

Webinar: Greener Reefers – The Future of Refrigerated Maritime Transport

Tuesday, April 29 · 9 - 10:30am CEST, hosted
by the Greener Reefer Transition Alliance

Goals of Today's Webinar

1. Set the Stage

Overview of the **Greener Reefers whitepaper** and **prototype**, focusing on the transition to **R290** and sustainable cooling solutions.

2. Understand the Impact

Learn about the role of **PFAS** and **TFA** in refrigeration systems, their formation, and the resulting **environmental** and **health risks**.

3. Explore Solutions

Actions to move toward **safer refrigerants** and **more sustainable practices** in the maritime industry.

4. Learn about the **Greener Reefer Transition Alliance (GRTA)**



AGENDA

01

WELCOME

Mark Major, KCC

02

WHITE PAPER

Kirsten Orschulok, GIZ

03

PFAS AND TFA

Daniel De Graaf, UBA

04

GREENER REEFER TRANSITION ALLIANCE

Lydia Ondraczek, GIZ

05

Q&A

Open Questions

Greener Reefers – Project and Prototype



Source: Microsoft Picture

01

Global Climate Commitments and Political Context for *Reefers* Today

1. Global Climate Agreements

2. Maritime-Specific Actions

3. Regional Regulations

2015

The Paris Agreement:

- Commitment to limit global warming to 1.5°C.
- National Determined Contributions (NDCs) driving technology adoption.

2016

Kigali Amendment to the Montreal Protocol:

- Phasedown of HFCs (high-GWP refrigerants).
- Estimated to prevent 0.4°C of warming by 2100.

2023

International Maritime Organization (IMO)

- Target: 50% GHG reduction from shipping by 2050.
- Encouragement of alternative fuels and technologies like R290.

2024

European Union F-Gas Regulation (2024):

- Quota system for HFCs.
- In discussion: EU REACH regarding ban on PFAS as “forever chemicals.”



United Nations Framework
Convention on Climate Change



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)
- Risk of R290 when used in marine container environment is higher compared to use 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



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 1 GWP** value and do not contain F-gases and **PFAS****.



Reefer containers. © GIZ Proklima

**The definition of Greener Reefers as used herein has been formulated by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Greener Reefers Project

Comissioned by



based on a decision of
the German Bundestag



Implemented by



Project Duration

April 2023 until April 2026

Project Budget

EUR 2.900.000



Source Microsoft Picture

White paper for immediate steps for a sustainable future

- Thanks to all contributions by the shipping and container industry to sharpen the content and providing insights to the maritime freight transport and logistics.
 - Wageningen University
 - Thermo King
 - and more and more
- Current reefer fleet operates with highly climate damaging refrigerant – 96% of reefers based on ATO Database
- Change needs to happen now – But how to transit to a sustainable future for one of the key freight transport modes?



Foreword by Otto Schacht

*"The global shipping industry is at a **pivotal juncture**... reefers play a critical role in transporting temperature-sensitive goods but rely on high-GWP refrigerants and energy-intensive operations. (...)*

*This paper **reflects a shared vision**... offering a roadmap for reducing emissions in the reefer sector through collaboration and public-private partnerships. (...)*

***Bold action is not just necessary—it is possible**... Together, we can make the reefer industry a leader in the fight against climate change."*

– **Otto Schacht**,
Former Head of Global Seafreight, Kühne+Nagel
Greener Reefers Transition Alliance ambassador



Role of Reefers in Global Trade and Sustainability

Reefers are insulated containers with advanced systems to regulate temperature (-30°C to +30°C) and humidity, ensuring the safe transport of perishables like food and pharmaceuticals.



96% use R134a, but a shift to low-GWP alternatives like R290 and R744 is driven by environmental and regulatory demands.



High-GWP refrigerants leak and waste energy, increasing emissions, while transitioning to natural refrigerants and improving energy efficiency offers sustainable solutions.



Reefer demand grows **8% annually** with new opportunities driven by consumer and industry trends



Powered by ships, grids, or diesel generators, reefers are **major energy consumers** requiring better efficiency. **Regulations**, such as the Kigali Amendment and EU F-Gas Regulation, mandate phasing down HFCs, driving innovation in greener technologies.



This paper by **GIZ and the Kühne Foundation** provides strategies to:

1. Adopt greener technologies.
2. Reduce emissions.
3. Ensure a sustainable cold chain.

Overview of current and future refrigerants used in reefers

Refrigerant	Energy-efficiency and Coefficient of performance (COP ¹)	Global warming potential (IPCC AR 6) ²	Costs of refrigerants ³	End-of-life	Side products/PFAS ⁴	Service and service ability ⁵	Knowledge/Application ⁶	Flammability ⁷	Toxicity of side products ⁸	Summary
R134a	✓	1530 ✗	✗	✗	✗	✓	✓	✓	✓	✗
R1234yf	✓	0.5 ✓	✗	✗	✗ ✗	✓	✓	✗	✗	✗ ✗
R290	✓ ✓	0.02 ✓	✓	✓	✓	✓	✓	✗	✓	✓ ✓
R744 (CO ₂)	✗	1 ✓	✓	✓	✓	✗	✗	✓	✓	✓

Future refrigeration technologies with natural refrigerants.Comparison of Energy Efficiency – Safety – Standards & Costs, 2013, Intermodal Europe Hamburg Messe by Holger König

IPCC Assessment report 6 Climate Change 2021: The Physical Science Basis

Significant price rise for higher GWP refrigerants - Cooling Post Cooling Post 25.02.2025

European Commission 19.10.2023, News Article by Directorate-General for Environment Health and environmental impacts prompt a call for strict ruling on ubiquitous ‘forever chemicals’

Future refrigeration technologies with natural refrigerants.Comparison of Energy Efficiency – Safety – Standards & Costs, 2013, Intermodal Europe Hamburg Messe by Holger König

Ibd.

UN Environment and ASHRAE Factsheet 1 “Update on New Refrigerants Designations and Safety Classifications” November 2022 UNEP/ASHRAE Refrigerant Fact Sheet #1—Update on New Refrigerants Designations and Safety Classifications

Michael Feller, Karin Lux, Christian Hohenstein, Andreas Kornath. Structure and Properties of 2,3,3,3-Tetrafluoropropene (HFO-1234yf). Zeitschrift für Naturforschung B, 2014; 69b: 379 DOI: 10.5560/ZNB.2014-4017

Emission and PFAS Mitigation Potential by Greener Reefers

Over 30 different scenarios

- Guided by political framework
- Timeframe until 2050, assumption of reefer first use of 15 years
- Includes technology introduction of R1234yf and R290

Database: ATO Database by Wageningen University

Reefer emissions are categorised into:

- **Direct emissions:** Leakage of refrigerants with high GWP.
- **Indirect emissions:** Energy consumption for refrigeration.
- Example: In 2018, refrigerant leaks from reefers emitted 3.74 million tonnes of CO₂-equivalent.

Figure 8. Yearly emissions of average scenarios and their variability

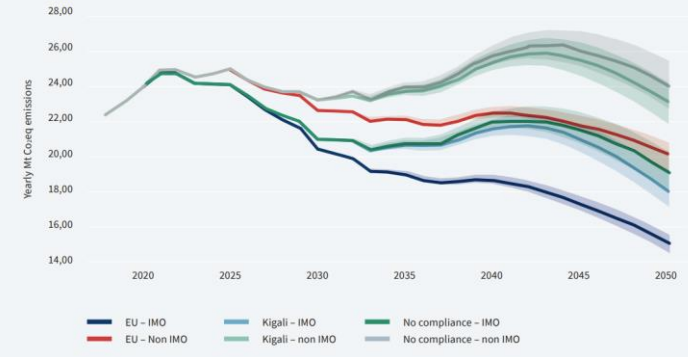
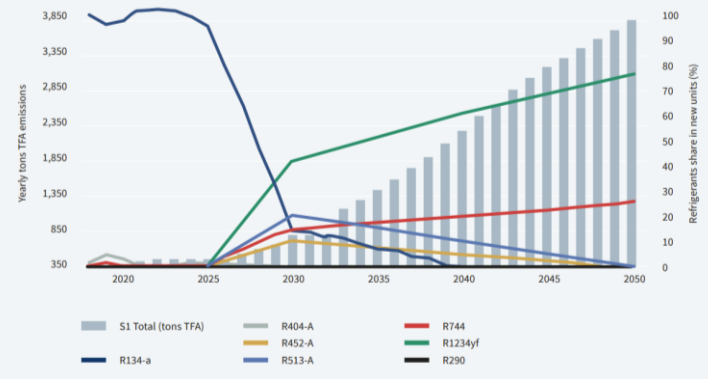


Figure 18. Refrigerant share in new units and the corresponding TFA emissions projection for scenario 1 (EU F-gas / No adoption)



Mitigation Potential –Results

Scenario Analysis:

- Best-case scenario: Rapid adoption of R290 in 50% of new reefers.
- Worst Case: Non-compliance with regulations adds 171.8 Mt CO₂eq by 2050, equal to emissions from 40 coal plants annually.

Energy Efficiency Gains:

- Enhanced insulation, better temperature control, and maintenance can achieve 20% energy efficiency improvements.

Key Mitigation Pathways:

- Switch to Natural Refrigerants:
 - R290: Low GWP and better energy efficiency.
 - R744: Non-flammable and recyclable.
 - Align with Paris Agreement & IMO GHG reduction targets.
 - Transitioning away from HFCs
 - prevents TFA and other harmful byproducts.

Figure 12. Behaviour of Direct and Indirect Emissions of selected scenarios, average off all years



Strategies for Scaling R290 Adoption

	Barriers to Upscaling R290	Key Upscaling Strategies
Technology	High flammability requires advanced safety measures.	Prototyping and field testing R290 reefers to demonstrate feasibility.
	Lack of widespread infrastructure for R290 handling and maintenance.	Encouraging manufacturers to integrate R290-compatible designs into production lines.
Regulatory and Policy	Limited adoption of ISO 20854:2019 in key markets.	Enforcing and aligning international standards (e.g., ISO 20854) across regions.
	Varying international standards create inconsistencies.	Incentivizing adoption through subsidies or tax benefits for R290 systems.
Market and Financing	High upfront costs for transitioning to R290-compatible systems.	Leveraging carbon markets and international climate initiatives to fund transitions.
	Insufficient financial incentives for stakeholders to adopt new technologies.	Fostering public-private partnerships to share costs and risks.
Capacity	Shortage of technicians skilled in handling flammable refrigerants.	Training programs for technicians, shipping companies, and port operators.
		Creating certifications for safe handling of flammable refrigerants.

The foundations for climate-friendly reefer containers, their use and safe handling are established.

Prototype for R290 reefer with Thermo King and Universitat Politècnica de Valencia.

- Including Operating Mode Risk Assessment (OMRA) following the ISO-Standard 20854:2019

Parallel process: Analysis and update of necessary standards and initiation of Eco label process

- Energy benchmarking for the eco label, differentiated between
- Preparation for ISO Standard 1496-2 chapter 8.6 or development of part 3. This depends on the ISO standard technical committee.

→ Safety guidance for ports handling flammable refrigerants, local risk assessment



Greener Reefers Prototype Design

- **Pillars**

- Meet the performance requirements → technology
 - Direct or indirect
 - Components technology
- Be safe
 - Operating Mode Risk Assessment will lead the safety technology integration in the unit design
- Agile delivery as the project schedule requires

- **Performance objectives**

- CFF (Container Fresh & Frozen) reefer by Thermo King will be the baseline
- Same cooling capacity and operating range
 - 6400 W @ -18/38 °C
 - Box temp. -30 °C to 30 °C with ambient from -30 °C to 50 °C
- Same temperature control quality
- Energy efficiency must be 10% better than CFF

- **Project Risks**

- Components availability for Marine environment
- Integration of new technologies and components in an existing product platform



Driving Sustainability: Benefits and Path Forward



Benefits & Why It Matters:

- Accelerates compliance with climate goals, including IMO 2023.
- Reduces emissions directly and indirectly
- Positions the reefer industry as a leader in sustainability, ensuring competitiveness.
- Meets growing demand for eco-friendly logistics solutions.



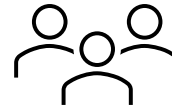
Conclusion:

Reefer containers are crucial for global trade but contribute significantly to emissions. Immediate action is needed to adopt sustainable cooling technologies to meet climate targets.



The Path Forward:

- **Natural Refrigerants:** R290 and R744 offer energy-efficient, eco-friendly solutions. Overcoming technical challenges is key.
- **Energy Efficiency:** Improvements like better insulation and optimized systems can reduce emissions by up to 20%.
- **Global Climate Goals:** Compliance with the Paris Agreement and IMO targets ensures long-term industry viability.



Collaborative Effort:

Industry-wide cooperation, including public-private partnerships, is essential for scaling solutions.



Refrigerants and PFAS: Understanding their health impact and upcoming EU regulation

02

Umweltbundesamt (UBA) – German Environment Agency

Mission:

"Für Mensch und Umwelt" ("For People and the Environment") – As Germany's central environmental protection agency, we are committed to ensuring a healthy environment for citizens, with clean air and water, and minimal pollution.

Tasks:

- **Research & Data Collection:** Gathering and analyzing environmental data on air, water, soil, climate, and public health.
- **Policy Advice:** Providing scientific support to ministries and governmental bodies.
- **Implementation:** Enforcing environmental laws, including CO₂ trading and the approval of chemicals and pesticides.
- **Public Outreach:** Providing information and answering questions from the public on environmental issues
- **Early Detection:** Identifying and assessing environmental risks to find timely solutions..

Staff:

Approximately 1,800 experts from various disciplines, including biology, chemistry, economics, law, and engineering, work together to develop sustainable environmental solutions.

Locations:

- Main office: Dessau-Roßlau
- Other offices: Berlin, Bad Elster, Langen

International Cooperation

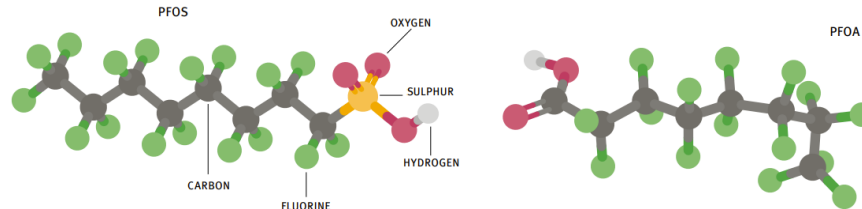
UBA acts as the German point of contact for several international organizations, including the World Health Organization (WHO), and contributes to global environmental initiatives.

Umwelt
Bundesamt 

What are PFAS and TFA?

What are PFAS?

- **PFAS** = *Per- and Polyfluorinated Alkyl Substances*,
- includes thousands of chemicals used in **waterproof fabrics, non-stick cookware, refrigerants, pesticides, etc.**
- Many PFAS are **persistent** in the environment: "Forever Chemicals"
- **Examples: PFOS & PFOA** (banned/restricted due to health concerns), **TFA**



What is TFA?

- **TFA (trifluoroacetic acid)**, is a basic chemical and a breakdown product of certain substances (e.g. R-1234yf)
- It is also **persistent** and contributes to PFAS contamination, especially in water and soil.
- TFA accumulates in the environment and poses a risk to ecosystems and human health, → environmental impact is still not fully understood



PFAS restriction proposal

- REACH (Registration, Evaluation, Assessment and Restriction of Chemicals) Regulation (EC) 1907/2006
- Proposal according to Annex XV submitted by Denmark, Netherlands, Norway, Sweden and Germany in February 2023
- addresses Per- und Polyfluoralkyl Substances (PFAS) due to their toxicity und persistence in the environment ('forever chemicals')
 - Example: Trifluoroacetic acid (TFA)
- Excerpt from the proposal:

“Some scientists argue that the **planetary boundaries for PFASs have already been exceeded**, and human biomonitoring studies show that the **cocktail of PFASs** to which parts of the general population are exposed to through different sources (e.g. food, drinking water, products containing PFASs, dust, air) **already may result in health risks.**”

PFAS restriction proposal

- **PFAS definition** includes **all fluorinated refrigerants** (except for R-23, R-32, R-152(a) und R-1132(a))
- Prohibition 18 months after Entry into Force (EiF; new equipment), exceptions for:
 - Refrigerants for very low temperature (≤ -50 °C) cooling (6,5 years after EiF)
 - Refrigerants in laboratory test and measuring appliances (13,5 years after EiF)
 - Refrigerants in refrigerated centrifuges (13,5 years after EiF)
 - Refrigerants in mobile AC and transport refrigeration (6,5 years after EiF)
- Refill of existing plants and appliances: allowed until 13,5 years after EiF

Distribution of PFAS & TFA in the Environment

Global Spread:

- PFAS and TFA are found worldwide, even in **remote areas** like the Arctic and Alps, spreading via **air** and **water**.

Environmental Compartments:

- Soil**: PFAS persist in soil, moving into groundwater, TFA moves faster into groundwater.
- Water**: PFAS and TFA are found in **surface waters** and **groundwater**; TFA also accumulates in **sediments**.

Food Chain:

- PFAS** accumulate in **plants** and **animals**, leading to human exposure via food and water.
- TFA** accumulates in marine ecosystems, entering the food chain.

Human Exposure:

- PFAS** enter via **food** (e.g., fish, fruits) and indoor **air/dust**.
- TFA** contributes through **drinking water** and **food**.

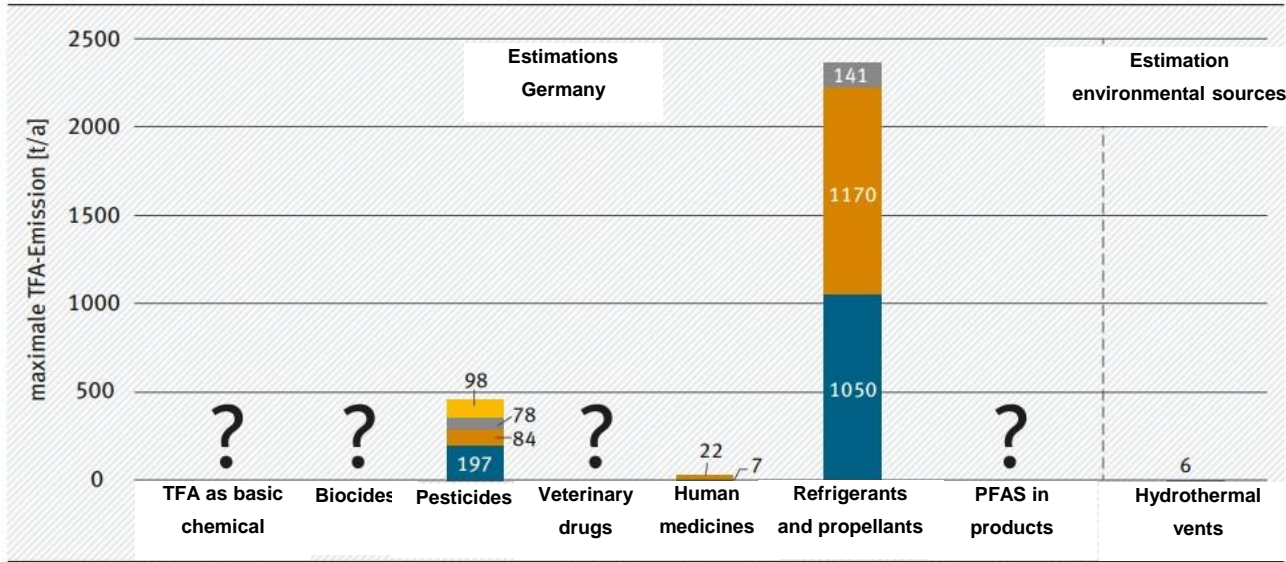
Once TFA enters surface waters, there is
no way to remove it from there.

Refrigerants (selection)

Refrigerant	Chemical designation	Safety classification	GWP ₁₀₀ ¹	TFA formation potential
R-32	Difluoromethane	A2L	675	-
R-125	Pentafluoroethane	A1	3.500	-
R-134a	Tetrafluoroethane	A1	1.430	7-20 %
R-227ea	Heptafluoropropane	A1	3.220	100 %
R-454B	Blend (R-32/R-1234yf)	A2L	465	31 %
R-454C	Blend (R-32/R-1234yf)	A2L	146	79 %
R-455A	Blend (R-32/R-1234yf/R-744)	A2L	146	76 %
R-513A	Blend (R-134a/R-1234yf)	A1	629	bis zu 65 %
R-515B	Blend (R-227ea/R-1234ze)	A1	288	bis zu 18%
R-1234yf	2,3,3,3-Tetrafluoropropene	A2L	0,501	100 %
R-1234ze(E)	Trans-1,3,3,3-Tetrafluoropropene	A2L	1,37	bis zu 10 %
R-1233zd(E)	Trans-Chlorine-3,3,3-Trifluoropropene	A1	3,88	bis zu 10 %
R-290	Propane	A3	0,02	-
R-600a	Isobutane	A3	0	-
R-717	Ammonia	B2	0	-
R-744	Carbon dioxide	A1	1	-

¹ Values from Regulation (EU) 2024/573, Annex I, II und VI

Estimated maximum TFA emissions in Germany in t/a from relevant sectors



TFA is a persistent liver and reproductive toxicant!

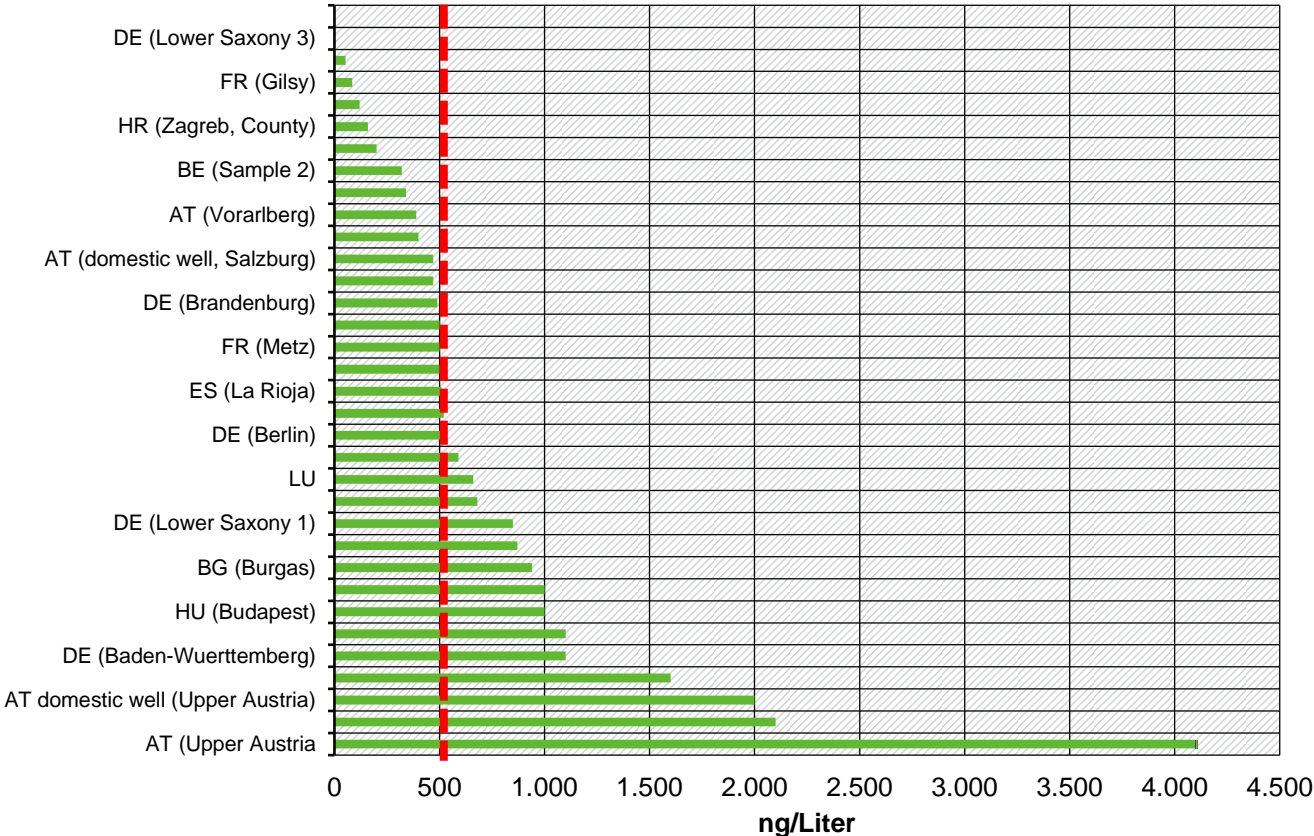
→ Proposal to re-classify TFA in Regulation (EU) 1272/2008 (CLP) under 1B:
Presumed human reproductive toxicant

Refrigerants and propellants: TFA from R-134a (blue), R-1234yf (orange), other refrigerants (grey)

Pesticides: Flufenacet (blau), Diflufenican (orange), Fluacinam (grau), other pesticides (yellow)

Source: Chemikalieneintrag in Gewässer vermindern – Trifluoracetat (TFA) als persistente und mobile Substanz mit vielen Quellen. UBA-Hintergrundpapier, November 2021, ISSN 2363-829X

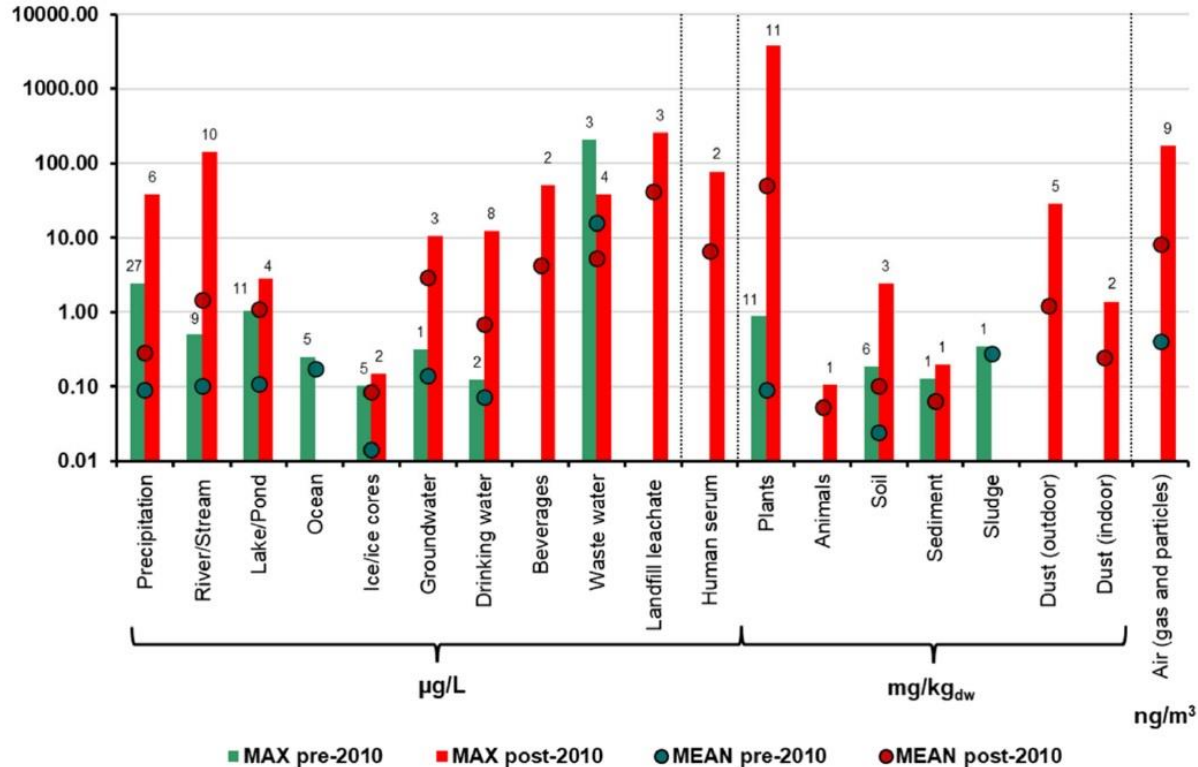
TFA in European drinking water (ng/L)



Red line: Limit „total PFAS“ (500 ng/L) according to Directive (EU) 2020/2184 (Drinking water Directive) as of January 2026

Source: Pesticides Action Network (PAN) Europe: TFA – The Forever Chemical in the Water We Drink. July 2024 (own illustration)

Increasing TFA concentrations in the environment

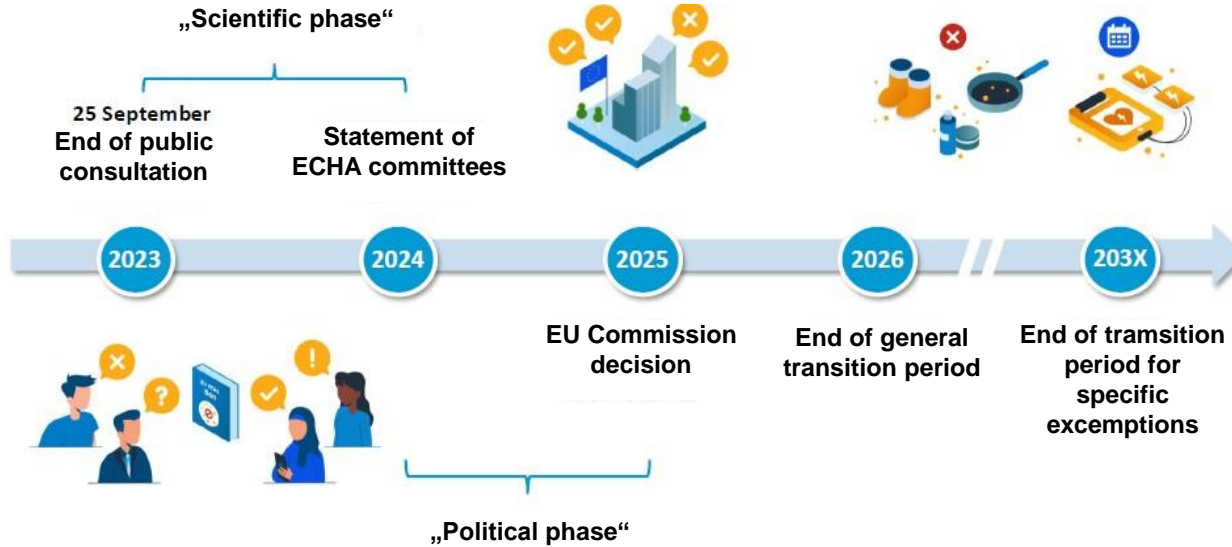


Maximum TFA values (bars) and average values (points) in respective media and periods.

“Obvious places to start would be to limit the direct production of TFA, and more importantly, of TFA precursors, such as HFOs (like HFO-1234yf [...])”

Quelle: Hans Peter H. Arp, Andrea Gredelj, Juliane Glüge, Martin Scheringer, and Ian T. Cousins: The Global Threat from the Irreversible Accumulation of Trifluoroacetic Acid (TFA). Environmental Science & Technology 2024, 58 (45), 19925-19935

PFAS restriction proposal: outlook



- ECHA committees: RAC (Risk Assessment Committee) and SEAC (Socio-economic Assessment Committee)
- „Given timeframe may change.“ -> Entry into Force 2028 (internal assumption EU Commission)

Summary

- **TFA** is a **persistent liver** and **reproductive toxicant** that accumulates in the environment
- **Major emission sources** are refrigerants and propellants such as **R-134a** and **R-1234yf**
- Proposed **EU PFAS restriction** would **prohibit** the use of most **fluorinated refrigerants**
- Use of natural refrigerants such as **R-290** **completely avoids TFA emissions**

Call to Action

1. Transition to Safer Refrigerants:

The maritime industry must **adopt environmentally-friendly refrigerants** such as **R290** (propane), which pose **no risk** to the environment and human health compared to **fluorinated gases** that break down into TFA.

2. Support Stronger Regulations:

Advocate for **stricter regulations** on PFAS and F-gases.

3. Raise Awareness:

Encourage stakeholders to promote sustainable practices.

4. Join the Movement:

Engage with initiatives like the **Greener Reefer Transition Alliance** for a **cleaner shipping industry**.

Thank you for your attention!

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<https://www.umweltbundesamt.de/themen/klima-energie/fluorierte-treibhausgase-fckw-0>



Jahre
Umweltbundesamt
1974–2024



Greener Reefer Transition Alliance

The Greener Reefers Transition Alliance

Let's move forward together
Revolutionizing Refrigerated Shipping for a Sustainable Future

**Greener Reefer
Transition Alliance**



The Alliance's Vision

- A collaborative initiative focused on **promoting environmentally sustainable and climate-friendly alternatives in the refrigerated maritime container industry.**
- bringing together industry frontrunners, innovators, public and private stakeholders to jointly move forward
- establish an enabling environment for the adoption of Greener Reefers.



- Lead the transition to sustainable refrigerated shipping.



- Innovate through natural refrigerants and energy-efficient technologies.



- Foster collaboration across the shipping ecosystem.



**Greener Reefer
Transition Alliance**

Join the Greener Reefer Alliance

- ✓ **Reduce direct carbon emissions** of the reefer and minimize environmental impact by the utilisation of natural refrigerants for cooling systems, that have a low global warming potential.
- ✓ **Reduce indirect carbon emissions** and minimise environmental impact by optimising the energy efficiency performance of the reefer system design, enhancing energy efficiency of container shipping during operations, and building capacity for servicing and handling them on ships and in ports as well as tackling the end-of-life aspects.
- ✓ **Promote Collaboration and Innovation** among key stakeholders in the shipping industry, including shipping companies, port authorities, manufacturers of reefer containers.
- ✓ **By facilitating knowledge and information sharing** and incentivising innovation, the initiative seeks to accelerate the development and adoption of sustainable technology and practices in the refrigerated cargo sector.
- ✓ **Demonstrate the technical and commercial viability of Greener Reefer** support pilot projects aimed at demonstrating the feasibility, effectiveness, and market readiness of sustainable practices and Greener Reefer technology in refrigerated cargo shipping.
- ✓ **Advocacy and Education** engage in advocacy efforts to raise awareness of the environmental impact of refrigerated cargo shipping and the benefits of adopting sustainable practices.



Joining the Alliance

- Accelerated access to expertise.
- Networking and collaboration opportunities.
- Market differentiation and competitive edge.
- Proactive risk mitigation and regulatory compliance.

Questions & Answers

We're happy to answer your questions!

Feel free to ask anything about today's presentation, the Greener Reefers project, PFAS, or TFA.

THANK YOU

We appreciate your time and participation today!

If you have any further questions or would like to receive updates on the project, feel free to reach out to us!



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Greener Reefers Transition
Alliance

