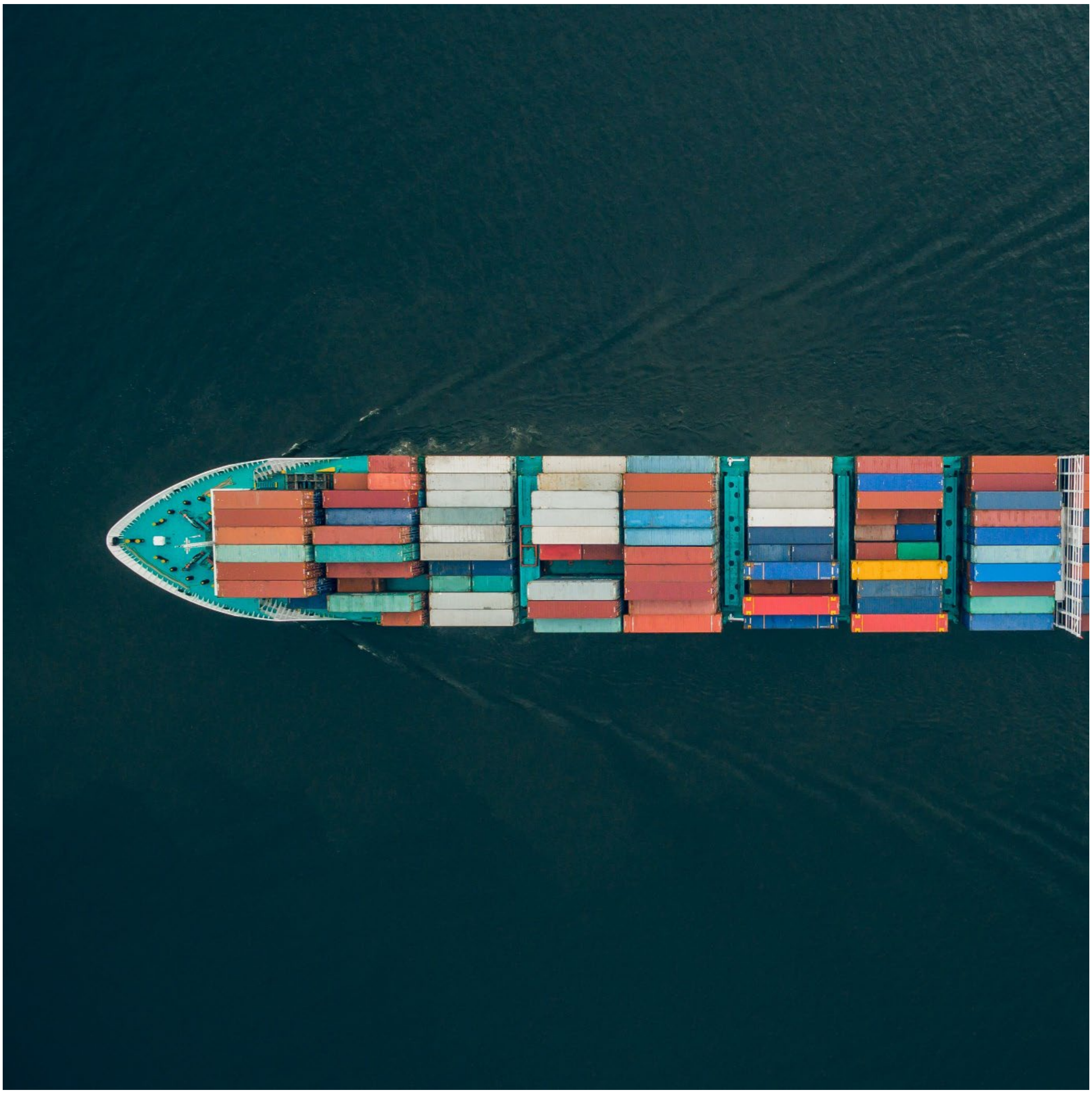
ATTENTION ALL SHIPPING

METHANOL GAINS MOMENTUM

INDUSTRY BACKGROUND FROM LONGSPUR RESEARCH



21 March 2023

Adam Forsyth
adam.forsyth@longspur.com
+44 (0) 131 357 6770

DECARBONISING SHIPPING

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21 March 2023

Research
Adam Forsyth
adam.forsyth@longspur.com
+44 (0) 131 357 6770

Max Campbell
max.campbell@longspur.com
+44 (0) 131 357 6771

Distribution
Adam Robertson
adam.robertson@longspur.com
+44 (0) 203 940 6602

ATTENTION ALL SHIPPING

Methanol is gaining traction as a shipping fuel largely because of new regulation at the IMO and in Europe. Methanol can deliver a viable route to compliance which can keep up with ever tightening regulation by offering both retrofit and replacement options and then allowing grey and lower emission methanol to be blended to meet compliance needs. As a result, we predict a total addressable annual market for methanol in shipping of 179MT HFO equivalent by 2050, which could almost double current methanol demand.

Growing orders for methanol fuelled vessels

There has been a significant growth in deliveries and orders of methanol fuelled vessels since we published our analysis of the decarbonisation of shipping last year (All At Sea; Methanol and Shipping. Longspur Research 22 January 2022). There are now over 100 methanol fuelled vessels in operation or on order with tankers representing the bulk of existing vessels but containerships dominating new orders. We see this demand as being driven by new and potential emission regulations.

IMO tightens sulphur controls in Mediterranean

The International Maritime Organisation has designated the Mediterranean as an Emission Control Area for sulphur oxides from 1 May 2025. This means that vessels cannot use very low sulphur fuel oil and will need to find alternatives which could include methanol given its negligible sulphur characteristics. The inclusion of the Mediterranean means ships using the Suez Canal as a gateway to the Mediterranean will be covered. The IMO is also introducing tightening energy efficiency limits requiring vessels to improve overall emissions efficiency and this could tighten further towards a 2030 target of a 40% reduction in CO2 emissions.

EU proposes significant tightening of shipping emissions

The EU is also tightening emissions for shipping, with a preliminary agreement to include shipping in the EU emission trading scheme (EU-ETS) from 2024, introducing taxation of marine fuels under the Energy Taxation Directive and perhaps most significantly, introducing significant emission penalties under the FuelEU Maritime Initiative.

Methanol is a key part of the decarbonisation toolkit

These changes could make existing maritime fuels more costly than low carbon alternatives as early as 2025. Methanol from natural gas (grey methanol) already offers some key advantages such as lower tank-to-wake emissions, complying with EMA sulphur limits and an ability to be blended with low carbon methanol to comply with the evolution of EU GHG limits. We see this flexibility as making it a strong option for ship owners now and as a result we see the fuel becoming a major part of the decarbonisation toolkit.

Industry background from Longspur Research

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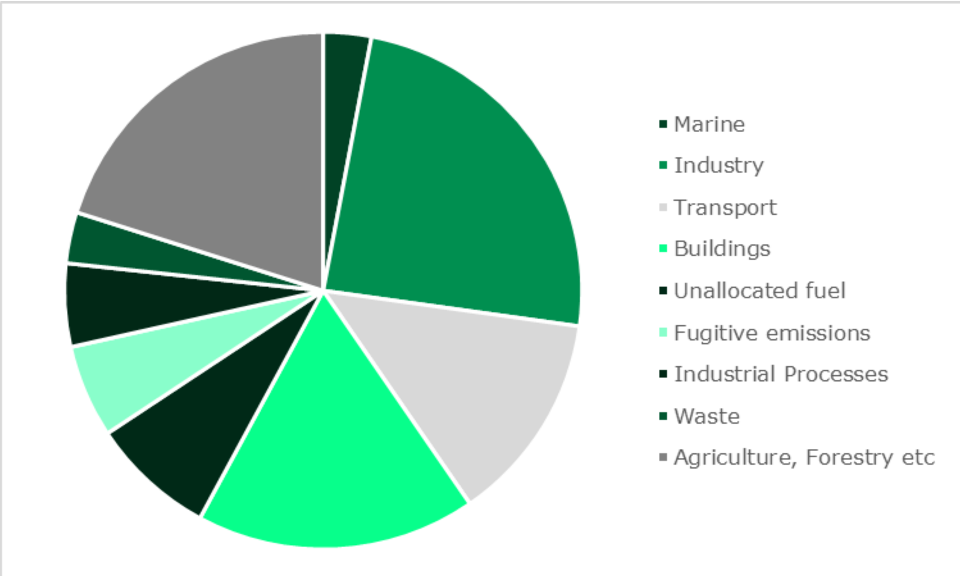
METHANOL AND SHIPPING

Last year we published an evaluation of options for the decarbonisation of shipping where we highlighted the benefits of methanol as a leading option given its ability to integrate into existing supply chains and offer an instant emissions reduction with grey methanol and a pathway to a genuine lower carbon solution in e-methanol and bio-methanol.

Since then, we have seen a range of ship owners moving towards methanol as a fuelling option and we have today published a more detailed look at methanol itself. We see this as particularly timely due to the introduction of stricter emissions regulation notably in the EU. Additionally, the IMO has now included the Mediterranean in its Emission Control Areas. This captures traffic using the Suez Canal as a gateway to the Mediterranean which is brings a substantial proportion of global trade.

The marine industry emits approximately 1 billion tonnes of carbon dioxide (CO_2) annually and accounts for around 3 - 4% of total global greenhouse gas (GHG) emissions. This is equivalent to the total annual CO_2 emissions of Germany. The IMO forecasts these emissions to grow by up to 130% from 2008 levels by 2050 with no further decarbonisation efforts[1].

Marine Emissions vs Global Total Emissions

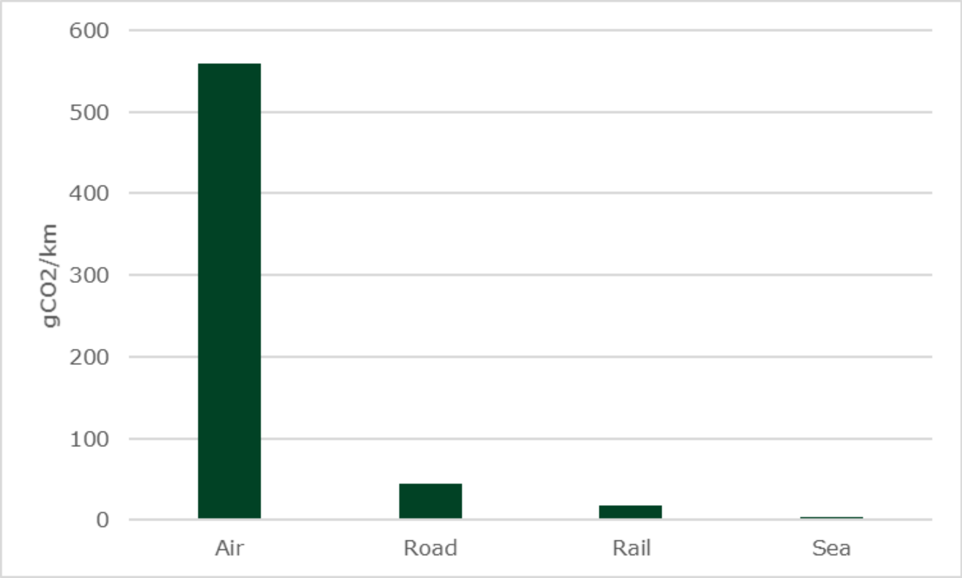


Source: Climate Watch, the World Resources Institute, IMO

The bulk of emissions are CO_2, but other greenhouse gases are emitted including methane and nitrous oxide (N_2O) with 100-year global warming potentials relative to CO_2 of 21 and 310 times respectively[2]. Additionally, acid rain gas SOx and ozone layer damaging NOx are emitted. Despite these emissions, shipping remains the lowest emission form of transport per kilometre travelled.

1. International Maritime Organisation Fourth Greenhouse Gas Study 2020
2. United Nations Intergovernmental Panel on Climate Change Second Assessment Report 1995

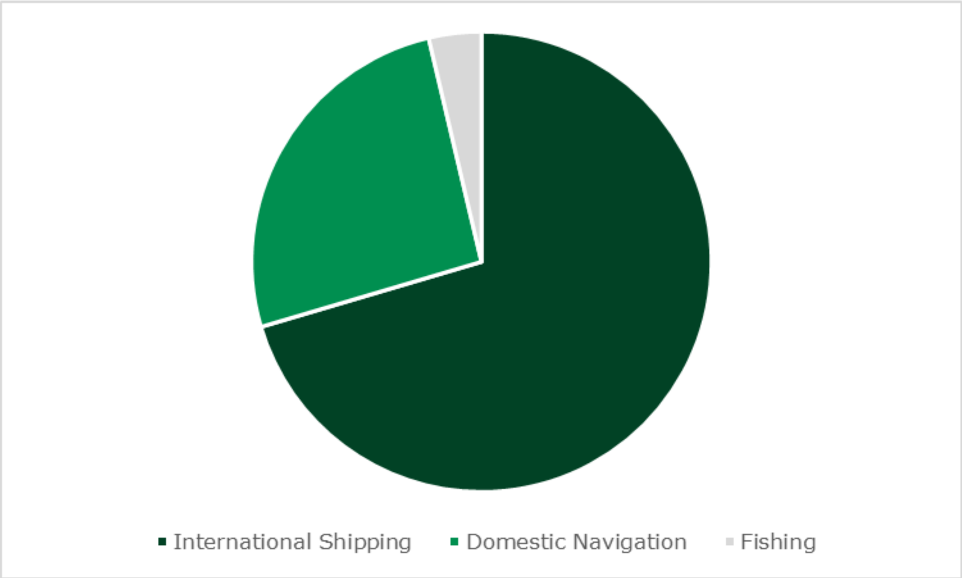
CO2 emissions per km



Source: CMS

The vast bulk of fuel consumption is from long distance larger vessels with container ships, bulkers and tankers together making up 80% of all fuel consumption.

HFO-equivalent fuel consumption by range related grouping



Source: Fourth IMO GHG Study 2020 (2018 data)

While electrification is key to the decarbonisation of land transport, the ranges involved in international shipping makes battery solutions less optimal and means that low carbon liquid fuels are key to decarbonising this sector.

WHY METHANOL IS BEST IN THE LONG RUN

There are a number of viable routes to marine decarbonisation including batteries, biofuels, hydrogen and hydrogen carriers. Batteries are only really suitable for short voyages; perfect for ferries and bumboats. The hydrogen-based options are liquified hydrogen, ammonia and methanol. All currently rely on natural gas for production but can be produced with the emissions captured to create "blue" fuel or, better still, using renewable energy to produce "green" fuel although ammonia has remaining N2O emission considerations. Only methanol dual fuel engines are currently available.

It can be seen that batteries are severely limited by density as far as long-haul shipping is concerned. Hydrogen in gas form is also limited but liquid hydrogen is acceptable as is ammonia. Biomethane and methanol are much closer to the high density seen in fossil fuel solutions.

For long haul, liquid fuels allow for the longer range required. Emission reductions are greatest for biomethane, green ammonia, green methanol and hydrogen. However, ammonia has a question mark over nitrous oxide emissions which can potentially increase its global warming potential as a fuel. It also has useability concerns given its toxicity and associated handling requirements. And the very high well to tank emissions of grey ammonia make it less suitable as transition option.

Hydrogen scores well on these areas with the possible exception of flammability although we think concerns here tend to be overstated. Methanol also does well given its relative lack of ecotoxicity and although some care is required to avoid human consumption this is easily managed.

Finally, while hydrogen has a low levelized cost at the point of production it is the point of delivery that matters and here methanol is the lowest cost.

Sustainable fuel options summarised

Criterium	Hydrogen	Ammonia	Methanol	LNG	Li-ion	HFO
GHG reduction potential	5	4	5	5	5	1
Density	2	3	4	4	1	5
Cost	2	1	3	1	2	5
Useability	4	3	4	3	4	3
Average	3	3	4	3	3	4

Source: Longspur Research based on Oko Institut eV

METHANOL THE BEST SOLUTION AVAILABLE TODAY

Taking all these factors into account suggests methanol is the best solution available today. Firstly, it is commercially and widely available today, and is technology proven so can be selected for new build (major shipyards have been building methanol-fuelled vessels for some time) or it can be retrofitted to existing fleets. It is dense enough to be useable without significantly displacing load capacity and it is useable without too many hazards. It can be bunkered vessel to vessel or shore to vessel. Finally, it is the lowest cost option at the point of delivery.

Other options should not be ruled out as individual use cases will work better with some solutions than others. Notably lithium-ion batteries will find markets in short haul shipping such as ferries and possibly OSVs.

MOMENTUM BUILDING FOR METHANOL

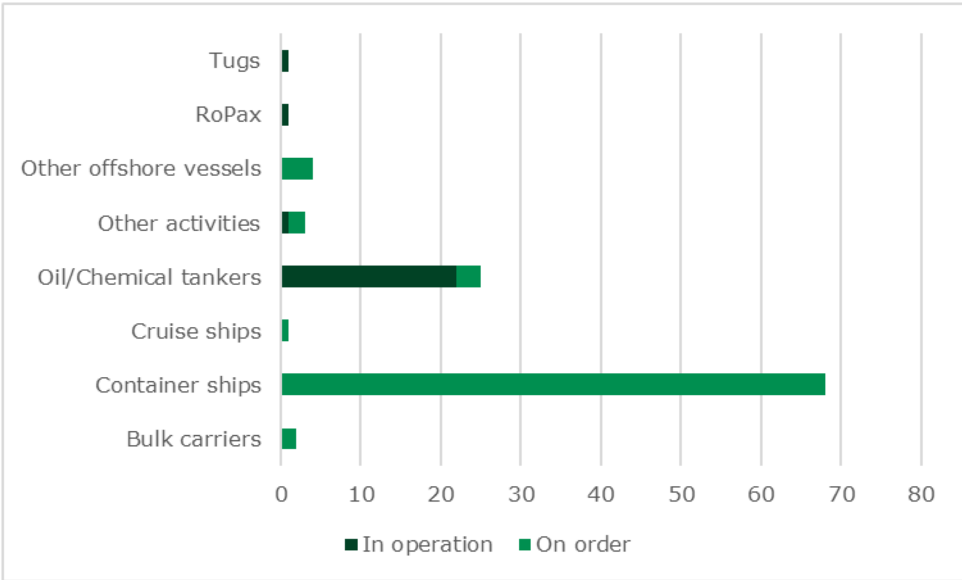
There are currently 25 methanol fuelled vessels in operation representing just 0.04% of gross tonnage. However, momentum is building.

In 2019 Stena Line formed a joint venture with Proman, Proman Stena Bulk, and ordered six vessels. 2021 saw this followed when Maersk announced that it had ordered two duel fuelled methanol feeder vessels from a Korean shipyard. It then announced an order for a further eight ocean going vessels and an approved option for an additional four vessels.

Maersk has now increased its commitment to 19 methanol-fuelled vessels and shipping major COSCO, which is now the largest operator by deadweight tonnage (dwt) in each of containerships, bulkers and tankers, has ordered 12 methanol fuelled containerships. Recently Hyundai Samho Heavy Industries has announced the receipt of an order for 12 methanol fuelled very large container ships (VLCS) from an unnamed counterparty.

The most recent DNV Alternative Fuels Insight shows 25 methanol fuelled vessels in operation and a further 81 on order taking the total of existing and on-order vessels to 106.

Methanol vessels in operation and on order



Source: DNV Alternative Fuels Insight

The bulk of existing vessels are tankers but new orders are dominated by container ships.

A PROVEN TECHNOLOGY

As a technology methanol fuelled engines are well proven. MAN Energy Solutions has provided over 20 of the engines in existing ships on the water and these have over 200,000 operational hours since their first introduction in 2016.

Alternative fuel vessels in operation and on order

	LNG	LPG	Methanol	Hydrogen
Bulk carriers	68		2	
Car ferries	129			
Car/passenger ferries	45			
Container ships	224		68	
Crude oil tankers	89			
Cruise ships	39		1	8
Fishing vessels	7			
Gas tankers	15	149		
General cargo ships	21			
Offshore supply ships	33			
Oil/Chemical tankers	88		25	
Other activities	21		3	9
Other offshore vessels	1		4	
RoPax	33		1	5
Ro-Ro cargo ships	15			
Tugs	38		1	1

Source: DNV Alternative Fuels Insight

REGULATION IS THE KEY DRIVER

A key driver in the uptake of methanol has been the strengthening of emission regulations with both the IMO and the EU seeking stricter controls.

IMO

In 2022 the IMO amended the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI. From 1 January 2023, all ships must calculate their attained Energy Efficiency Existing Ship Index (EEXI) which measures their energy efficiency compared to a baseline, the Energy Efficiency Design Index (EEDI). All vessels of 400 gross tonnage (gt) and above will be covered. New vessels are already covered under the EEDI which sees tighter assumptions based on reference lines according to ship type. Each ship type must then show a percentage reduction against these lines with four phases of reduction depending on the year in which the ship is built.

EEDI for new build vessels rules that ships delivered after 2015 must meet toughening fuel efficiency targets. Ships delivered under Phase 1 (2015), Phase 2 (2020), and Phase 3 (2022 or 2025, depending on ship type) of the EEDI are required to reduce their carbon intensity by 10%, 20%, and 30% or more.

Existing ships are covered by EEXI and must also meet efficiency targets which vary by vessel but can be 30% or even higher with a 50% reduction in carbon intensity consumption required for the largest container ships.

EEXI efficiency targets

Ship type	Size (dwt or gt)	Reduction factor
Bulk carrier	10,000 – 19,999	0 – 20%*
	20,000 – 199,999	20%
	200,000+	15%
Gas carrier	2,000 – 9,999	0 – 20%*
	10,000 – 14,999	20%
	15,000+	30%
Tanker	4,000 – 19,999	0 – 20%*
	20,000 – 199,999	20%
	200,000+	15%
Container ship	10,000 – 14,999	0 – 20%*
	15,000 – 39,999	20%
	40,000 – 79,999	30%
	80,000 – 119,999	35%
	120,000 – 199,999	45%
	200,000	50%
General cargo ship	3,000 – 14,999	0 – 30%*
	15,000+	30%
Refrigerated cargo carrier	3,000 – 4,999	0 – 15%*
	5,000	15%
Combination carrier	4,000 – 19,999	0 – 20%*
	20,000	20%
LNG carrier	10,000+	30%
Ro-ro cargo ship (vehicle)	10,000+	15%
Ro-ro cargo ship	1,000 – 1,999	0 – 5%*
	2,000+	5%
Ro-ro passenger ship	250 – 999	0 – 5%*
	1,000+	5%
Cruise passenger ship	25,000 – 74,999	0 – 30%*
	75,000+	30%

Source: International Council on Clean Transportation

Additionally, vessels must calculate their Carbon Intensity Indicator (CII) which is an annual measure of CO_2 intensity per cargo-carrying capacity (dwt, gt) and nautical mile. From 2024, vessels will be required to demonstrate a continuous fall in CII. Vessels will be rated according to performance and vessels with non-compliant performance over three consecutive years will be required to implement an approved correction plan to bring them back to at least the lowest compliant rating within a year.

Table of CII reduction factors

2023	5% reduction
2024	7% reduction
2025	9% reduction
2026	11% reduction
2027 to 2030	Review to be conducted by 1 January 2026, but expected to be in the range from 11% to 22%

Source: IMO

These moves are aimed at enforcing the IMO target of a 40% reduction in CO2 emissions from all ships by 2030 compared to a 2008 baseline. A reduction of 70% in CO2 emissions and 50% in GHG emissions is targeted by 2050 which the IMO believes to be in line with the Paris Agreement. Broadly speaking this applies to all vessels of 5,000gt and above although there are different rules for specific vessel types.

SULPHUR

The IMO has also tightened emission limits on sulphur oxides. Overall limits had already been introduced in 2020 reducing the upper limit on the sulphur content of fuel to 0.5% from 3.5% under the IMO 2020 regulation prescribed in the MARPOL Convention. Both very low sulphur fuel oil (VLSFO) and marine gas oil (MGO) are compliant and the use of sulphur scrubbers is also accepted to meet the limit. Heavy fuel oil (HFO) is not compliant and most ships have switched from this to VLSFO although some have fitted sulphur scrubbers.

The IMO also designates certain areas as Emission Control Areas where the maximum allowed sulphur content is 0.1% rather than 0.5%. These already include the North and Baltic Seas as well as coastal areas of North America and the Caribbean. In December 2022 the IMO adopted amendments to designate the Mediterranean Sea, as a whole, as an Emission Control Area for Sulphur Oxides and Particulate Matter, under MARPOL Annex VI. The amendment is expected to enter into force on 1 May 2024, with the new limit taking effect from 1 May 2025. VLSFO will not meet the tougher limit so vessel owners will need to seek alternative fuelling solutions. The inclusion of the Mediterranean is important as it captures trade through the Suez Canal which accounts for 12% of global trade and 30% of all global container traffic and taking roughly four times the tonnage of the Panama Canal.

EU

The EU Green Deal and the updated Fit for 55 programmes have brought in significantly meaningful controls for greenhouse gas emissions affecting all shipping travelling within as well as to and from EU ports. The overall aim of the Fit for 55 programme is to deliver a 55% reduction in carbon emissions by 2030. There are four separate initiatives that will affect shipping:

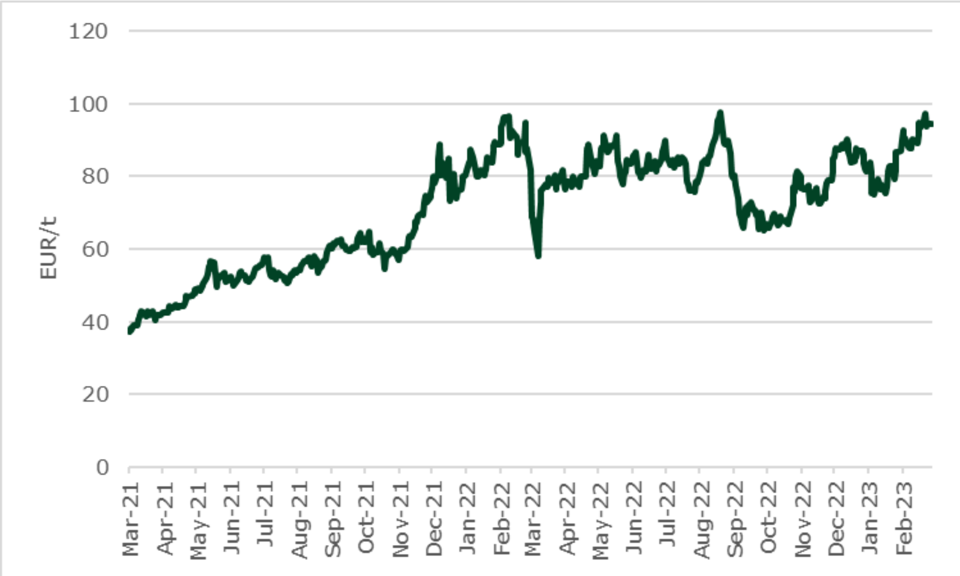
- EU ETS
- FuelEU Maritime Initiative
- Energy Taxation Directive
- Alternative Fuels Infrastructure Directive

ETS

The European Emissions Trading Scheme (EU-ETS) is a carbon credit scheme under which polluting companies are allowed a certain level of GHG emissions with the allowance represented by EU Allowances (EUAs) which can be traded if actual emissions are below the allowed level. As proposed for shipping each company with ships trading in EEA-EFTA states will be required to surrender emissions allowances corresponding to a certain amount of its emissions over a calendar year starting in 2024.

The ETS allows an efficient market driven approach to emissions abatement. Allowances are allocated at the level of member states and distributed via auction so that companies effectively have to pay for any emissions by acquiring EUAs either at auction or in the secondary market. As a result, it effectively prices every tonne of carbon emitted. In the past twelve months, EUAs have been trading in a range between €60/t and €100/t with the €100/t level broken in August 2022 and again in February 2023.

EUA prices



Source: Bloomberg

As part of the green deal, shipping is now looking likely to be included in the ETS with all vessels of 5,000gt or above transporting passengers or cargo for commercial purposes and calling at EU ports being covered from 2024 regardless of flag. 100% of emissions on voyages between EU ports will be covered as will 50% of emissions arising on all other voyages commencing or ending at EU ports. Offshore vessels will be included from 2027. Non-compliance where a company has failed to surrender allowance for two or more years can result in expulsion orders or detention of vessels.

The current proposal covers CO2 emissions released starting in 2024 onwards. Furthermore, NOx, particulates and methane are expected to be included from 2026. Emissions are tank-to-wake emissions rather than well-to-wake.

Additionally, the UK which is no longer part of the EU ETS but has its own UK ETS has indicated that it is likely to expand the UK scheme to include shipping. The draft EU legislation proposes to require EUAs to be surrendered for emissions as follows.

EU-ETS shipping phase-in

Verified emissions to be surrendered	From
40%	2024
70%	2025
100%	2026

Source: European Parliament

FuelEU Maritime Initiative

The FuelEU Maritime Initiative sets increasing cuts in vessel greenhouse gas emissions from a 2020 baseline. Failure to meet these emission targets will result in significant fines and will apply to all vessels over 5,000gtvisiting a port within the EU regardless of the vessel's flag. As with EU-ETS compliance, it will measure all emissions arising from voyages between ports in the EU and 50% of emissions arising on all other voyages commencing or ending at EU ports. The penalties for non-compliance are likely to be high with a probable payment of €2,400 per tonne of CO2 as determined by an external verifier using a prescribed methodology.

As per the EU Parliament proposal, the targets begin at a 2% reduction in GHG emissions from 1 January 2025 and rise to 80% from 1 January 2050.

FuelEU proposed GHG reductions

From 1 Jan	GHG cut from 2020 baseline
2025	2%
2030	6%
2035	20%
2040	38%
2045	64%
2050	80%

Source: European Parliament

Maritime tax - Energy Tax directive

The existing energy tax under the EU Energy Taxation Directive is due to be amended this year and will impose taxes on all marine fuel used for voyages within the EU. There will be an initial ten-year transition period where taxes will be lower but after 2033 higher rates will apply.

The taxation rates are shown below with lower carbon fuels being taxed less heavily than traditional fossil fuels.

EU Energy Tax Directive – Amended maritime tax

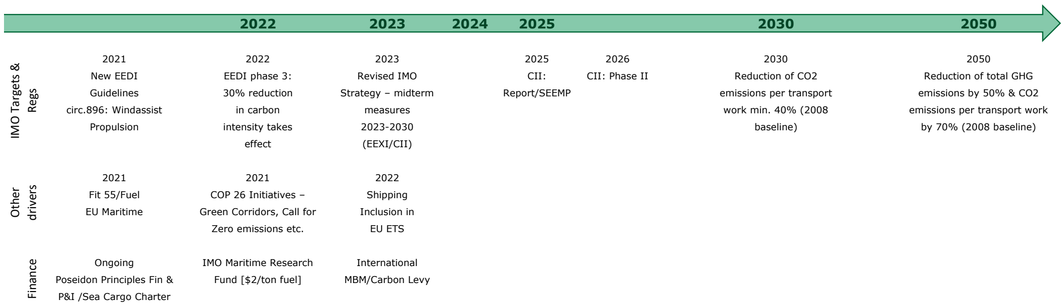
EUR/GJ	Transition period	After transition
HFO etc	0.9	0.9
LPG, LNG	0.6	0.9
Feed crop biofuel	0.45	0.9
Sustainable biofuel	0.45	0.45
Low carbon fuels	0.15	0.45
Renewable fuels	0.15	0.15

Source: European Parliament

ALTERNATIVE FUELS INFRASTRUCTURE DIRECTIVE

This is an enabling directive aimed at ensuring the development of refuelling infrastructure for low carbon solutions across Europe. It includes common design standards and includes a requirement that member states have a plan for national policies for the use and provision of infrastructure for alternative fuels for shipping. It will also provide for green electricity access in ports as well as access to LNG refuelling.

Summary of regulatory developments



Source: Anemoi

HOW THE EU MEASURES WILL ALTER THE ECONOMICS OF SHIPPING

We have calculated the costs of the various EU measures per MWh of marine engine output as a way of comparing fuels and assessing the relative costs of each. We have shown the main fossil fuels including hydrogen, ammonia and methanol made using existing natural gas based processes; the so-called grey fuels. We have compared these with green fuels, biomethane derived LNG, hydrogen from electrolysis with renewable electricity, ammonia from green hydrogen and the Haber Bosch process and finally either bio-methanol or e-methanol.

We have used the EU default carbon intensity figures for all fuels with the exception of green methanol where the default has simply used the grey methanol figure. We expect the FuelEU regulation to accept actual values where these can be demonstrated. Fuel costs are from current commodity spot prices for grey fuels where available or from estimated production costs for green fuels as calculated by Dais et al (Dias V, Pochet M, Contino F and Jeanmart H (2020) Energy and Economic Costs of Chemical Storage. Front. Mech. Eng. 6:21). See pages 22 and 23 for a fuller discussion of costs.

Impact of EU measures on fuel costs in 2025

	Fuel cost	EU tax	ETS cost	FuelEU penalty	Total cost
	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh
Grey fuels					
VLSFO	49	3	28	50	130
LNG	69	3	20	0	92
Hydrogen	193	3	0	1160	1356
Ammonia	182	3	0	859	1045
Methanol	63	3	25	296	387
Low carbon fuels					
LNG	49	1	20	0	285
Hydrogen	120	1	0	0	492
Ammonia	19	1	0	0	262
Methanol	20	1	25	0	244

Source: Longspur Research

This shows that in 2025 traditional fuelled vessels using very low sulphur fuel oil (VLSFO) are now at a cost disadvantage to LNG if sailing to EU ports or in EU waters but that other fuel options are more expensive. However, as the FuelEU targets get tougher things change. Notably by 2040, LNG is captured and is overtaken by green methanol as the cheapest option. So, on a long term view using pure green methanol is the best option but at the moment it is more expensive than VLSFO and LNG. This is not the whole story as the option to blend green and grey methanol (or ammonia) can result in more optimal solutions.

Impact of EU measures on fuel costs

	2025	2030	2035	2040	2045	2050
Grey fuels						
VLSFO	130	230	580	1030	1679	2079
LNG	92	92	133	583	1232	1632
Hydrogen	1356	1455	1805	2255	2904	3304
Ammonia	1045	1145	1495	1944	2594	2994
Methanol	387	487	837	1286	1936	2336
Low carbon fuels						
LNG	285	285	285	285	919	1319
Hydrogen	492	492	492	492	492	492
Ammonia	262	262	262	262	262	262
Methanol	244	244	244	244	244	244

Source: Longspur Research

We can work out how much low carbon fuel would be required to bring the grey fuels below the FuelEU thresholds. Initially LNG does not need any blending but again by 2040 the fact that this is not really a low carbon fuel starts to impact and it would need to be blended with biomethane and after 2045 would need to be 100% biomethane. Green methanol can be blended in relatively small quantities initially to bring grey methanol below the thresholds.

Green fuel blending levels to avoid FuelEU penalties

	2025	2030	2035	2040	2045	2050
LNG	0%	0%	8%	97%	100%	100%
Hydrogen	32%	35%	45%	57%	75%	86%
Ammonia	27%	30%	41%	55%	75%	87%
Methanol	12%	16%	29%	47%	72%	88%

Source: Longspur Research

From this we can work out the cost of the blended fuel with the avoidance of FuelEU penalties for the alternatives to VLSFO. Unblended LNG still remains the cheapest option until 2040 but methanol blends are cheaper than VLSFO across the period and the cheapest option from 2040. For those taking a long term view, with vessel lives of 30+ years in some cases, this makes methanol blends attractive even now.

Blended fuel costs to avoid FuelEU penalties

	2025	2030	2035	2040	2045	2050
VLSFO	130	230	580	1030	1679	2079
LNG	89	89	105	278	284	284
Hydrogen	289	297	326	363	417	450
Ammonia	203	206	215	226	241	251
Methanol	106	112	133	161	201	225

Source: Longspur Research

While LNG appears to be the best option in the years up to 2035 this assumed only limited methane slip. Methane slip is the release of unburnt methane from the combustion process and also the release of methane from other parts of the lifecycle. Methane is a highly potent greenhouse gas equivalent to 28 to 36 times that of CO2 when assessed over a 100 year period.

Methane slip depends on engine type and loading but can increase overall LNG emissions from the 75gCO2e/MJ level assumed in our calculations above to as much as 93gCO2e/MJ.

Methane slip ranges for different engine types

Engine Type	CH4 slip (%wt)	GHG WtW(gCO2eq/MJ)
HP2st (>25%&<85%)	0.19	76.6~77.9
LP2st without EGR (>25%&<85%)	1.1~1.4	81.3~83.1
LP2st with EGR (>25%&<85%)	0.8~1	79.5~80.9
LP4st (>50% load)	1.5~3.3	83.6~93.0

Source: Maersk Mc-Kinney Moller Center

Including methane slip, LNG starts to trigger FuelEU thresholds much earlier and at the high point will see LNG triggering the 2025 threshold. On that basis methanol looks cheaper by comparison in all years.

Blended fuel costs to avoid FuelEU penalties including CH4 slip

	2025	2030	2035	2040	2045	2050
VLSFO	130	230	580	1030	1679	2079
LNG	107	126	194	281	284	284
Hydrogen	289	297	326	363	417	450
Ammonia	203	206	215	226	241	251
Methanol	106	112	133	161	201	225

Source: Longspur Research

EVOLUTION OF INFRASTRUCTURE

The supply chain for methanol is growing. Methanol is widely produced and has been transported and used around the world for over 100 years. It is part of tested and established infrastructure. There are now more than 100 ports supplying methanol with 47 of these with storage facilities in excess of 50,000 tonnes.

Ports supplying methanol

Source: Methanol Institute Renewable Methanol Database of Methanol Ports, © 2023 Mapbox, © OpenStreetMap

It is likely that the number of ports supplying methanol will grow. Key to this will be the evolution of regulation.

Methanol bunkering is relatively straightforward. As a liquid fuel at ambient temperatures, it can be handled with similar processes to marine oil. It is no more dangerous than conventional fuels such as gasoline or diesel. In fact, because it has better dispersal characteristics, the impact of spillages on crew or on the environment are minimal, reducing the overall risk profile for the fuel.

Methanol bunkering regulation is still in its early stages of development, with very limited industry regulation in place across the globe. Lloyds Register has developed marine fuel and safe bunkering guidelines report in conjunction with the Methanol Institute which has been shared with the IMO. The Bunkering Technical Reference on Methanol aims to put in place guidelines that will allow proper regulation and make the adoption of methanol as a marine fuel straightforward for operators.

A number of companies are also taking a lead in this area including China State Shipbuilding Corporation (CSSC) which has developed an onshore methanol bunkering system. This comprises an unloading hose that transfers pressurized methanol in liquid form to the receiving ship via a ship-to-shore connection. The filling station can work on two tankers simultaneously and its maximum filling capacity is 60 tonnes/hour.

SEGMENTING THE SHIPPING MARKET

While we see methanol as the strongest contender as a solution for deep sea shipping, other solutions are likely to find markets if only because there are a vast range of use cases. Even traditional shipping has a range of different solutions ranging including low speed diesel, high speed diesel and diesel electric. We therefore see all the low carbon options of batteries, hydrogen, ammonia and methanol all finding markets.

Short voyages can be completely electric using batteries but energy density means that range becomes an issue at around 100 nautical miles. For most ferries batteries are an obvious solution. Additionally offshore service vessels may move to battery power. While range could be an issue here, the growth in offshore wind energy and also the decarbonisation of offshore oil and gas production (the irony of the zero carbon oil rig) means that an all-electric solution may become prevalent. There is also some possibility that offshore hydrogen production from wind farms becomes common as a means of dealing with wind curtailment and this could result in relevant service vessels being hydrogen powered.

Hydrogen still appears expensive at the point of delivery. It remains one of the cheaper options at the point of production but transport and storage add to the costs. There may be cases where hydrogen is being compressed anyway and there are some efficient compressed hydrogen shipping designs coming forward so these vessels are likely to be powered by hydrogen. There have been several cruise ships built powered with hydrogen as well as a number of super yachts where the low vibration and near silent running of fuel cells is considered worth paying for. Whether this becomes a preferred option over methanol for the cruise industry remains to be seen although it is difficult to see where the obvious advantage lies.

Ammonia has a similar cost and emission profile to methanol but suffers from its causticity. This means crews must be trained to a higher standard which can add cost. However, there is already a substantial seaborne ammonia trade the tankers involved already have trained crew so we would expect these to opt for ammonia as a propulsion solution. Other specialist tankers may also follow this route for similar reasons.

As a result, we see the best options for each segment as follows and from this can calculate total addressable markets for the relevant solutions based on full decarbonisation in 2050.

Low carbon shipping fuel based on 2018 usage

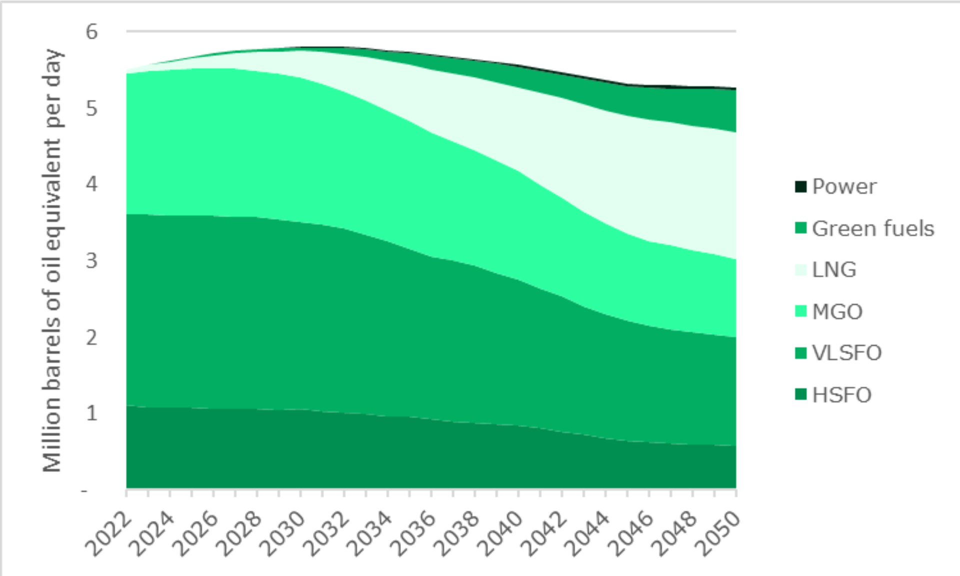
HFO equivalent kt	Total	CH3OH	NH3	LNG
Containerships	63,906	63,906		
Oil tankers	37,045	4,631	4,631	
Chemicals tankers	17,450		17,450	
Gas tankers	19,965			19,965
Bulk carriers	54,359	54,359		
General cargo	12,731	12,731		
Totals	205,456	135,627	22,081	19,965

Source: Longspur Research

STATISTICS ON UPTAKE OF ALTERNATIVE FUELS

Bloomberg New Energy Finance (BNEF) provides forecasts for marine fuels out to 2050. These show a rather disappointing uptake in green fuels with these and electric power only accounting for 11% of energy provision by 2050.

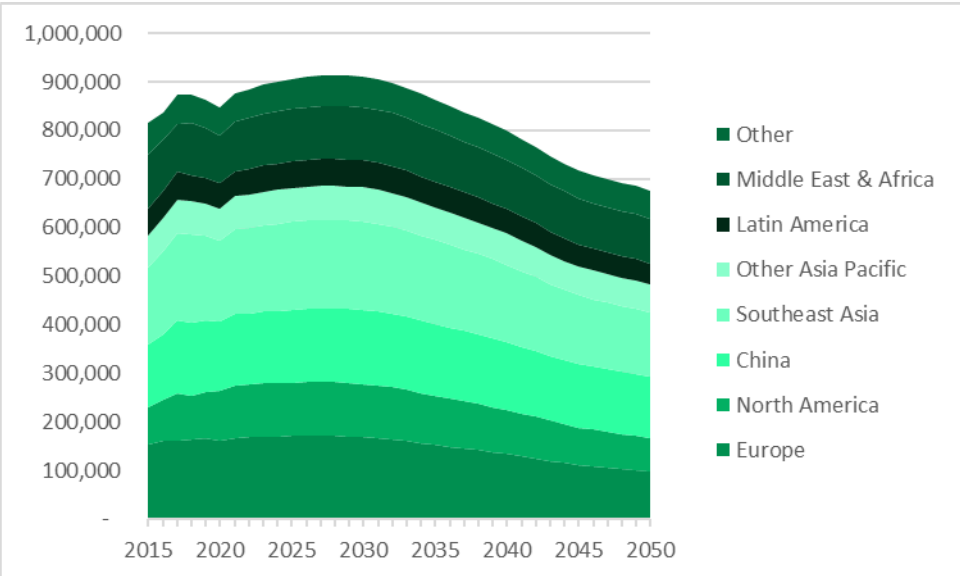
Shipping fuel demand forecasts



Source: Bloomberg New Energy Finance

Not surprisingly the emissions related to this scenario do not show a fall consistent with the net zero outcome required to keep global warming to 1.50C.

Shipping emission forecasts

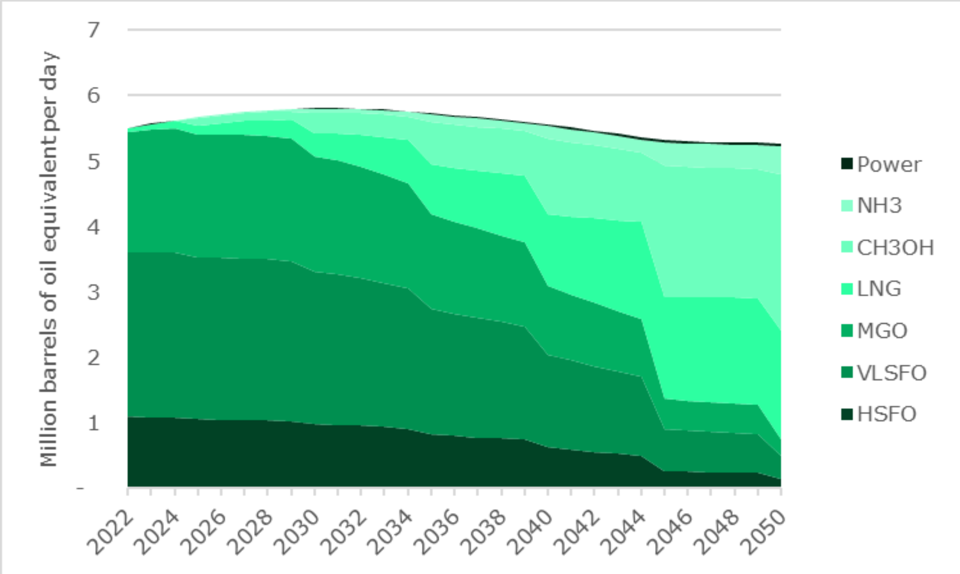


Source: Bloomberg New Energy Finance

We think that, given the EU and IMO initiatives, shipping will move more rapidly towards decarbonisation. If we use the FuelEU targets as guide to the phasing out of high emission fuels HSFO, VLSFO and MGO, we can get a picture of what a Paris compliant outcome might look like.

By restricting high emission fuels to the FuelEU targets but keeping the BNEF LNG forecasts to reflect the fact that a lot of new LNG vessels are entering the market currently we can get a picture of the remaining market for low carbon fuels. We then allocate this demand according to our assumptions between vessel types.

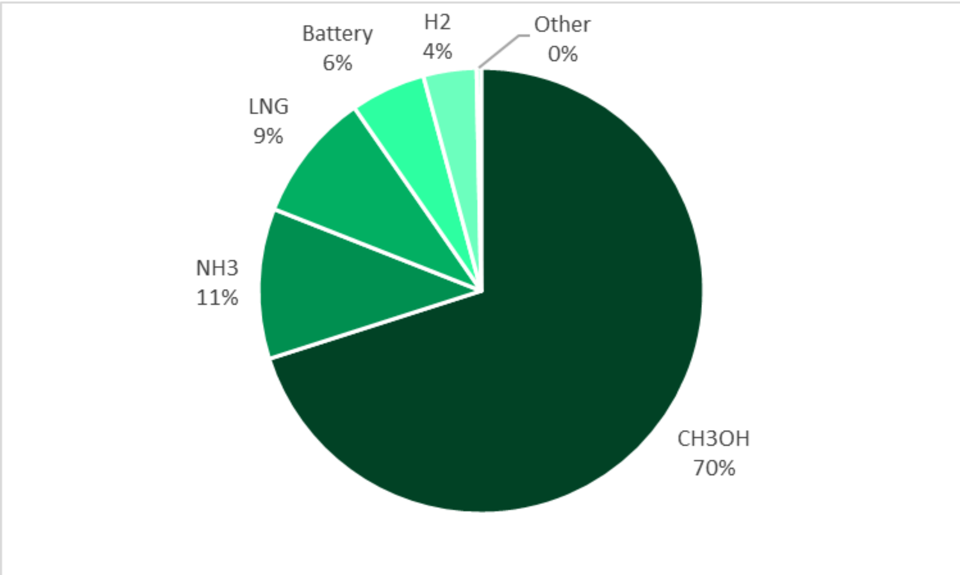
Paris compliance shipping fuel demand forecasts



Source: Bloomberg New Energy Finance, Longspur Research

The 2050 market is then split as follows which might be seen at the total addressable market for low carbon fuels. This suggests the main fuel will be methanol by 2050.

Low carbon solutions split in 2050



Source: Longspur Research

Based on this we estimate that methanol could have a total annual addressable market in 2050 of 179 Mt HFO equivalent. Current methanol demand is c.107 Mt so this represents a more than doubling of existing demand.

Low carbon shipping fuel based on 2050

HFO equivalent kt	**Total**	**CH3OH**	**NH3**	**LNG**
Containerships	88,322	88,322		
Oil tankers	38,823	4,853	4,853	
Chemicals tankers	28,036		28,036	
Gas tankers	33,354			33,354
Bulk carriers	69,150	69,150		
General cargo	16,648	16,648		
Totals	274,334	178,973	32,889	33,354

Source: Longspur Research

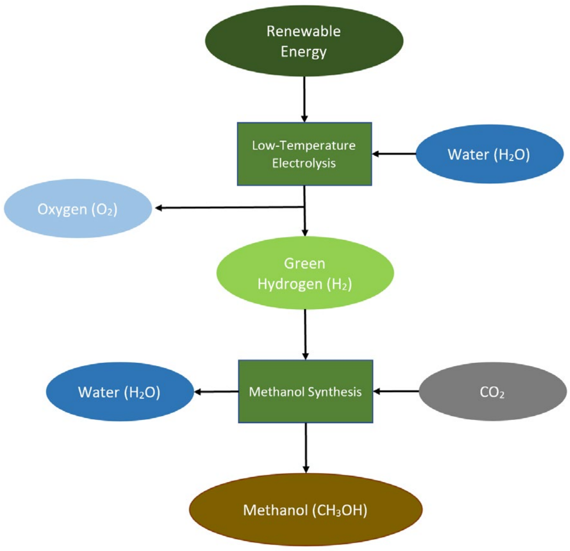
METHANOL IN DETAIL

Methanol has been identified by the IMO as a fuel that delivers climate benefits today. Methanol is four parts hydrogen, one part carbon and one part oxygen and is typically produced from natural gas through reformation of the gas with steam to produce syngas and then converting and distilling the syngas to produce methanol. This is known as 'grey' methanol and today accounts for 95% of total methanol used in the shipping industry. In saying this, grey methanol produces 80% less NOx, 99% less SOx, 95% Particulate Matter (PM) and approximately 20% less CO2 than HFO on a tank-to-wake basis according to MAN Energy Solutions, enabling compliance to the IMO's 2020 SOx emission regulations as well as the Tier III NOx emission regulations when combined with modern engine technology.

Whilst 'grey' methanol is considered a low carbon pathway fuel, the benefit of methanol is greatly enhanced through its ability to evolve into 'blue' and then 'green' methanol as these processes become more commonplace. 'Blue' methanol is produced through the utilisation of Carbon Capture and Storage (CCS) and natural gas. CCS is the process of capturing CO2 before it enters the earth's atmosphere and storing it underground or reusing it. Additionally, 'green' methanol or renewable methanol in the form of bio-methanol derived from biomass or e-methanol derived from renewable energy has potential to produce a zero-carbon fuel.

RENEWABLE METHANOL

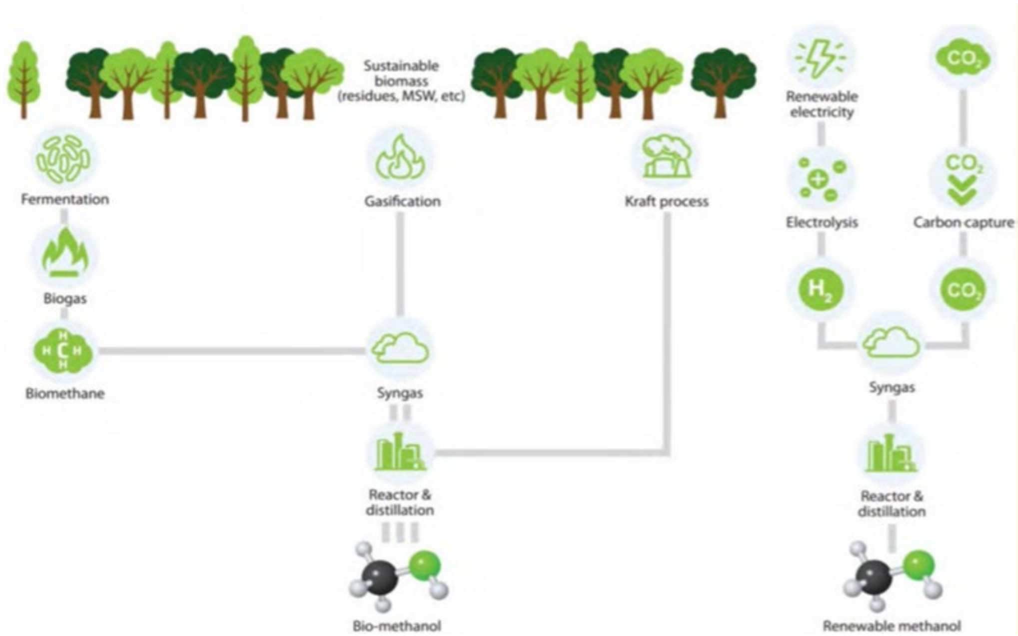
Renewable methanol process map



Source: Longspur Research

Renewable methanol can be produced using renewable feedstocks and renewable energy in the form of either bio-methanol or Green e-methanol. Bio-methanol is produced from biomass from sustainable biomass feedstocks such as forestry and agricultural waste, biogas from landfill, sewage, municipal solid waste (MSW) and black liquor from the pulp and paper industry (IRENA 2020). Green e-methanol is produced by combining green hydrogen from renewable energy through electrolysis and CO2 from carbon capture.

Bio-methanol and renewable methanol compared



Source: Proman - Sea Commerce presentation 2021

Methanol is available in over 120 ports and is already being used by over 20 ships making it the fourth most used marine fuel globally. One of the reasons for this is the ability of methanol to be stored and transported using current infrastructure as it remains in liquid form at normal air temperature and pressure. Bunkering is already available on a vessel to vessel or shore to vessel basis.

Additionally, methanol is considered the safest alternative fuel with a long history of handling in both shipping and a number of other energy applications. In addition to being easily handled and transported, methanol is a clear and biodegradable liquid and when spilled in water quickly dilutes to non-toxic levels with no environmental effects or damage to marine ecosystems. The safety of methanol was confirmed in November 2020 with the IMO's approval of guidelines for methanol to be used as a safe ship fuel.

Engine Technology Capabilities

Considerable progress has been made in recent times to enable methanol to be used as a drop-in fuel or dual fuel using current engine technologies. Both Wartsila and MAN have developed methanol dual fuel engines built using the same technology as diesel fuel engines with nominal changes needed at little cost. One operator already has over 200,000 hours of safe operation of methanol dual fuel engines.

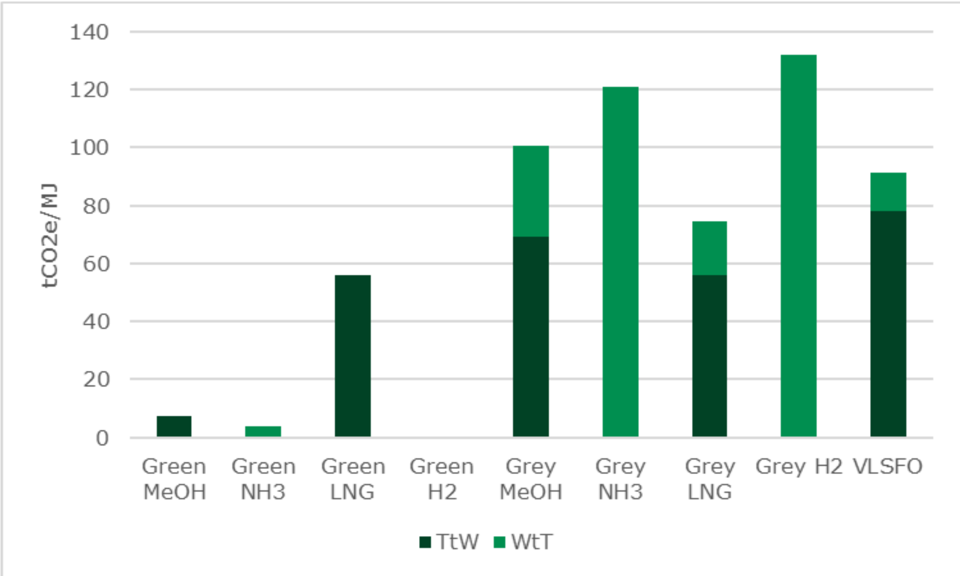
EMISSIONS

Using very low sulphur fuel oil (VLSFO) as a reference point, the International Convention for the Prevention of Pollution from Ships (MARPOL) calculates 3.114 tonnes of CO2 per tonne of fuel (tCO2/t fuel) tank-to-wake. Alternative fuels ammonia and hydrogen have similarly high emissions when produced using fossil fuels given the high amount of energy required in the production process. In fact, hydrogen and ammonia produce 64% and 48% more well-to-wake emissions when compared to VLSFO when using fossil fuels in the well-to-tank process. Hydrogen is emission free tank-to-wake given that water is the only bi-product of the process and burning ammonia will require pilot fuel for combustion given its low flammability as well as potential NOx emissions. Based on the need for a pilot light, CO2 emissions are calculated at 0.098tCO2/t fuel tank-to-wake assuming the ammonia is produced from green hydrogen which has zero CO2 emissions.

LNG from fossil fuels reduced emissions by 12% at 2.750tCO_2/t fuel when compared to VLSFO tank-to-wake according to MARPOL with the potential to reduce CO_2 emissions by 100% well-to-wake when using bio-LNG and even result in negative emissions when CO_2 is captured in the process. This is based on burning LNG in a dual fuelled diesel engine. However, a high level of energy is required for green bio-LNG and CCS and will only be feasible when the price of renewable electricity becomes more competitive and CCS technology further develops.

Based on the EU default levels, grey methanol actually has slightly higher CO_2 emissions than VLSFO on a well-to-wake basis and grey hydrogen and grey ammonia are even higher. Grey methanol does have reduced SOx, particulate matter and NOx emissions, something which VLSFO cannot provide. Green methanol using hydrogen produced from electrolysis of water and CCS capturing CO_2 can enable nearly 100% reduction in CO_2 well-to-wake if all the CO_2 is captured with only small emissions from the combustion of pilot light fuel.

Well-to-wake emissions



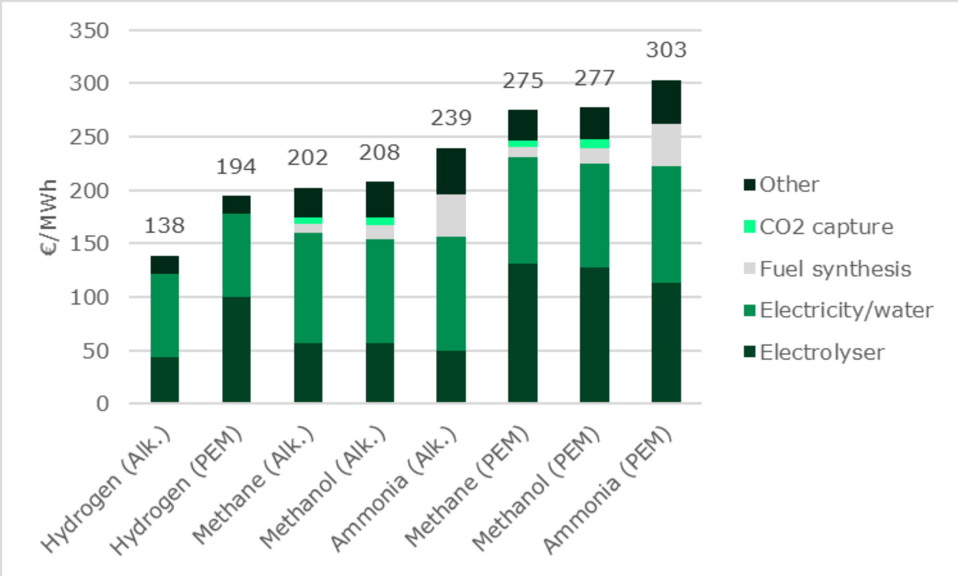
Source: Longspur Research, Ricardo, Europa

LEVELISED COSTS COMPARED

We have used levelized cost calculations from Dias et al (Dias V, Pochet M, Contino F and Jeanmart H (2020) Energy and Economic Costs of Chemical Storage. Front. Mech. Eng. 6:21) which in turn are based on multiple references and in our view are well constructed.

The outcomes for the main shipping fuel alternatives are dependent on the exact method of production. Most use hydrogen as an input and this can be created using SMR plus CCS ("blue" hydrogen) or from electrolysis using either alkaline or PEM electrolysers. We show the cheapest options below.

Production costs for marine fuels suggest hydrogen lowest cost



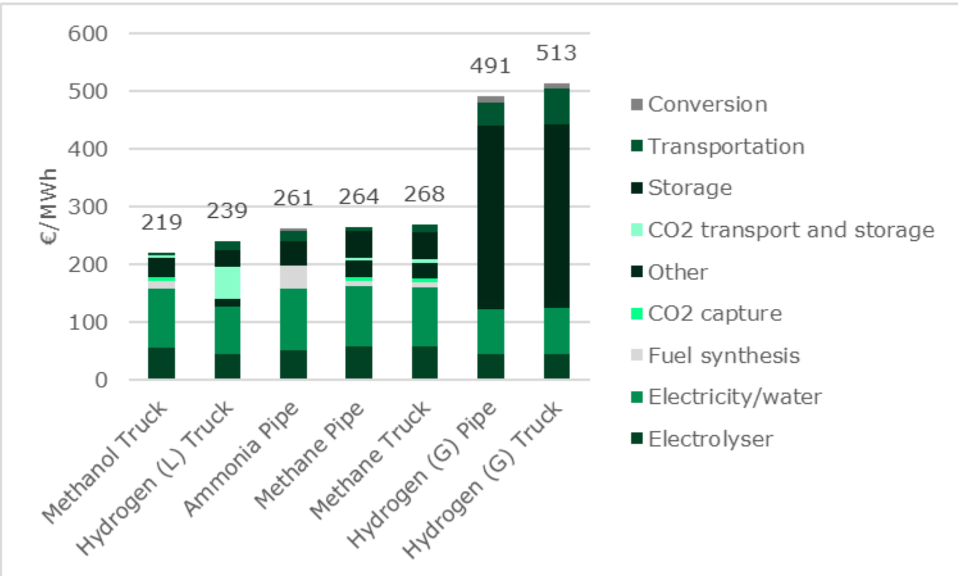
Source: Longspur Research, Dias et al

This suggests that hydrogen is the cheapest fuel to produce at the point of production. However, these calculations are only for the cost of fuel at the point of production and do not include delivery and storage costs.

Hydrogen can be stored in any state, as a compressed gas, or liquified or even as a solid using hydrides or sorbents. All these forms of storage consume energy reducing the final efficiency of the fuel and adding to its levelized cost. By comparison, methanol is a liquid and easily stored and transported at ambient temperatures. Ammonia requires some cooling to -33ºC to liquify it.

Dias et al have also provided levelized costs at the point of use including assumptions on storage and transport.

Full delivered costs show methanol as lowest cost option



Source: Longspur Research, Dias et al

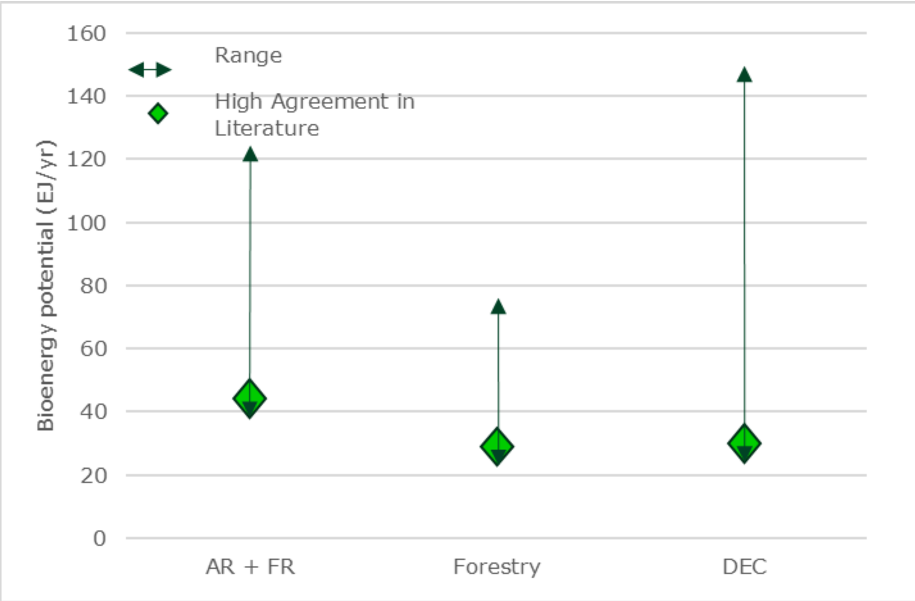
This shows the somewhat dramatic impact of cost and storage on the final levelized cost of hydrogen in a gaseous state. Liquid hydrogen is more reasonable and beats ammonia and methane but methanol, even trucked in, has the cheapest levelized cost at the point of delivery.

IS THERE ENOUGH FEEDSTOCK FOR BIO-METHANOL?

Both biofuels and e-methanol require CO_2 and to be genuine low carbon solutions this CO_2 must be removed from the air. That can be achieved by direct air capture which is inefficiently energy intensive or by photosynthesis in biomass. The biomass route combined with carbon capture is the key to producing CO_2 for these processes. One of the main criticisms of using either fuel is based on concerns that there may be insufficient biomass that can be harvested in a sustainable fashion to make the process genuinely low carbon.

A great many assessments of sustainable global bioenergy potential have been published with a large range of outcomes. However, the availability figures with a high level of agreement in scientific literature point to a figure of about 100 EJ of sustainable biomass available annually.

Ranges/high literature agreement on sustainable bioenergy potential



Source: Grantham Institute

Using post-combustion carbon capture, we estimate that this would generate 6bn tonnes of CO_2 per annum. That in turn would produce 4bn tonnes of methanol, equivalent to 2bn tonnes of HFO after adjusting for the lower energy density. We calculate the international shipping market demand after deducting 75% of oil and gas tanker demand (they won't be needed in a zero-carbon world) at 178mt or 9% of the available supply. There will be other calls on sustainable biomass including for sustainable aviation fuel and negative emission requirements, but we do not see 9% as especially onerous.

The calculation for eLNG is slightly more onerous as more CO_2 is required per kg produced and we estimate a requirement of 11% of available supply if eLNG was the only solution.

Sustainable biomass share for marine use

	Methanol	eLNG	Units
Sustainable biomass available	100	100	EJ
BECCS capacity	1.0	1.0	TW
CO2 produced	6145	6145	mt CO2
Methanol/CH4 produced	4425	2458	mt methanol/CH4
Equivalent HFO	1997	1643	mt HFO
Total addressable marine market	178	178	mt HFO
Share of sustainable biomass	9%	11%	

Source: Longspur Research

Further comfort is given in the very recent (October 2021) study by Imperial College London Consultants on European biomass which concludes that "the potential availability of sustainable biomass, with no harm to biodiversity, could support an advanced and waste-based biofuel production of up to 175mtoe in 2050." In other words, European sustainable biomass alone could more or less support the global marine requirement of 178mt for biomass.

The study itself appears conservative as the following quotation shows.

"It is important to highlight that the biomass potential availability estimated in this study are based on very conservative assumptions. [ ] Therefore, it can be concluded that the biomass potentials in 2030 and 2050 would most probably be higher than those estimated by this study."

EFFICIENCY SOLUTIONS ALSO SEEING DEMAND

While we have focused on fuelling options for the decarbonisation, we also see the incremental nature of much of the regulation as driving demand for marine efficiency solutions as well.

Depending on ship type and size, and the targeted reference speed, there are a number of developed solutions that can be implemented to improve overall vessel efficiency.

- Retrofitting a bulbous bow optimized for the actual operational profile
- Retrofitting an optimized propeller
- Retrofitting propulsion improving devices (PIDs), e.g. stern ducts, wake equalizing ducts (WED), pre-swirl ducts (PSD), pre-swirl stators (PSS), vortex generator fins (VGF), propeller boss cap fins (PBCF), rudder bulbs in combination with propeller caps, twisted rudders, etc.
- Retrofitting air lubrication systems (ALS)
- Retrofitting wind-assisted propulsion systems (WAPS) e.g. Flettner rotors

It can be seen that these options are all suitable for retrofitting on existing vessels, potentially helping to prolong vessel lives especially if it means beating the earlier emission thresholds from either the IMO or the EU.

We are already seeing demand for these solutions being developed with one Flettner rotor provider in discussions for installations on over 100 vessels.

METHANOL - A KEY TO DECARBONISATION

Existing maritime fuels look set to become more costly than low carbon alternatives as IMO and EU emission regulation tightens. This could impact from as early as 2025. Methanol from natural gas (grey methanol) already offers some key advantages such as lower tank-to-wake emissions, complying with EMA sulphur limits and an ability to be blended with low carbon methanol to comply with the evolution of EU GHG limits. We see this flexibility as making it a strong option for ship owners now and as a result we see the fuel becoming a major part of the decarbonisation toolkit.

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Longspur Research

10 Castle Street,

Edinburgh. EH2 3AT

UK

Longspur Capital

20 North Audley Street,

London. W1K 6WE

UK

www.longspur.com

Longspur Research
10 Castle Street,
Edinburgh. EH2 3AT
UK

Longspur Capital Markets
20 North Audley Street,
London. W1K 6WE
UK