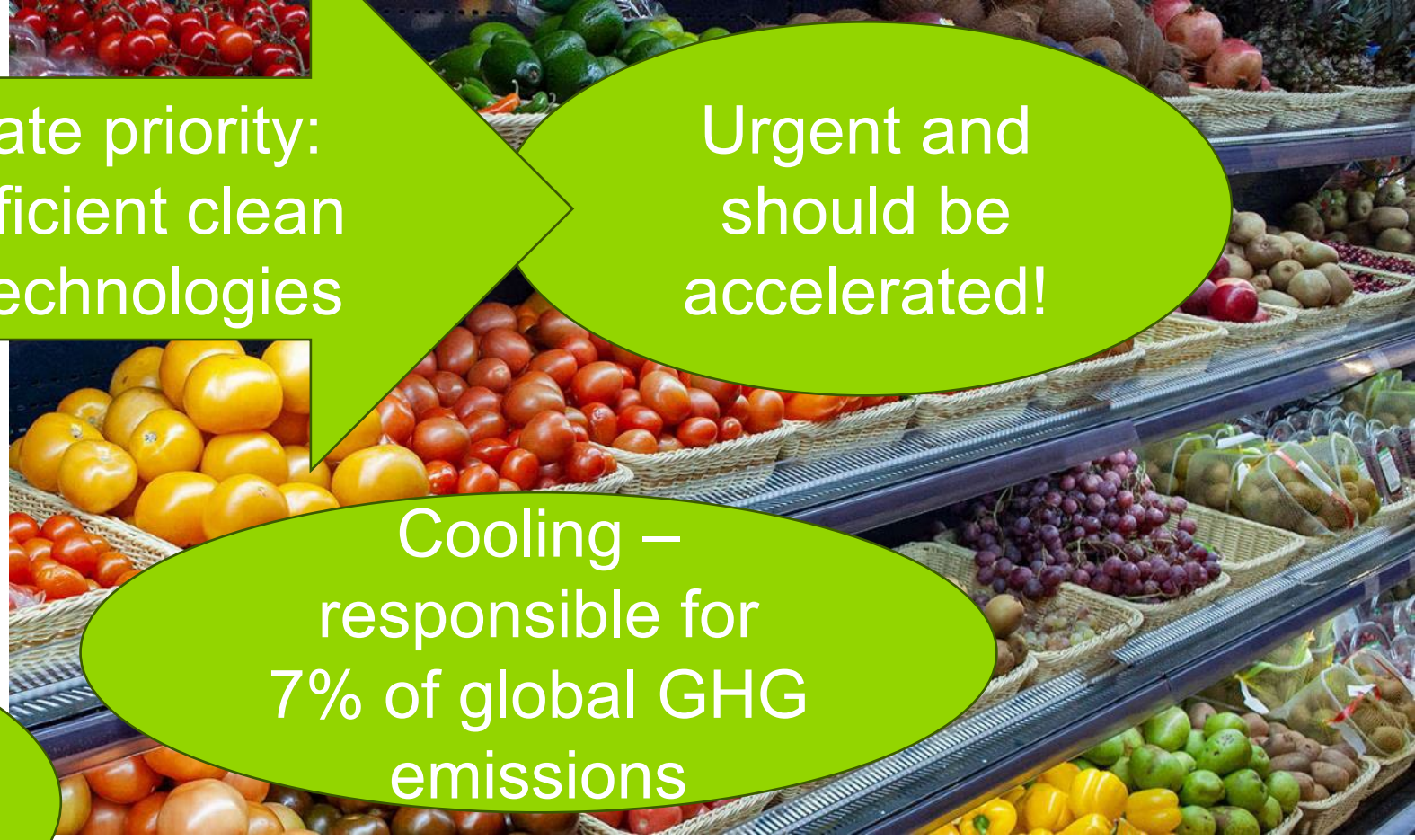
Kristina N. Widell

Senior Researcher, SINTEF Ocean

Energy efficient and climate friendly refrigeration systems



UN climate priority: Highly efficient clean cooling technologies

Urgent and should be accelerated!

Cooling – responsible for 7% of global GHG emissions

1/3 of food produced is lost

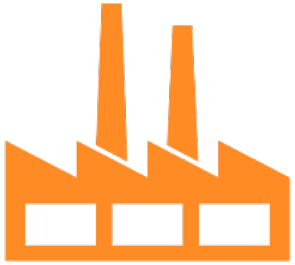
1/3 of total GHG emissions related to food systems

Food cold chain

60% of all food

Refrigeration systems necessary

Processing



Transport

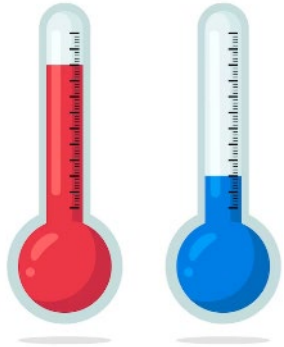
Storage

Transport

Short distance - last mile

Retail

Domestic



- Keep product quality high
- Efficient use of resources
- Low emissions

3 degree report

1/3 of food produced is lost

- Freezing of food
  - Extend storage life
  - Maintain nutritional quality and prevent deterioration
  - Optimise utilisation (scheduled consumption and reduce food waste)

Processing and packaging

Refrigeration reefer containers:
50% cooling
50% freezing

3 degree report

3 °C

- Changing from -18°C to -15°C for frozen storage
  - Reducing energy demand
    - 2-3% per 1 °C
    - Industry case: up to 10%
  - Reducing carbon emissions
    - Equivalent to carbon emitted by nearly 4 million cars/yr.
    - Reefers: propulsion system (fossil fuel)

How should we do this?

- Keep product quality high
- Efficient use of resources
- Low emissions

Refrigerants

Safety

Energy efficiency

Energy demand

Refrigerants: when do we have a problem?

- Refrigerants leaking
  - Production
  - Filling, servicing
  - Components malfunctioning
  - End-of-life-treatment

Solution:

Natural Refrigerants

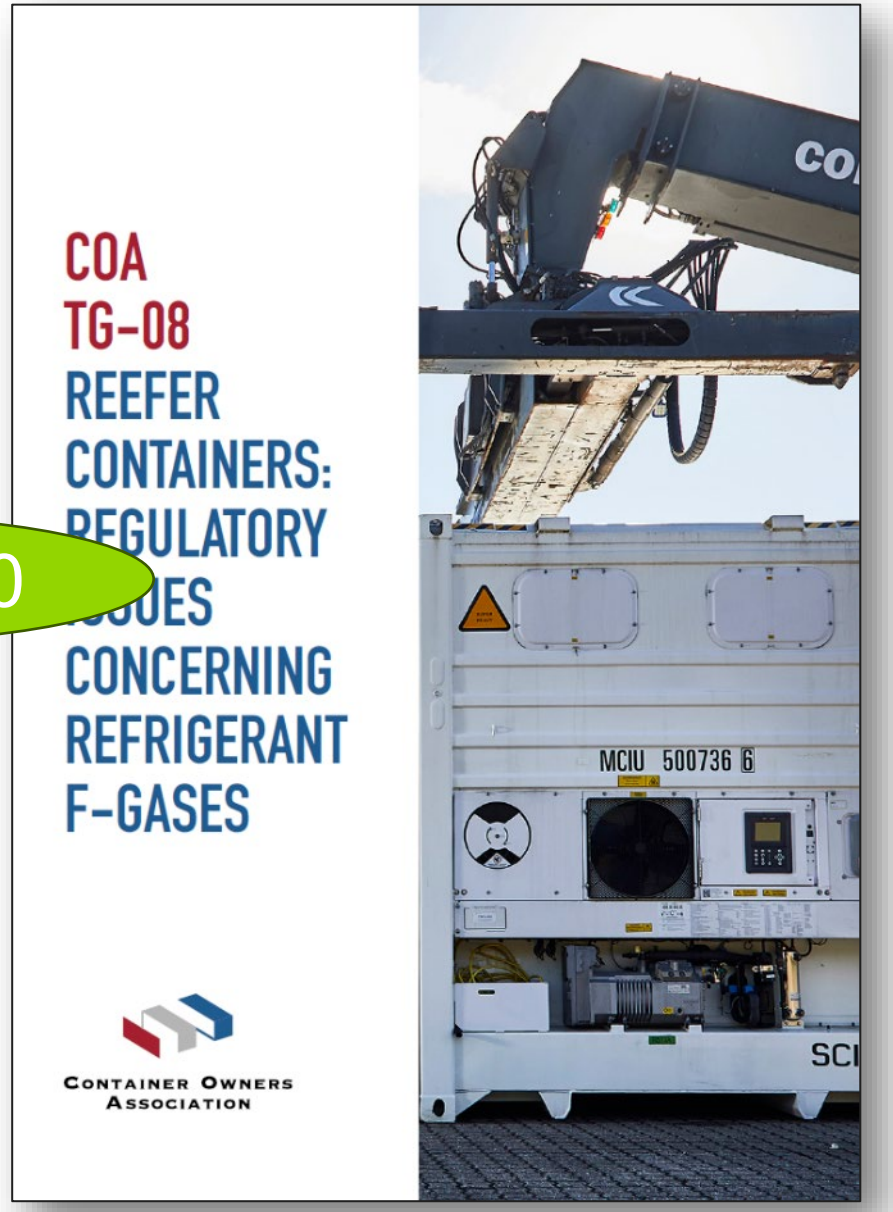
- ODP: Ozone depletion potential (R22)
- GWP: Global warming potential (R134a)
- PFAS: Environmental and health risks («HFOs»)

No unexpected surprises (€ £ $...)

Reefers

- Information supplied by the COA Reefer Forum Work Group
- Overview of current and proposed regulations that restrict the use of refrigerant F-Gases and the consequential issues
- R134a is used in 96% of the existing reefer container fleet
- No immediately available alternative refrigerant that meets all the required operational criteria

GWP=1430



Reefers

- Regulation of F-gas refrigerants – overview
  - EU regulation, IMO resolution, REACH etc
- Reefer container global fleet & operating criteria
  - Global shipments of perishable refrigerated cargo were 307 million tonnes in 2022
  - The operating life of a marine reefer container is 18 years.
  - Operate in ambient temperatures varying from -30 °C to +50 °C
- Refrigerant options
  - R1234yf
  - R744 / CO_2
  - R290 / Propane

How should we do this?

- Keep product quality high
- Efficient use of resources
- Low emissions

Refrigerants Safety Energy efficiency

Safety: important messages

- Following standards, guidelines and codes of good practice has reduced the number of accidents
- Some accidents happen when technicians are not properly trained and informed

How should we do this?

- Keep product quality high
- Efficient use of resources
- Low emissions

Refrigerants Safety Energy efficiency

Energy efficiency: why so important?

- Energy savings
  - Reduction in energy demand: spend less to get the same result
- Lower environmental impact
  - Reduction in greenhouse gases and other pollutants
- Energy security
  - Less dependency on imported energy

- Reduced energy costs
  - Increased economy competitiveness and job creation

Summary

R&D Collaboration

- **Food is essential: Food cold chain**
- **Refrigerants: Natural working fluids**
- **Safety: Good practice, training and education**
- **Energy:**
  - **Reduce energy demand**
  - **Prevent food loss and waste**

ENOUGH
EUROPEAN FOOD CHAIN SUPPLY TO REDUCE GHG EMISSIONS BY 2050

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Ref: Widell, Hafner, Minetto, Pachai, Evans: "Training on clean cooling and heating solutions"

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Q & A

● MONTREAL PROTOCOL
▶ ADVANCING
✱ CLIMATE ACTION

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Thank you for listening!