INSTITUT INTERNATIONAL DU FROID
INTERNATIONAL INSTITUTE OF REFRIGERATION

UN environment programme

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COLD CHAIN TECHNOLOGY BRIEF | 2025

FISHING VESSEL APPLICATIONS

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November 2025

http://dx.doi.org/10.18462/unep.iir.coldchainbrief.fishing.10.2025

SUMMARY

The global fishing sector faces a dual challenge: the lack of adequate onboard chilling systems leads to significant food loss, while the continued use of high-GWP refrigerants threatens environmental integrity and public health.

This brief presents an overview of the different existing refrigeration technologies in fishing vessels along with the environmental impacts of refrigerants used, and introduces environmentally friendly and energy-efficient technologies. Sustainability and safety in fishing vessels refrigeration encompass proper management of existing systems to prevent refrigerant leaks, as well as ongoing research and development into further improvement of the overall energy efficiency of systems.

Technological solutions to improve energy use, flexibility, and operational efficiency are suggested in the brief, including digitalisation to optimise maintenance and system design, as well as integrated heating and cooling solutions like waste heat recovery and cold thermal energy storage.

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INTRODUCTION

Globally, according to FAO, inadequate cold chain infrastructure contributes to the loss of 30-35% of seafood production annually (FAO, 2022), with losses reaching up to 50% in small-scale fisheries (FAO, 2018). The International Institute of Refrigeration (IIR) estimated that 19% of fish and seafood produced for human consumption in 2017 was lost due to an inadequate cold chain (➔ Figure 1).

Modernising the global cold chain, based on efficient technologies and sustainable refrigerants, could reduce the CO_2 emissions of the current cold chain by nearly 50%, while also preventing up to 55% of food losses currently attributable to cold chain shortcomings.

A major challenge lies in the lack of adequate chilling and freezing systems on many fishing vessels. This results in spoilage, reduced product quality, and increased discards – wasting not only food but also the energy used to catch it. Some vessels rely on chemical preservatives like acids or formalin, which can compromise both product quality and health.

Immediate chilling of the catch – at a temperature around the melting point of ice (0 °C) – is a better alternative to ensure a longer shelf life (➔ Figure 2). Depending on fishing practices (e.g. length of fishing trip) and the type of fish species, onboard freezing may be more suitable than chilling (Wibawa et al., 2022).

On board chilling or freezing can significantly reduce overall greenhouse gas emissions by preventing food loss and preserving perishable products. However, if the electricity powering refrigeration systems is generated using fossil-fuel-powered generators, implementing onboard refrigeration systems may increase energy demand and emissions. Furthermore, estimates from the International Maritime Organization (IMO) (IMO, 2020) suggest that R-22 refrigerant leakage from maritime shipping represents about 2.88 million tonnes of CO_2e annually.

Therefore, well-designed, energy efficient systems coupled with renewable energy using low GWP refrigerants are essential for achieving lower GHG emissions.

This technical brief aims to raise awareness about the current and future refrigeration technologies used on fishing vessels.

FISH AND SEAFOOD PRODUCTION LOST DUE TO LACK OF REFRIGERATION PER WORLD REGION

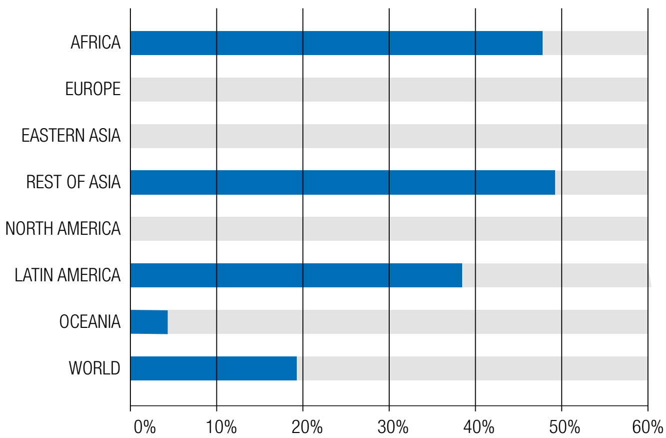

Figure 1 | Proportion of fish and seafood produced for human consumption in 2017 lost due to lack of refrigeration according to the IIR. (Sarr et al., 2023)

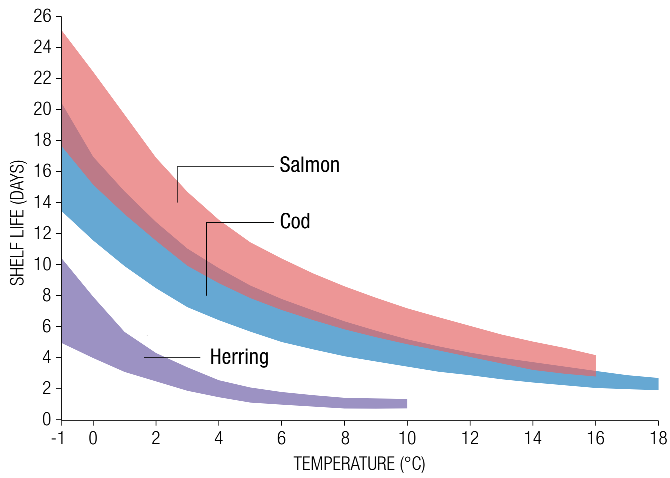

Figure 2 | Relation between temperature and shelf life for three different types of fish. (Adapted from Magnussen, 1993)

OVERVIEW OF REFRIGERATED FISHING VESSELS

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2.1 Fishing vessel types and practices

According to FAO (FAO, 2024), the global fishing fleet numbered approximately 4.9 million vessels in 2022 – of which two thirds were motorised – reflecting a decline from the peak of 5.3 million recorded in 2019. Small-scale vessels continue to dominate, making up an estimated 89% of the total fleet. Asia remains the leading region for fishing activity, accounting for 71% of the global fleet, primarily in China, India, and Indonesia (FAO, 2024).

Fishing vessels employ a wide range of gear types depending on their target species and scale of operation. Large-scale industrial fishing primarily relies on bottom trawls, purse seines and pelagic longlines – methods that dominate global catch volumes but vary significantly in their environmental impact. Meanwhile, small-scale fisheries use simpler gear like gillnets, handlines, and traps, which typically have lower bycatch rates but account for most of the world's fishing workforce.

From catch to consumer, processing methods vary significantly across regions. Nevertheless, FAO reports that refrigeration, namely freezing, is the main method of preserving fishery and aquaculture products for food purposes (FAO, 2024). ➔ Figure 3 illustrates significant regional disparities in the proportion of fish and seafood produced for human consumption that is refrigerated. The horizontal bar chart illustrates significant regional disparities: Europe and Eastern Asia show nearly universal refrigeration rates close to 100%, while Africa lags behind with less than 10%. Other regions such as North America, Latin America, and Oceania fall in between, highlighting the uneven access to cold chain infrastructure globally.

The refrigeration practices onboard fishing vessels vary significantly depending on vessel type and fishing method. ➔ Table 1 below summarises the main refrigeration practices by vessel type.

Vessel type	Refrigeration practice
Trawlers	RSW systems, ice storage, onboard freezing and processing lines
Purse seiners	RSW systems, freezing to -50 °C, fish pumps for onboard transfer
Longliners	Ultra-low temperature freezers, bait storage tanks
Gillnetters	Ice storage, some equipped with freezers and processing lines
Factory trawlers	Full processing plants onboard, including gutting, filleting, freezing, and packaging
Fish carriers/ reefers	Dedicated refrigerated transport holds for fish and fish products
Trap setters	Ice storage, live holding tanks for crustaceans
Multipurpose vessels	Combination of RSW, ice, and freezing systems depending on gear and catch type

Table 1 | Summary of refrigeration systems by fishing vessel type (Ruiz, 2012; Shawyer and Pizzali, 2003; Widell et al., 2023)
This information was collected through desk research and may vary depending on vessel specifications and regional practices, and operational conditions.

RATIO OF REFRIGERATED FISH AND SEAFOOD PER WORLD REGION

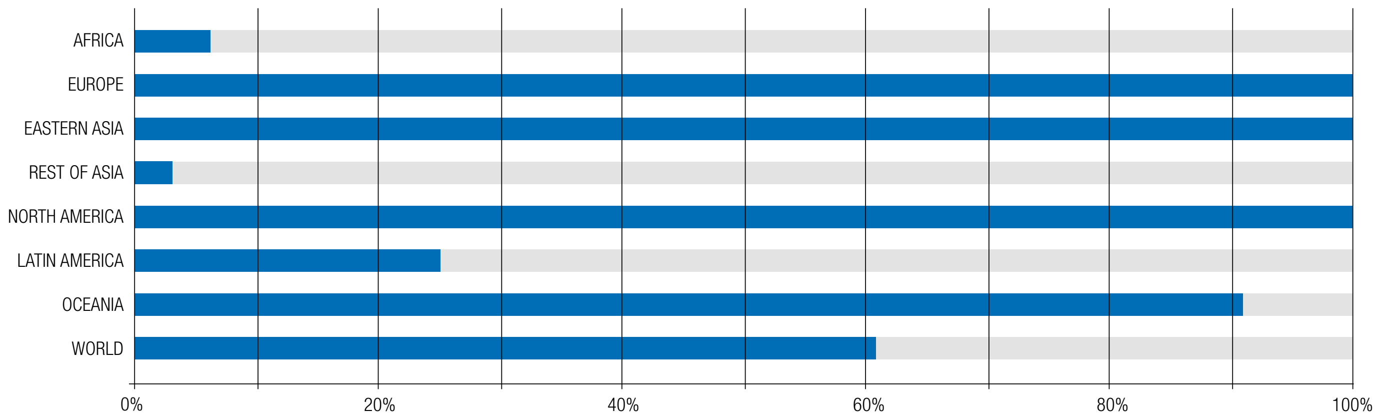

Figure 3 | Proportion of fish and seafood produced for human consumption in 2017 that is actually refrigerated, according to the IIR. (Sarr et al., 2023)

2.2 Refrigeration on board

Small artisanal fishing vessels do not have refrigeration systems installed. Motorised small-scale fishing vessels, may either carry ice from shore or have a small refrigeration system on board. Medium to large commercial vessels typically feature refrigerated sea water (RSW) tanks, plate freezers, or ice-making machines. Large industrial-scale vessels, which operate on long-distance and/or extended trips (typically several months), require deep freezing to preserve the fish. Depending on the fish species, fishing gear, and processing needs, these vessels often have fully equipped factory installations with a variety of energy and process systems, including blast freezers, plate freezers, RSW tanks, and ice machines. This section provides examples of different types and capacities of refrigeration systems.

2.2.1 Refrigerated seawater systems

Refrigerated seawater (RSW) is a widely used method for rapidly chilling large quantities of fish, typically employed on board larger pelagic purse seiners, trawlers and longline vessels. An RSW system comprises a refrigeration unit that cools seawater to temperatures between –1.5 °C and +0.5 °C. The chilled seawater circulates through multiple tanks, facilitated by a network of pipes, valves, and large seawater pumps, as illustrated in ➔ Figure 4.

CASE STUDY APPLICATION OF RSW SYSTEMS IN NORWEGIAN PELAGIC FISHERIES

Fishing vessels operating in Norwegian waters have utilised refrigerated seawater (RSW) systems for over five decades, particularly within the pelagic fisheries targeting species like herring and mackerel. These vessels, typically ranging from 50 to 80 metres in length, are designed to handle substantial catch volumes – often up to 1,000 tonnes – requiring robust onboard chilling solutions to maintain product quality.

RSW systems on board these vessels commonly use ammonia as the refrigerant due to its high efficiency and suitability for large-scale operations. However, CO_2-based systems are emerging as alternatives for smaller capacities: they are safer to handle and offer reduced health risks in case of leaks. To meet the demanding cooling needs, it is not uncommon for larger vessels to operate two or three ammonia-based RSW units, each delivering approximately 1 MW of cooling capacity. This setup ensures security, rapid temperature reduction and optimal preservation from the moment of catch.

2.2.2 RSW systems with CO_2

Compact and space-saving refrigeration units, particularly the compressors, offer advantages for vessels with limited space. In colder climatic regions, subcritical and transcritical

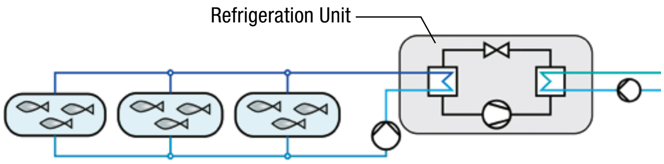

Figure 4 | Principle drawing of an RSW system. Seawater is drawn from the ocean, chilled and circulated through tanks holding the catch.

CO_2 units are popular due to their compactness and high coefficient of performance (COP), providing an energy efficient solution. Component availability, safety, and compactness are reasons for a growing market share. Small CO_2 systems can be used for both RSW chilling and freezing applications, providing a straightforward and energy efficient option for certain vessel types (Söylemez et al., 2022).

Fishing vessels operating in high seawater temperatures – often around 30 °C in tropical and equatorial regions – face unique challenges when it comes to onboard refrigeration. The choice of cooling technology depends largely on the vessel's primary refrigeration needs. For vessels where RSW chilling is the dominant requirement, ammonia (R-717) remains the most energy-efficient solution due to its excellent thermodynamic properties and high cooling capacity (Bodys et al., 2018).

However, when onboard freezing is also required – especially for preserving high-value species – a cascade system combining R-717 and CO_2 (R-744) may be considered. These systems can achieve freezing temperatures as low as –50 °C in the CO_2 stage, making them suitable for deep-freezing applications.

In many warm-climate regions, particularly in the Global South, the transition away from legacy refrigerants like R-22 toward alternatives is often hindered by regulatory barriers, safety concerns, and limited technical capacity (DNV, 2011). For these regions and end-users willing to phase out synthetic working fluids, R-744 systems can be a viable alternative if the system architecture is adapted for high heat-rejection temperatures (Bodys et al., 2018; Semaev, 2021).

2.2.3 Plate and blast freezers

For fishing vessels operating far from shore and remaining at sea for several weeks, the catch must be frozen.

Vertical plate freezers illustrated in ➔ Figure 5 are typically used on board whitefish trawlers, where whole, gutted fish are frozen into 25 or 50 kg blocks. Their vertical design allows easy top-loading, with blocks released downward after freezing. Vessels that process fish onboard, such as filleting and portioning, may use horizontal plate freezers or individual quick freezing (IQF) systems, which freeze products in cartons or as individual portions.

IQF systems rapidly freeze thin products (e.g. fillets) placed on belts or conveyors by blasting high-velocity, low-temperature air across the surface. This method enables fast heat transfer, allowing products around 2 cm thick to freeze in 10 minutes or less.

Figure 5 | Cod frozen in vertical plate freezers.
(photo: Guro M. Tveit, SINTEF Ocean)

2.2.4 Ice and slurry applications

Ice or slurry can either be brought from shore before departure or produced on board using ice makers or slurry generators. Fish stored with ice is illustrated in ➔ Figure 6. To account for melting during transit from shore, large enough quantities must be loaded to ensure that the entire catch remains chilled until delivery or landing.

Figure 6 | Fresh fish stored in ice.

Alternatively, ice or slurry can be generated on board, either freshwater or seawater, allowing the flexibility to adjust production based on catch size and duration at sea. An ice slurry installation typically consists of a refrigeration system connected to an ice slurry generator, a storage tank for the produced slurry and a delivery system.

CASE STUDY DEVELOPMENT OF AN R-290 ICE SLURRY SYSTEM FOR FISHING VESSELS IN INDIA

India is currently pioneering the development of onboard ice slurry systems using R-290 (propane) as a refrigerant, tailored to meet the demands of fishing operations in warm coastal waters. Simulation studies have shown that a 30 kW R-290-based system can achieve a coefficient of performance (COP) of 1.76, even under extreme tropical conditions – with evaporation temperatures at −25 °C and condensation temperatures reaching +40 °C (Singha et al., 2025).

2.2.5 Heat-driven refrigeration systems: challenges and opportunities in warm countries

Some refrigeration systems, like absorption chillers, use heat instead of electricity to cool fish on board. This can be useful when there is extra heat available, such as from the vessel's engine. In theory, this makes them a good fit for fishing vessels operating in warm regions, where engine heat is abundant.

A study of the Mediterranean fishing fleet showed that waste heat from engines – such as exhaust and cooling water – could be enough to meet refrigeration needs on some vessels (Palomba et al., 2019). However, in practice, most fishing vessels don't produce enough surplus heat to run these systems effectively, especially for demanding tasks like making refrigerated seawater (RSW) or ice.

Additionally, absorption chillers are large, heavy, complex, and expensive, which makes them hard to install and operate on small or medium-sized fishing boats. These factors limit their use in developing countries, where space, cost, and simplicity are key considerations for onboard equipment.

2.2.6 Brine freezing

Brine freezing is another method used for certain species, such as tuna, sardines or anchovies intended for canning (Larminat et al., 2018). Brine typically refers to a solution of salt and water, commonly sodium chloride (NaCl) or calcium chloride ($CaCl_2$), which lowers the freezing point of the liquid. These salts have eutectic points[i] of –21 °C for NaCl and –55 °C for $CaCl_2$, enabling rapid freezing at sub-zero temperatures without forming ice in the brine itself. Compared to air freezing, brine offers significantly higher heat transfer rates and can reduce the overall energy use. However, it may also lead to salt uptake in the product, which can affect quality depending on the species and end use.

2.3 Life cycle assessment case study – Indonesia

CASE STUDY LIFE CYCLE ASSESSMENT OF FISH PRESERVATION METHODS ON INDONESIAN FISHING VESSELS

Indonesia, as an archipelagic nation, relies heavily on capture fisheries as a primary source of livelihood for its coastal communities. In 2019, over 2 million fishers were engaged in capture fisheries, operating approximately 1 million fishing vessels (Wibawa et al., 2022). A major challenge facing the national fishing fleet lies in its technological limitations. Roughly 70% of the vessels are small-scale boats, equipped with minimal onboard technology. Typical fishing operations – such as sailing to fishing grounds, deploying and retrieving nets, and preserving the catch in the fish hold – are associated with various environmental emissions. Notably, the shipping sector in Indonesia, which includes capture fisheries, accounts for about 19% of the nation's CO_2 emissions (Puspa, 2021).

Indonesia's fishing sector relies heavily on traditional preservation methods, primarily block ice transported from shore. As part of efforts to modernise and reduce emissions in line with the country's commitments under the Paris Agreement and the Montreal Protocol, this case study compares the environmental performance of two preservation systems:

- **Block ice** (shore-produced, transported to vessel).
- **Flake ice machine** (onboard production using refrigerant system).

Block ice was found to have a 95% lower impact on ozone depletion and a 97% lower global warming potential compared to onboard flake ice machines. The authors recommend that, if flake ice systems are to be used, they should operate with more environmentally friendly refrigerants – such as ammonia – to significantly reduce environmental harm and align with national commitments to the Paris Agreement and the Montreal Protocol.

i Eutectic point: The specific temperature and composition at which a mixture of substances solidifies or melts simultaneously into a single phase, providing a stable and consistent temperature during the phase change.

Figure 7 | Small fishing vessels, Indonesia
(https://commons.wikimedia.org/wiki/File:Fishing_boats,_Probolinggo,_2016_%2802%29.jpg)

CURRENT REFRIGERANTS USED, ENVIRONMENTAL IMPACT AND LONGER-TERM ALTERNATIVES

3

Prior to the Montreal Protocol compliance requirements, the global fishing fleet relied predominantly on R-22, an HCFC employed for all refrigeration applications for reasons of efficiency, cost, and safety (UNEP, 2023a). In the 2010s, several countries engaged in phasing out HCFCs, which led to fishing vessels being retrofitted from R-22 to either R-507A/R-744 or R-717/R-744. For instance, the Galician fishing sector in Spain completed its gradual transition from R-22 in 2015 (Gabrielii and Jafarzadeh, 2020).

Unfortunately, conversion costs are high. In some Article 5 island countries, where fisheries represent one of the largest refrigerant end users, refrigerant leakage from aging vessels is not addressed due to high costs for leak detection and repair (UNEP, 2024a).

In the Maldives, a small island developing state (SIDS) with an economy depending substantially on the fisheries sector, R-22 was used in 85% of fishing vessels in 2018 while 15% used ammonia (Ministry of Environment and Energy, Republic of Maldives, 2018). With support from the Multilateral Fund for the Implementation of the Montreal Protocol (MLF), the government of Maldives achieved a complete HCFC phase-out by 2023 (Multilateral Fund, 2025).

According to the UNEP Technology and Economic Assessment Panel (TEAP) 2022 report, R-717 (ammonia) which was common before 1970, is currently returning in fishing vessels (UNEP, 2023b). This transition aligns with the International Maritime Organization's 2023 GHG Strategy (IMO, 2023), which calls for the uptake of zero or near-zero GHG emission technologies and fuels in maritime vessels. IMO Regulation 12 of MARPOL annex VI prohibits the installation of systems using ozone-depleting substances such as CFCs and HCFCs (e.g. R-22) on ships constructed after 1 January 2020 (IMO, n.d.).

Many refrigerants currently used in the global fishing fleet pose significant environmental challenges due to their high GWP and ODP. Refrigerant losses, which occur due to system leaks caused by the constant movement of vessels, account for up to 2% of the total maritime emissions (Hafner et al., 2019).

The International Maritime Organization has estimated that 1,589 tonnes of R-22 refrigerant are lost annually from fishing vessels (IMO, 2020). R-22 has a high GWP_{100}[ii] of 1,810 and ODP of 0.055. Based on estimated annual losses, this equals to approximately 2.88 million tonnes of CO_2e, comparable to the yearly emissions of over 600,000 gasoline cars. These reported refrigerant loss figures are widely considered to be underestimated, as emissions have not been consistently or accurately measured in many countries (United Nations Conference on Trade and Development, 2024), suggesting that the actual climate impact may be significantly greater than currently reflected.

Transitioning to sustainable refrigerants is therefore essential to mitigate the negative impact of these emissions. Furthermore, refrigerant losses represent a significant growing financial burden for vessel owners, as the global prices of halogenated hydrocarbons are currently rising rapidly.

Hydrofluoroolefins (HFOs), such as R-1234yf and R-1234ze, represent the latest generation of fluorinated refrigerants developed to replace high-GWP hydrofluorocarbons (HFCs). These substances are characterised by zero ODP and low GWP, primarily due to their short atmospheric lifetimes. However, their environmental profile is more complex. Upon atmospheric degradation, HFOs – as well as legacy HFCs like R-134a – can form trifluoroacetic acid (TFA), a highly persistent and water-soluble compound. TFA is widely recognised as a perfluorinated substance (PFAS) and has been increasingly detected in surface waters and precipitation globally (European FluoroCarbons Technical Committee, n.d.). While the UNEP Environmental Effects Assessment Panel (EEAP) notes that current environmental concentrations of TFA are below thresholds of concern for human and ecological health (UNEP, 2024b), its persistence and potential for accumulation in localised areas remain subjects of ongoing scientific and regulatory scrutiny. Additionally, the flammability and toxicity profiles of certain HFOs raise safety considerations, particularly in confined environments such as marine vessels.

Effective life cycle management of synthetic refrigerants is essential to minimising their environmental impact during both operational use and end-of-life disposal. This includes

ii Global warming potential over a 100-year timeframe.

proper handling, recovery at the end of the system's service life, and recycling. In situations where full conversion to natural refrigerants is not feasible, it is recommended to retrofit existing systems to ensure maximum refrigerant containment. This involves using high-integrity components, implementing leak detection systems, and applying rigorous maintenance protocols. However, practical experience, particularly in maritime environments, indicates that maintaining low leakage rates is challenging due to continuous mechanical vibrations and movement. Even land-based systems frequently struggle to achieve annual leakage rates below 10%. In such cases, the use of indirect cooling systems with secondary fluids, e.g. carbon dioxide, can significantly reduce the loss of primary refrigerants and improve overall containment efficiency.

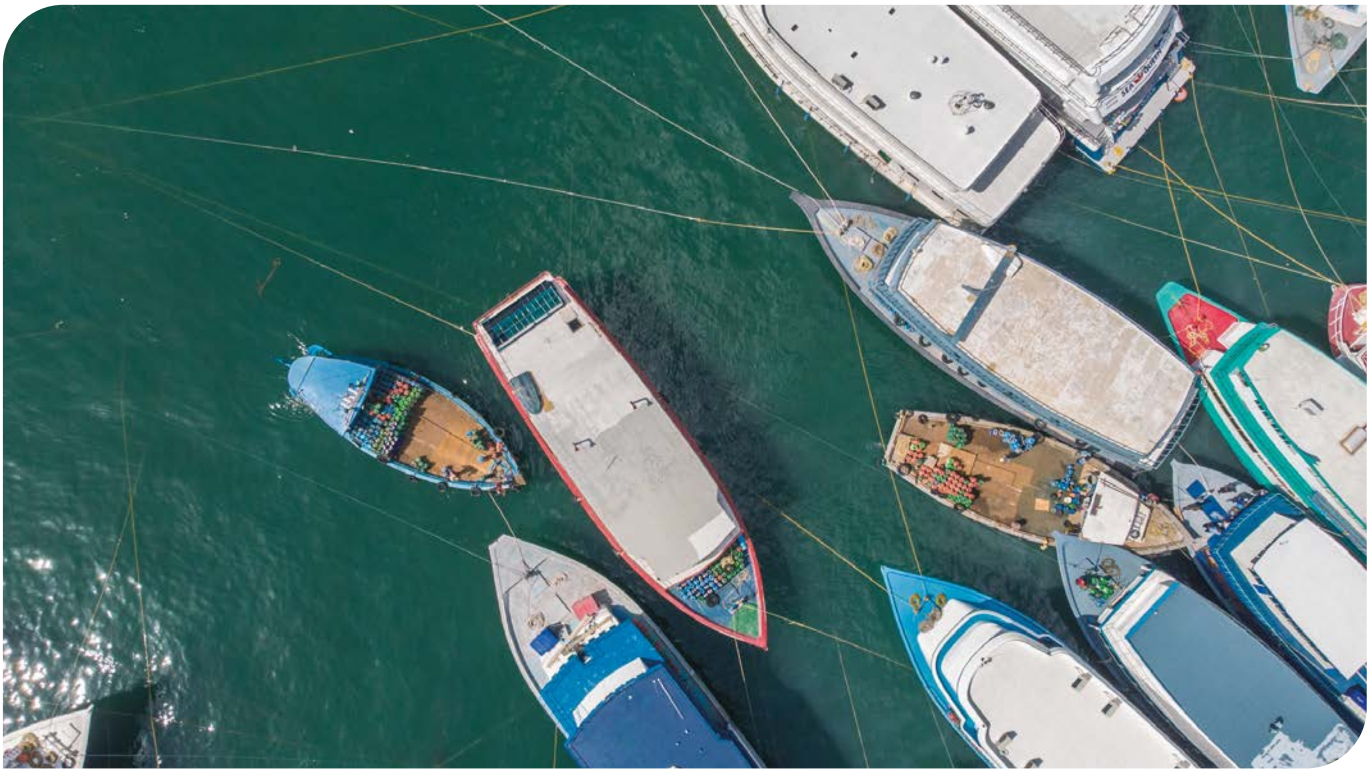

Figure 8 | Aerial view of Malé North Harbour, the main hub for the distribution of good in the Maldives © Asian Development Bank. (Flickr https://www.flickr.com/photos/asiandevelopmentbank/48786644873/in/photostream/)

TECHNOLOGY TRENDS AND DEVELOPMENT

4

4.1 Marine adaptations in seafood processing

Processing seafood onboard fishing vessels, such as cutting, freezing, and storing, is similar to land-based food processing, but the equipment must be adapted for marine conditions. Limited space, constant movement, and exposure to harsh environments require systems that are compact, durable, and highly reliable.

Materials used in refrigeration must resist corrosion, especially in seawater-cooled systems. Shell and tube condensers are commonly used, with copper-nickel tubes suitable for seawater environments. However, material compatibility with refrigerants is crucial. Titanium is often preferred because it is highly corrosion-resistant and compatible with a wide range of refrigerants, making it ideal for marine applications, where reliability and longevity are essential.

4.2 Onboard digitalisation

Digitalisation and automation are transforming the maritime sector, driving competitiveness, operational efficiency, and decarbonisation efforts toward zero emissions by mid-century (DNV, 2024). For fishing vessels, data from onboard systems – like integrated automation systems (IAS), vessel monitoring systems (VMS), refrigeration systems, and catch diaries – combined with external sources (e.g. weather forecasts, sales data) and informal insights (e.g. experience, paper records), can optimise operations. Skippers can use machinery data for predictive maintenance and fault prevention, while historical catch data can improve fishing routes, reducing fuel use. For refrigeration systems, analysing thermal data can enhance design, sizing, and operational efficiency, supporting overall performance improvements and reduced energy demand. The use of drones for locating fish could be a more energy-efficient and lower-emission alternative to having the fishing vessel search for fish schools directly.

4.3 Propulsion, fuels and integration of heating and cooling

Fishing vessels currently rely on diesel engines for propulsion and onboard power, but global environmental regulations are accelerating the shift toward cleaner energy sources such as low-carbon fuels, batteries, and hybrid systems. This transition presents an opportunity to modernise onboard energy use, particularly for cooling and heating, which are critical in hot climates. Unlike land-based facilities that benefit from integrated systems, marine vessels often operate refrigeration, air conditioning, and heating separately, leading to inefficiencies. As hybrid systems reduce the availability of waste heat, technologies like thermal energy storage (TES) can help balance energy demand and improve efficiency. Waste heat recovery (WHR) and the use of cryogenic fuels such as liquefied natural gas (LNG) offer additional opportunities to recover energy and reduce fuel consumption.

4.4 Safety management

Refrigeration systems on board fishing vessels must comply with international safety standards such as EN-378, as well as national and/or regional maritime regulations and classification society requirements. Design decisions should be based on thorough risk assessments and coordinated with relevant stakeholders, including insurers and regulatory bodies.

Most refrigerant is contained within machinery spaces equipped with leak detection, ventilation, and restricted access, especially when flammable substances are used. Non-flammable refrigerants are preferred in working areas for safety reasons. Carbon dioxide (CO_2) is increasingly used in marine applications due to its suitability for low-temperature systems and its non-flammable nature, though it requires careful system design to manage toxicity risks. Fluorinated gases, while common, can degrade into corrosive byproducts, posing risks to equipment. Overall, safe and efficient refrigeration design depends on appropriate material selection, containment strategies, and crew training.

DEVELOPMENT PERSPECTIVES AND CHALLENGES

5

Despite the widespread use of refrigeration systems in the fishing sector, there remains significant potential for innovation to improve energy efficiency, system control, and equipment sizing. Optimising these systems can lead to lower fuel consumption and reduced emissions, especially on larger vessels where automation and early fault detection can enhance performance and reduce maintenance needs.

Small RSW systems are particularly underdeveloped, yet they are essential for small-scale vessels, which make up the majority of the global fleet. Targeted research and development in this area can help maintain catch quality and support sustainability.

However, the rising temperature of seawater, especially in tropical and subtropical regions, poses an additional challenge. There will probably be a higher need for refrigeration to preserve the catch. Warmer intake water also reduces the efficiency of RSW systems, requiring greater energy input to achieve the same cooling effect. This not only increases fuel consumption but also places more stress on refrigeration equipment, potentially shortening its lifespan and increasing maintenance costs. Designing systems that can adapt to higher ambient and seawater temperatures is becoming increasingly important for future-proofing marine refrigeration.

In marine transport, many refrigerated containers still rely on high-GWP refrigerants. Advancing compact, energy-efficient systems for both fishing and transport sectors is key to reducing environmental impact and supporting the transition to cleaner maritime operations.

Figure 9 | Large industrial fishing trawlers operating together in the Andman Sea (Mergui Archipelago, Myanmar)

CONCLUSIONS AND RECOMMENDATIONS

6

The global fishing sector faces a dual challenge: the lack of adequate onboard chilling systems leads to significant food loss, while the continued use of high-GWP refrigerants threatens environmental integrity and public health. Addressing these issues is not only a matter of technological upgrade – it is a strategic imperative for sustainable development.

Transitioning to energy-efficient refrigeration systems that utilise natural refrigerants offers a transformative opportunity. These systems are already commercially available and increasingly adapted for small-scale vessels, which make up the majority of the global fleet. Their adoption can drastically reduce food waste, improve seafood quality, and mitigate climate and environmental impacts.

This transition must be guided by a **"One Health" approach**, recognising that the health of people, animals, and ecosystems are deeply interconnected. Reducing harmful refrigerant emissions protects marine biodiversity, prevents contamination of food chains, and contributes to healthier communities. Sustainable refrigeration is therefore not just a technical solution – it is a public health intervention, an environmental safeguard, and a food security strategy.

To realise this vision, coordinated global action is needed. This includes:

- **Policy mandates** for onboard chilling and freezing systems.
- **Education and training** for fishers and operators.
- **Regulatory enforcement** to phase out harmful refrigerants.
- **Investment in innovation** for scalable, low GWP refrigerant technologies.
- **Digitalisation** to optimise operations and reduce emissions.

By integrating sustainability and safety into fisheries refrigeration strategies, we can support healthier marine ecosystems, improve resource efficiency, and enhance the long-term viability of the sector.

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ABBREVIATIONS AND ACRONYMS

AC	Air conditioning
CFC	Chlorofluorocarbon
CO2	Carbon dioxide (R-744)
COP	Coefficient of performance
CSW	Chilled seawater
CTES	Cold thermal energy storage
FAO	Food and Agriculture Organization
GHG	Greenhouse gas
GWP	Global warming potential
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefin
IMO	International Maritime Organization
LNG	Liquefied natural gas
NH3	Ammonia (R-717)
ODP	Ozone-depleting potential
PFAS	Per- and polyfluoroalkyl substances
RSW	Refrigerated seawater
TES	Thermal energy storage
WHR	Waste heat recovery

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