

DECARBONISATION ACROSS SECTORS - WHAT CAN WE LEARN FROM EACH OTHER?

LEADING SUSTAINABLE SHIPPING TECHNOLOGIES FORUM

JOHANNES HARDING



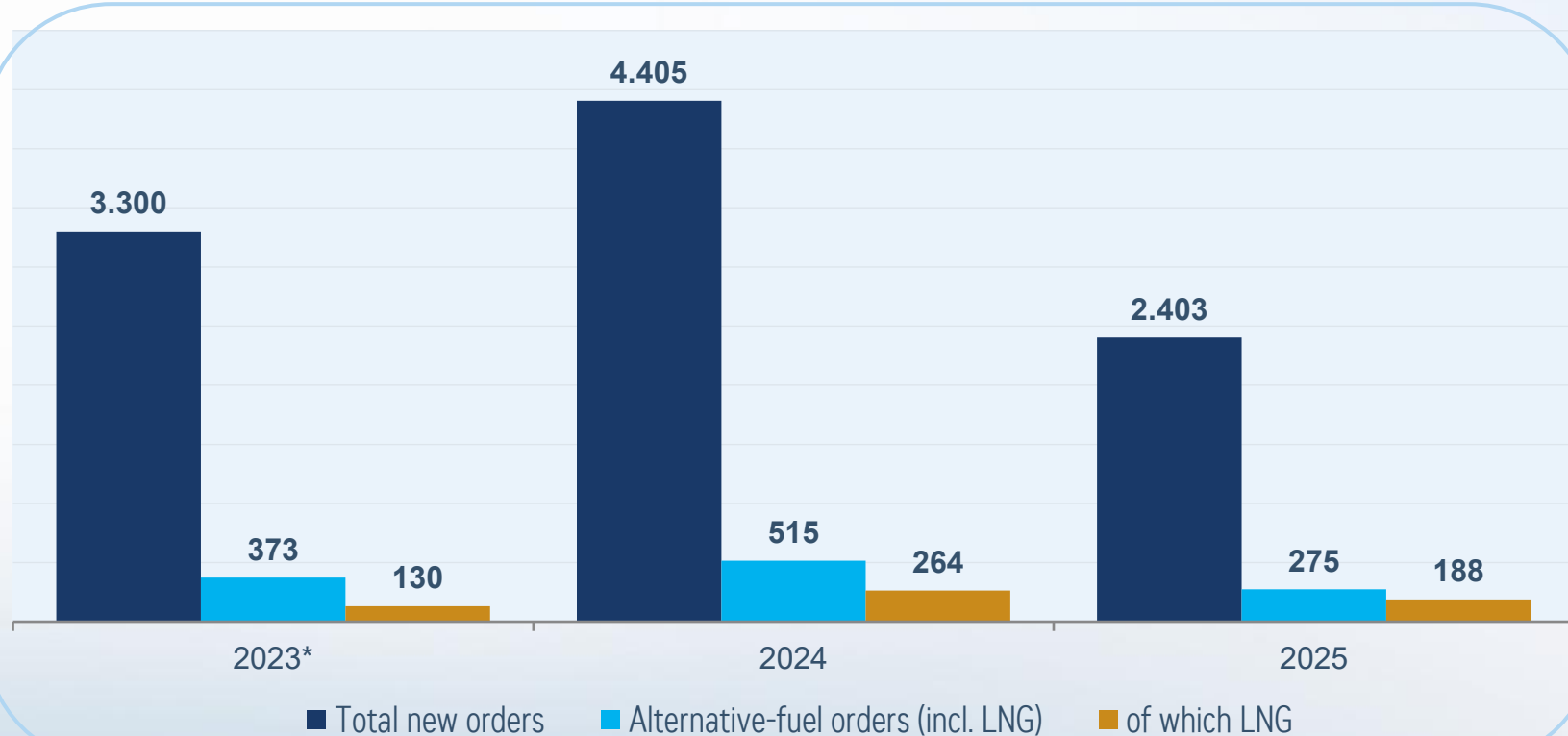
MARITIME DECARBONISATION TECHNOLOGIES EXIST, MATURITY DIFFERS ACROSS OPTIONS.

	Available today: bridge and drop-in solutions		Frontier and portfolio options						
	Biofuels HVO / B100	LNG / bio-LNG	Battery- electric	Hybrid	Methanol systems	Ammonia systems	PEM fuel cells	SOFC	Carbon capture
Regulatory status*	Drop-in, RED- certified	Fossil LNG: bridge only; bio-LNG over- complies	Zero tank-to- wake emissions	Efficiency gain; no standalone zero-emission path	Well-to-wake credit depends on green methanol	No CO ₂ at combustion; N ₂ O and toxicity open	Zero TtW emissions with H ₂ PFAS restriction risk	Zero-at-berth; >1 MW pending	Captured CO ₂ not credited
Infrastructure availability*	Existing bunkering; no new infrastructure	Widest alt-fuel bunkering; bio-LNG drop- in	Shore-power roll-out to 2030; range- limited	Existing fuel + shore charging	~20 green- MeOH ports	Bunkering trials only	H ₂ bunkering voluntary	Compatible with existing fuels	CO ₂ offloading and storage infrastructure still limited
Technical and commercial maturity*	Fully commercial	Fully commercial	Commercial in niche	Established	Commercial scale-up	First commercial use expected 2026	Commercial niche	Accelerating pilots	Validated pilots
Typical application*	 Any ship (drop-in)	 Container, large deep-sea	 Ferries, harbour craft	 Tugs, ferries, IWW	 Deep-sea 2S + high-speed 4S	 Deep-sea 2S only	 Yacht / short- sea	 Auxiliary, large ships	 Retrofit fossil fleet

² * Maturity: propulsion technology, not fuel availability. Infrastructure: bunkering and charging. Regulatory status: recognition under FuelEU Maritime, EU ETS and RED, with open safety and chemical-law questions flagged separately. Zero-emission / TtW (tank-to-wake) refers to on-board emissions only. Typical application: illustrative.



MARITIME MARKET UPTAKE REMAINS LIMITED DESPITE AVAILABLE TECHNOLOGY OPTIONS.



Number of new vessel orders. "Alternative fuels" includes fossil LNG and does not equal zero-emission vessels. Sources: DNV AFI (excl. LNG carriers); Clarksons; *2023 total from S&P/IHS (different database, limited comparability).



- Alternative-fuel orders: around 11 % of total orders in each year shown
- LNG accounted for 68 % of alternative-fuel orders in 2025, while total alternative-fuel orders declined
- Ammonia and LPG remain marginal

Takeaway

- Alternative-fuel vessel orders remain a minority of total new orders.
- **Hypothesis:** drop-in fuels and compliance flexibility reduce the immediate pressure to adopt fundamentally innovative technology.

WHILE EU SHIPPING RULES ARE IN FORCE, A BINDING GLOBAL GHG FUEL STANDARD HAS NOT YET BEEN ADOPTED.

GLOBAL · IMO

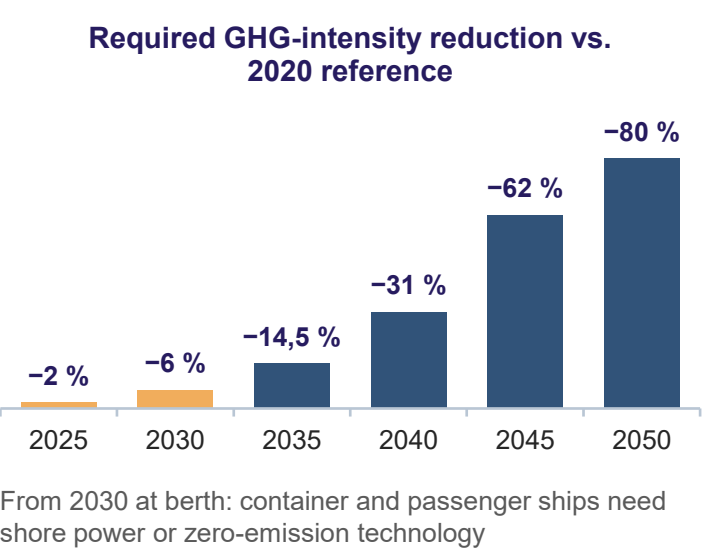
Net-Zero Framework: approved in draft, not adopted
Planned global fuel standard + GHG pricing for ships > 5,000 GT

- **Apr 2025 · MEPC 83**
Draft approved
- **Oct 2025 · MEPC/ES.2**
Adoption adjourned for one year
- **Apr 2026 · MEPC 84**
Working group to rebuild consensus
- **Dec 2026 · MEPC 85 (planned)**
Extraordinary session scheduled to resume on 4 Dec

No binding effect expected before 2028

REGIONAL · EU

FuelEU Maritime: in force since January 2025
Limits the GHG intensity of energy used on board (well-to-wake) · ships > 5,000 GT at EU ports ·
100 % of intra-EU and 50 % of extra-EU voyages



First reporting year (2025)
92 %
of ships complied through pooling
 $\approx \frac{1}{3}$
of the reduction came from LNG, the rest from biofuel blends
~2035
for some vessel profiles, fossil LNG may support compliance into the early-to-mid 2030s, depending particularly on methane slip

Takeaway

- > First compliance steps can largely be met with existing fuels and pooling (shared compliance balances across ships and operators).
- > This limits the immediate pressure for technology shifts, but not the long-term need for deeper decarbonisation.



HEAT REGULATION IS ALSO EVOLVING, YET LARGE HEAT-PUMP CAPACITY HAS GROWN STRONGLY SINCE 2023.

Regulatory snapshot

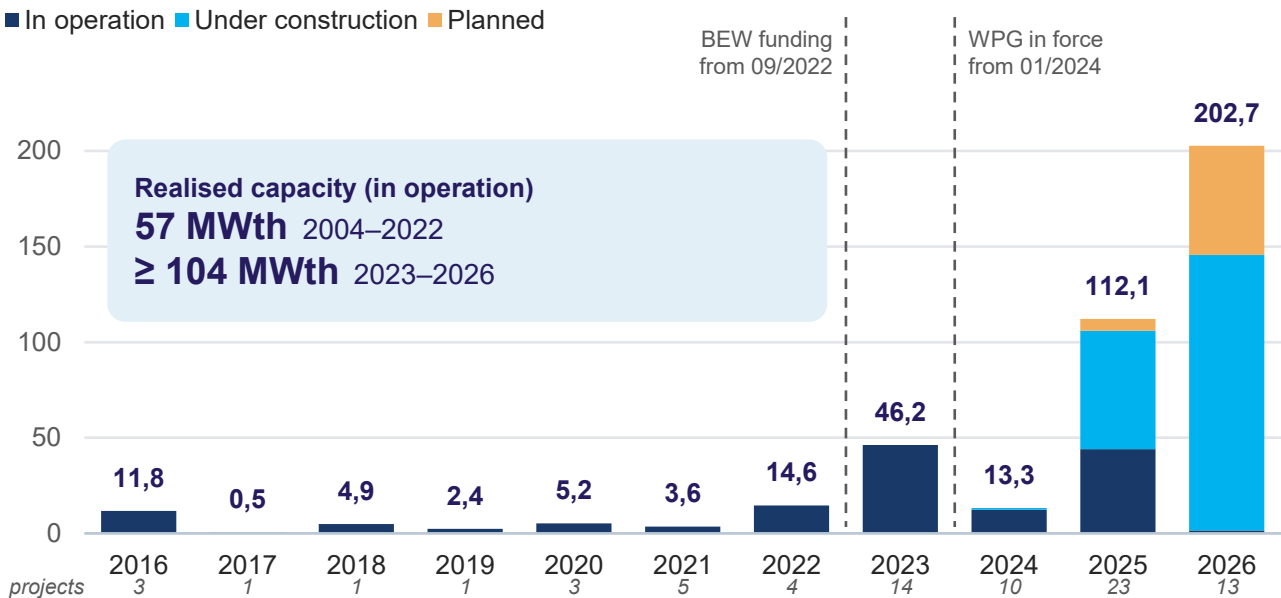
Building mandate (GEG) and heat planning (WPG)

- 2023**
GEG amendment passed
- Jan 2024**
GEG and WPG entered into force
- Jul 2026**
GModG passed; 65 % building rule repealed
- From 2030**
Binding network target: at least 30 % renewables or waste heat

**The obligation applies network by network.
It cannot be pooled or relocated.**

Market uptake in Germany

Large heat-pump capacity (MWth) by scheduled commissioning year and project status



Takeaway

- Realised capacity since 2023 already exceeds the 2004–2022 total, and a much larger pipeline is under construction or planned. Possible drivers:
 - **Funding:** BEW support for project implementation
 - **Municipal clients:** Over 80 % of projects from municipal utilities
 - **Regional scope:** Regulation, infrastructure and investment meet locally
 - **Place-bound infrastructure:** A heat network cannot relocate

ZEPELIN PROVIDES DECARBONISATION SOLUTIONS FOR MARITIME APPLICATIONS, MUNICIPAL HEATING AND OTHER SEGMENTS.

Maritime solutions and development direction

Battery- hybrid



Battery hybrid: scalable 30 kWh system | LFP | C-rate 1 | type approval pending

Methanol dual-fuel retrofit



CAT/MaK methanol retrofit: for C32 and above

Active Equipment Connect



Active Equipment Connect: Diagnostics and system analysis

Fuel Cell Solutions



PEM and SOFC solutions

Reference project: 4 MWth large-scale heat pump



Technical configuration

- **Heat source:** treated wastewater (sewage treatment plant)
- **Heat supply:** district heating network
- **Configuration:** 2 × 2 MWth large-scale heat pumps
- **Integration:** innovative CHP (iKWK) project with advanced control technology