Methane slip reduction technologies and the enabling conditions for renewable hydrogen-derived fuels

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Background——why we need green fuel for shipping

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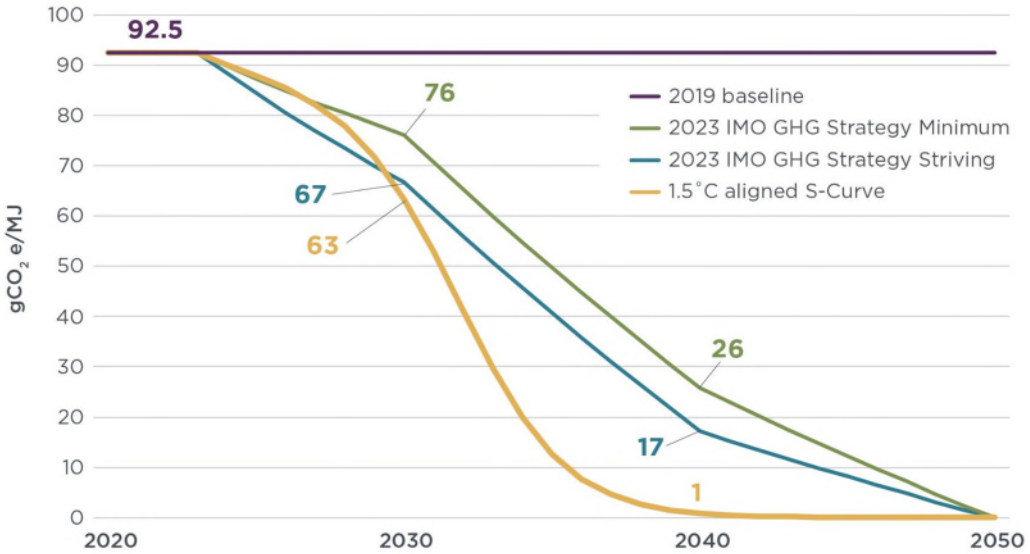
IMO's GHG strategy target

- To reach the IMO's GHG strategy target, the GHG emission intensity of fuel must be reduced by at least 18% by 2030, and by 72% by 2040.
- To get 1.5°C-aligned target, even higher GHG reduction of fuel.



Scenario	Metric	2027	2030	2035	2040	2045	2050
Minimum IMO target	GHG intensity	82	76	50	26	12	0
	Reduction from 2019 baseline	11%	18%	46%	72%	87%	100%
"Striving" IMO target	GHG intensity	77	67	41	17	8	0
	Reduction from 2019 baseline	17%	28%	56%	81%	91%	100%
1.5°C-compatible	GHG intensity	82	63	13	1	0	0
	Reduction from 2019 baseline	11%	32%	86%	99%	100%	100%

https://theicct.org/aligning-the-imos-greenhouse-gas-fuel-standard-with-its-ghg-strategy-and-the-paris-agreement-jan24/

The methane slip from LNG ships, and reduction technologies

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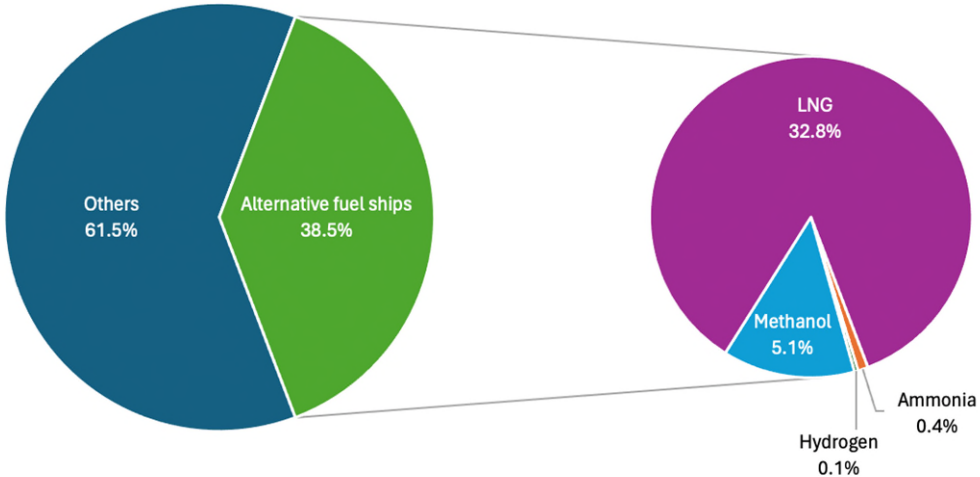
Alternative fuel ship market (2023-2026)

For the ships to be delivered 2023-2026:

- In GT, over 60% of new-built ships are still conventional fossil-fuel ships.
- Over 85% of the alternative fuel ships are LNG ships.
- Besides LNG ships, methanol looks a main choice in the next few years.



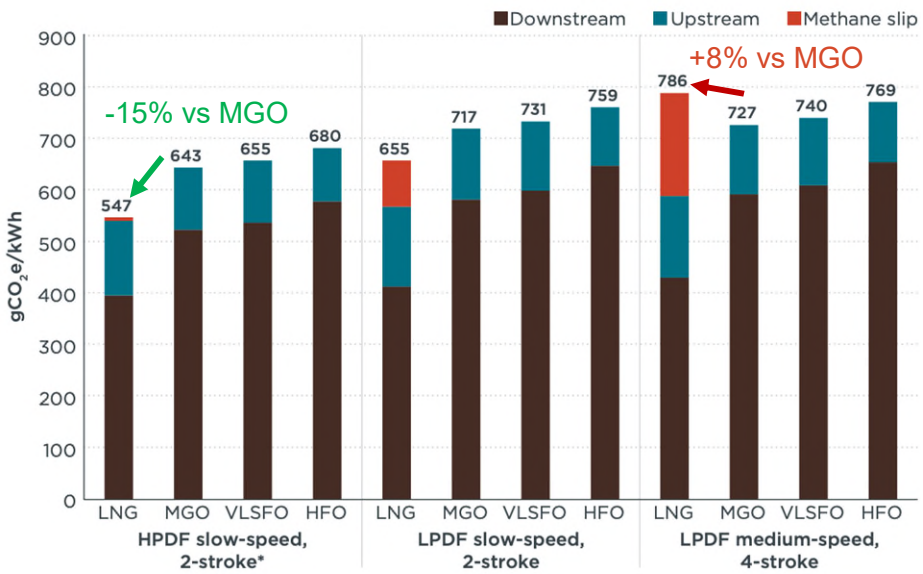
Marine LNG engines come in two main varieties; unfortunately, the most popular (and cheapest) engine type is the leakiest

- Lean Burn Spark Ignited engines (LBSI); Low Pressure Dual Fuel engines (LPDF); High Pressure Dual Fuel engines (HPDF); Steam Turbine engines (ST)

Least leaky:	Most leaky:
HPDF: High-pressure, dual fuel, 2-stroke, slow-speed (<100 rpm)	LPDF: Low-pressure, dual fuel, 4-stroke, medium-speed (~500 rpm)
~0.15% methane slip	~3.5 to ~4.5% methane slip
>90 ships, mainly LNG carriers, as well as container ships	>400 ships, mainly LNG carriers as well as cruise ships

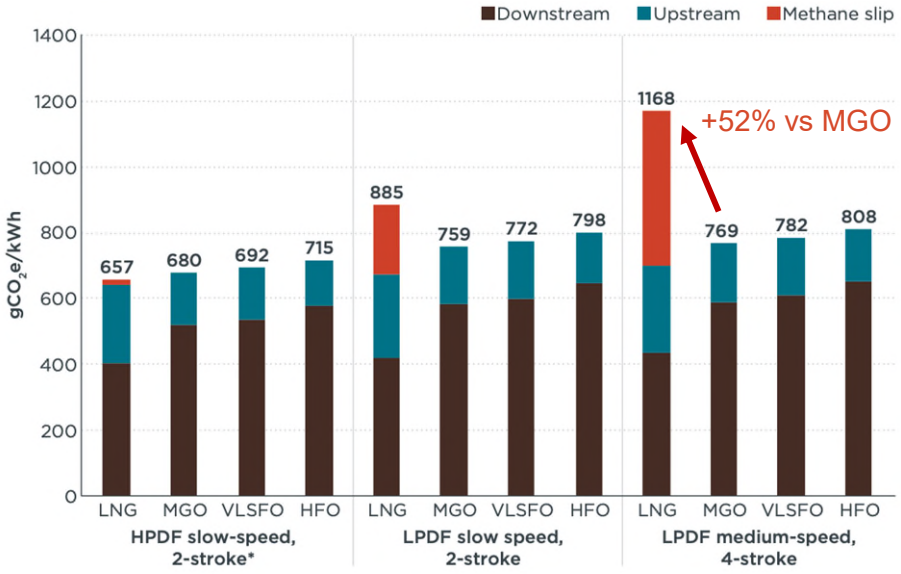
Pavlenko et al. (2020). *The climate implications of using LNG as a marine fuel*. Available at the International Council on Clean Transportation website at https://theicct.org/publications/climate-impacts-LNG-marine-fuel-2020

LNG's life-cycle GHG reduction potential is limited due to methane slip



*SSD has similar life-cycle emissions as HPDF for conventional fuels.

Life-cycle GHG emissions by engine and fuel type, **100-year GWP**



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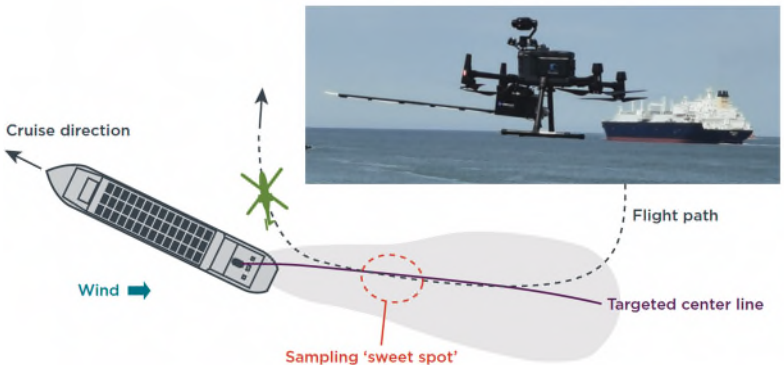
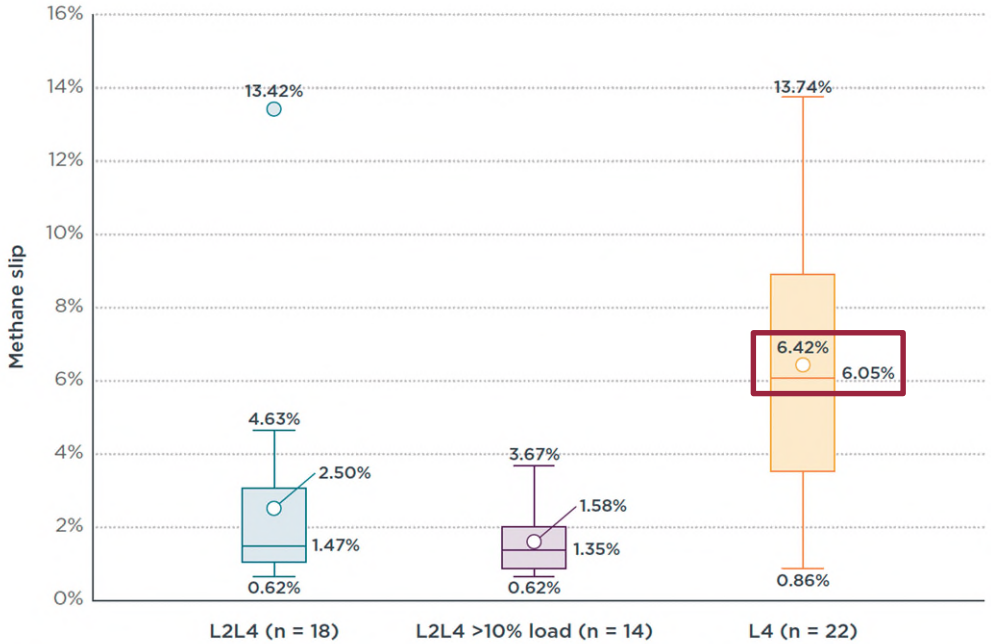
The real-world methane slip might be worse than we thought

Real-world fugitive emissions from LNG ship:

- Methane slip from low pressure 4-stroke (L4) LNG engine with mean value of 6.42%
- Comparing to the assumption in FuelEU and IMO's work（3.1% and 3.5%）, the real-world methane slip is even worse.

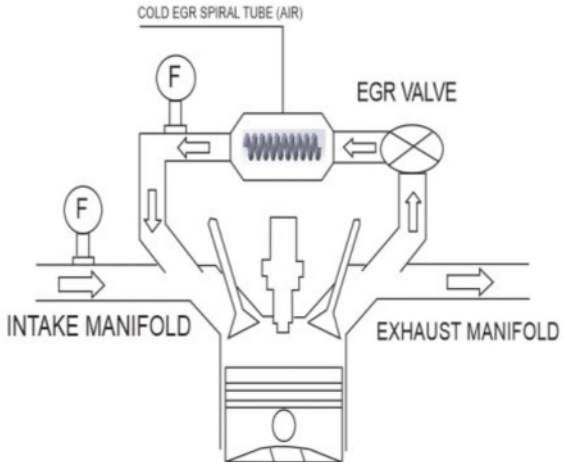


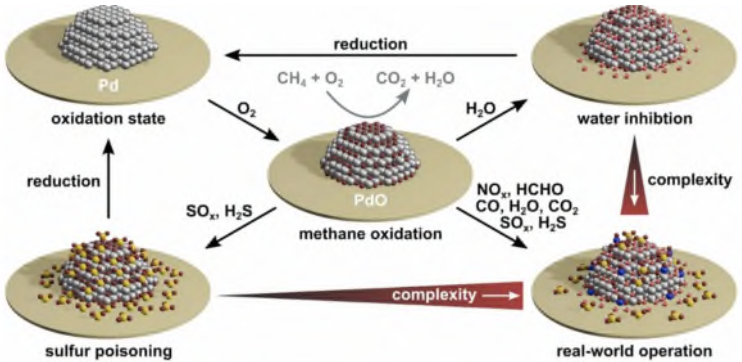


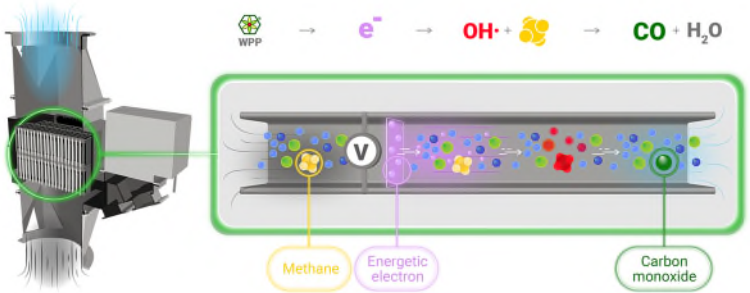
Note: Dot shows outliers; whiskers show minimum and maximum (excluding outliers); circle inside box is the average; horizontal line is the median; box is the interquartile range.

Methane slip reduction technologies

- Engine technologies
  - high pressure (direct) injection
  - exhaust gas recirculation (EGR)
  - engine tuning and control software
- After-treatment technologies
  - Methane oxidation catalyst (MOC)
  - Plasma reduction systems (PRS)







Limits/challenges of the technologies

	Engine Optimization (20%)	Methane Oxidation Catalysts (70%)	Direct gas injection (90%+)
How	Optimize combustion.	Convert CH_4 to CO_2 and H_2O.	Inject gas into the cylinder at high pressure.
Tradeoff	Increased NO_x emissions.	Additional capital, operating, and maintenance costs.	Requires NO_x aftertreatment, increasing capital, operating, and maintenance costs.
Limitation	Could require expensive exhaust aftertreatment technologies for NO_x compliance.	Pilot fuels and lubrication oils contain contaminants that can render MOCs ineffective. Work poorly under low temperature.	High costs of retrofitting, including downtime.
Verdict	**Plausible**	**Unlikely**	**Unlikely**

Enabling conditions for renewable hydrogen-derived fuels

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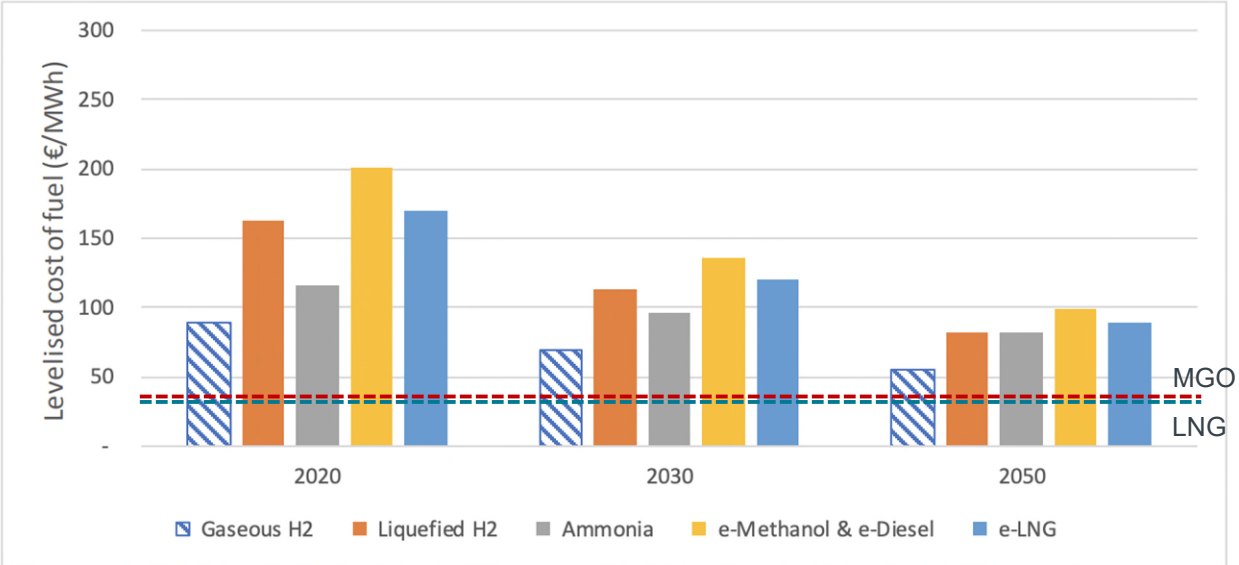
Cost challenges for renewable hydrogen-derived fuels

- For now, the cost of the renewable hydrogen-derived fuels are much higher than conventional fossil fuels
- With maturity of technologies, the cost would not reach breakeven point
- Incentive policies/punishment policies would be essential



Medium-term measures from IMO under development

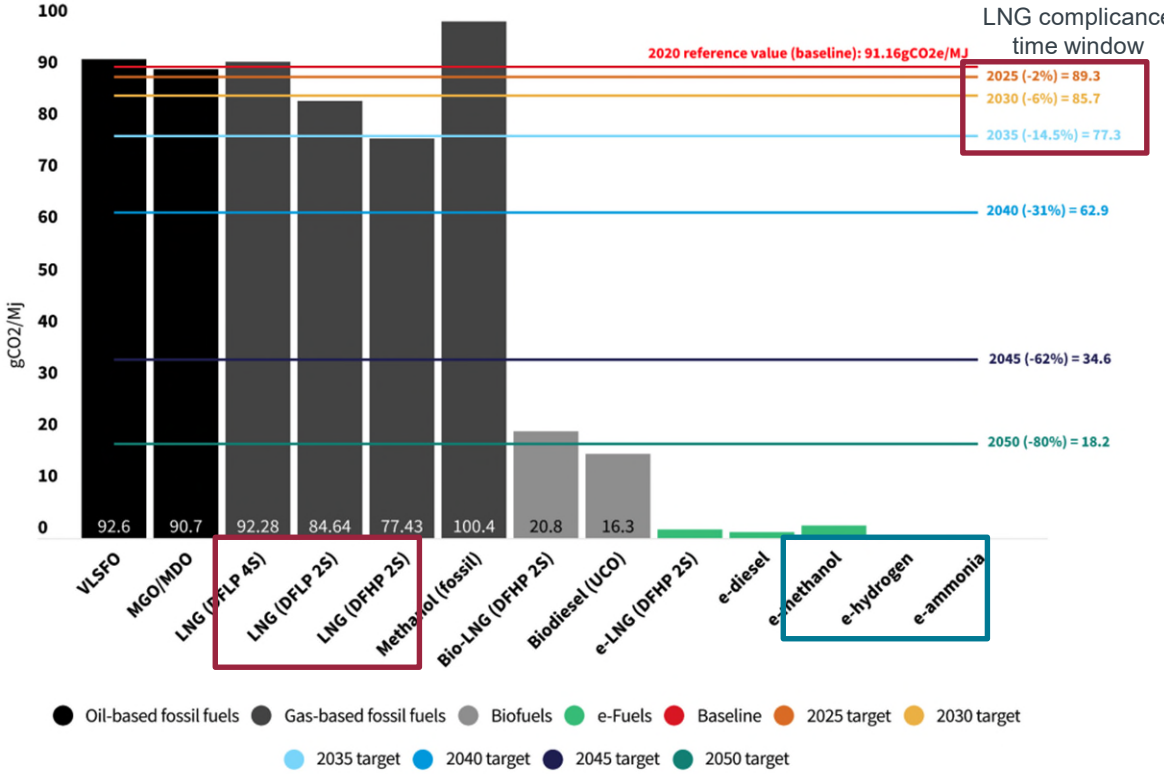
Basket of candidate mid-term GHG reduction measures:

MEPC 80 (3-7 July 2023) adopted the 2023 IMO Strategy on Reduction of GHG Emissions from Ships. The 2023 GHG Strategy states that a basket of candidate measure(s), delivering on the reduction targets, should be developed and finalized comprised of both:

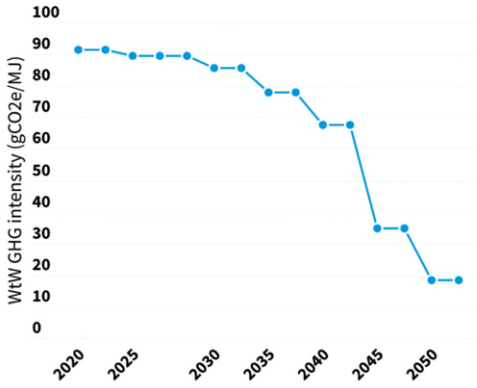
1. a technical element, namely a goal-based marine fuel standard regulating the phased reduction of the marine fuel's GHG intensity;

2. an economic element, on the basis of a maritime GHG emissions pricing mechanism.

Regulation under FuelEU Maritime



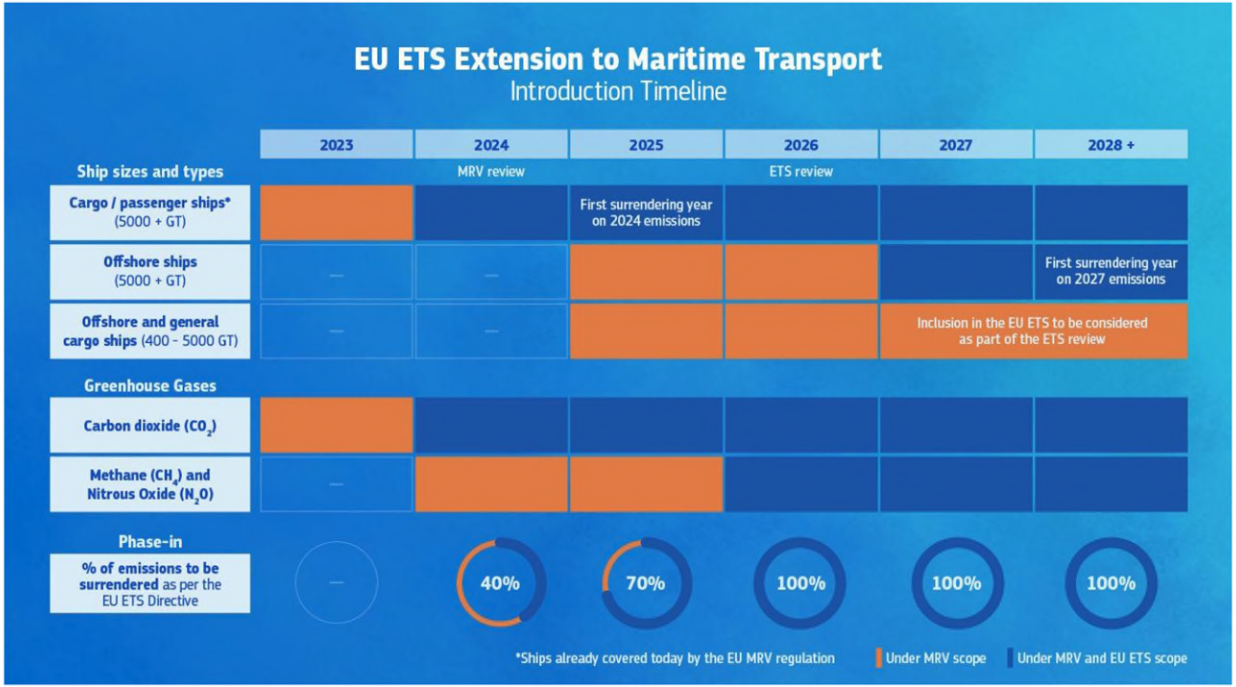
FEUM	Reduction targets	GHG thresholds (gCO2e/MJ)
2020 baseline		91.16
2025-2029	-2%	89.34
2030-2034	-6%	85.69
2035-2039	-14.5%	77.94
2040-2044	-31%	62.90
2045-2049	-62%	34.64
2050+	80%	18.23



https://te-cdn.ams3.digitaloceanspaces.com/files/202307_FUEM_Explainer_Briefing_2023_TE.pdf

EU-ETS

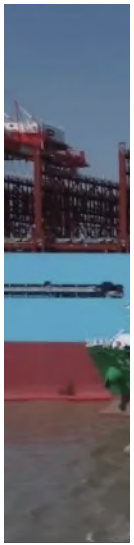
- Since 2024, covering maritime transport
- Shipping companies have to surrender allowances for GHG emissions
- The levy will be reallocated to support shipping decarbonization in EU

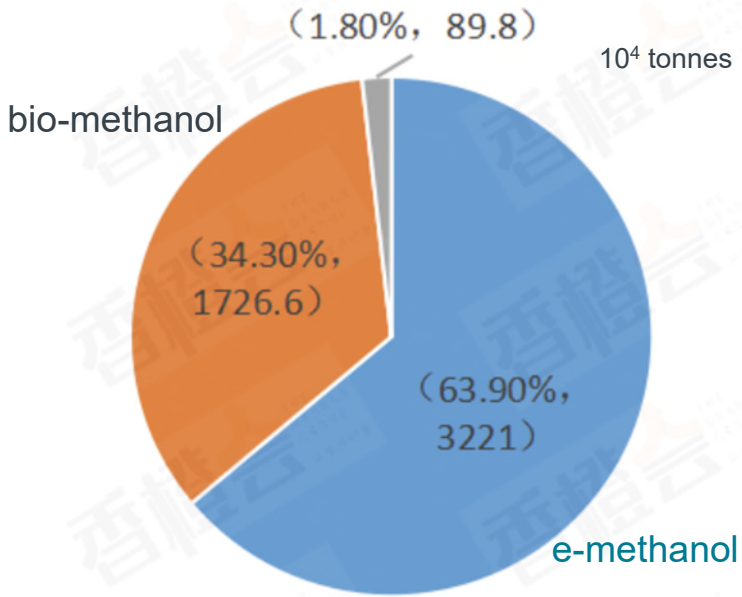


https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector/faq-maritime-transport-eu-emissions-trading-system-ets_en#buying-and-surrendering-allowances-in-the-union-registry

Enabling conditions in China

- In 2024, Astrid Maersk berthed at Yangshan port in Shanghai for the first green methanol bunkering with simultaneous cargo and bunkering operations in China.
- With over 100 green-methanol production projects, over 50 million tonnes capacity
- August 2024, National Energy Administration published ‘Tackle key problems of green liquid fuel technology and pilot industrialization’, providing loan support, and CCER support





New incentive policy in China

- Broader coverage to all sized ships
- Broader coverage for new/clean energy ship

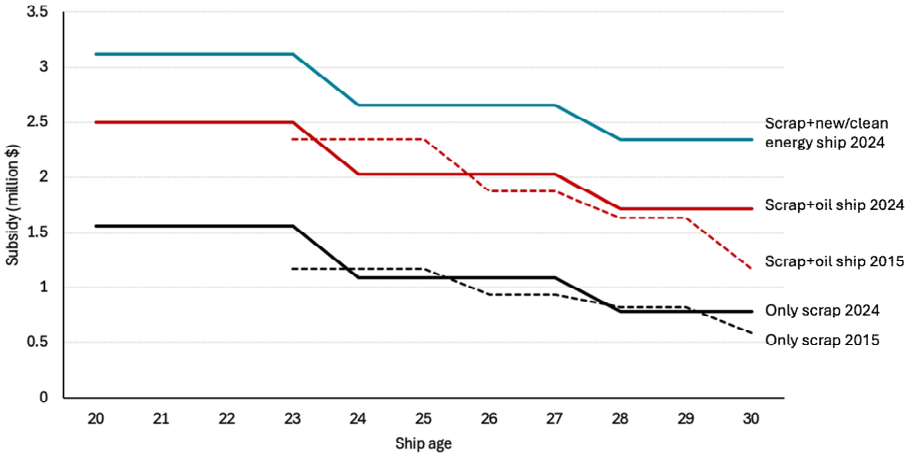
交通运输部 国家发展改革委关于印发《交通运输老旧营运船舶报废更新补贴实施细则》的通知

交规划发〔2024〕95号

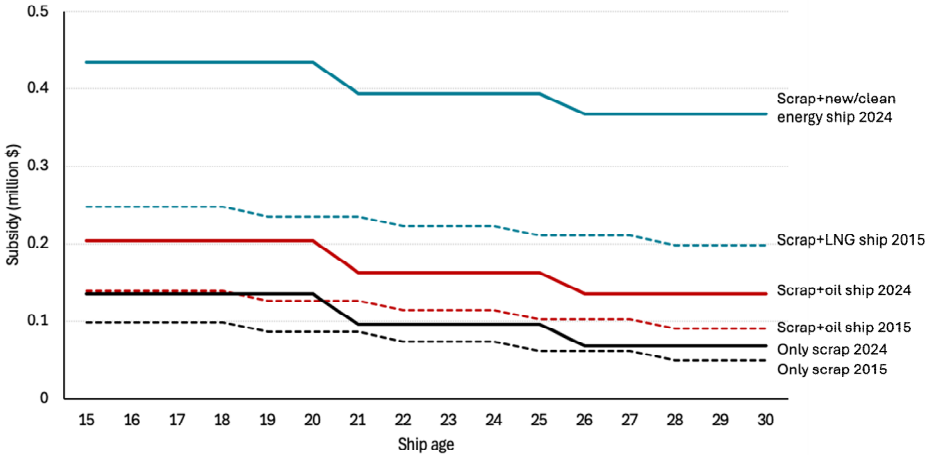
	Subsidy policy year	ship type	DWT (tonne)	GT (tonne)	ship age (year)
Qualification requirements of subsidy to early scrapping	2015	coastal ship	• ≥600 for single- hull oil tanker • none for others	≥1,000 for others	1-10 years before mandatory retirement
	2024		/	/	• 20-30 for cargo ship • 15-25 for passenger ship
	2015	inland-river ship	• ≥600 for single- hull oil tanker • none for others	• ≤200 for ship in Beijing-hangzhou Canal trunk line • ≤300 for ship in Xijiang trunk line • none for others	• 15-30 for cargo ship, 15-36 for cargo ship in Heilongjiang River system • 10-25 for passenger ship
	2024		/	/	• 15-30 for cargo ship • 10-25 for passenger ship
Qualification requirements of subsidy to new-built ship	2015	coastal ship	/	≥GT of the early scrapped one	/
	2024		/	/	/
	2015	inland-river ship	/	≥400	/
	2024		/	/	/
		New/clean energy options			
Additional subsidy to new-built new/clean energy ship	2015	LNG			
	2024	Methanol, hydrogen, ammonia, LNG, battery-electric			

New incentive policy in China

- Stronger support comparing to previous policy in 2015
- More subsidy to new-built new/clean energy ship



Subsidy to a 10,000 GT coastal bulk carrier



Subsidy to a 1000 GT inland-river bulk carrier

Conclusions

Conclusions

LNG ships

- LNG's life-cycle GHG reduction potential is limited due to methane slip
- Even with methane slip reduction technologies, fossil-based LNG will not be a finally option

Enabling renewable hydrogen-derived fuels

- There are economic policies/fuel regulations exist/coming soon, enabling the application of renewable hydrogen-derived fuels, both from international and China domestic perspectives.

Thanks!

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