RENEWABLE FUEL ECONOMICS

Alternative fuel retrofits:
A CAPEX, OPEX and payback illustration

WIN GD

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01

Regulatory uncertainty favours retrofitting

For operators awaiting the final shape of global maritime decarbonisation regulation, fuel choices are fraught with peril. Little wonder many are postponing the decision for their newbuild vessels – but at what cost?

A global regime that reinforces the ambition of IMO's Greenhouse Gas (GHG) Reduction Strategy, to reach net-zero emissions from international shipping by or around 2050, will demand the use of zero or near-zero emission (ZNZ) fuels. But as the cost and availability of those fuels remains unsettled, the regulation also needs to incentivise their uptake and, indirectly, their production.

Without that incentive, ordering a vessel equipped for anything beyond widely available conventional fuel is either a calculation made on assured long-term supply, or a gamble that a fuel's net cost – the price of fuel plus any investments, penalties or rewards related to its use – will compare favourably against today's options.

The global orderbook shows exactly how investors behave faced with such uncertainty. Before adoption of IMO's Net Zero Framework (NZF) was delayed in October 2025, newbuilds using alternative fuels claimed 45% of orderbook gross tonnage in 2024, according to Clarksons. In the first half of 2025 that had risen to 56% before collapsing to just 37% for the full year.

Despite the impending prospect of a global carbon pricing scheme for shipping, well over 60% of current orders are for conventional fuel.

Conventionally fuelled newbuilds are a sound decision on any one of three bases: that a global GHG framework never emerges; that low-carbon, drop-in alternatives to conventional fuel, such as biodiesel, become widely and cheaply available; or that conventional engines can be converted to use clean fuels should regulatory drivers become clearer.

WinGD's portfolio of retrofit-ready diesel X-Engines and dual-fuel X-DF engines – for LNG (low pressure and high pressure), ammonia and LPG, methanol and ethanol – ensure that the conversion pathway at least is technically assured. Questions around commercial viability lie well beyond the engine technology, and form the starting point of the current modelling exercise.

Assuming the IMO Net Zero Framework – or one of several proposed adaptations of it – are adopted in December, what are the capital and operating expenses for a vessel aiming to retrofit for LNG, ammonia or methanol in 2030? What fuel costs and fuel GHG intensities will make such a conversion feasible? And, crucially, what level of subsidies could be needed to safeguard meaningful payback for ship owners investing in alternative fuel retrofits?

02

An integrated retrofit solution

Technically feasible retrofitting means much more than having an alternative fuel conversion package available for your engine.

WinGD's engine portfolio spans multiple fuels, from today's fossil derivatives to tomorrow's renewable alternatives – with engines using LNG, methanol and ammonia already in service. But being ready to convert means more than fuel availability: it means an engine designed for efficient operation on all fuels, one that is engineered from the outset for conversion, and a project structure that can deliver it efficiently.

That efficiency starts with the engines themselves. WinGD's X-Engines remain a benchmark for Diesel-cycle fuel efficiency in the merchant fleet – in particular the X92-1.1, formerly the X92-B, an undisputed benchmark in the large container vessel segment.

All modern WinGD engines are built with conversion already in mind. The X-Engine and high-pressure X-DF platform share a common architecture across fuels: bedplate, column and running gear carry over between designs, so a conversion changes the fuel supply and injection system rather than the engine itself.

WinGD Retrofit Solutions carries that thinking into the project itself. Engaging with owners, shipyards and class societies from the first feasibility study, WinGD teams assess the vessel, define the scope, and manage the conversion through to sea trials.

Being ready to convert means more than fuel availability: it means an engine designed from the outset for conversion, and a project structure that can deliver it efficiently

03

Three retrofit pathways

To assess the viability of retrofitting, WinGD modelled three hypothetical retrofits taking place in 2030, under a regime similar to the IMO Net Zero Framework as drafted – see chapter 06 for full details of the regulatory framework.

The vessel modelled is a 16,000 TEU container ship with a 33,300 kW X92-1.1 two-stroke main engine operating 6,000 hours a year.

Fuel consumption for the reference vessel and each retrofit pathway is derived from engine performance data for the equivalent dual-fuel engine, so the pathways differ in fuel type and quantity but not in the work the ship does.

The pathways differ in fuel type and quantity but not in the work the ship does

The reference vessel burns 14,302 tonnes of VLSFO a year. Each alternative pathway carries an additional capital cost for the engine and fuel containment system, taken in full in 2030 and shown below.

The model considers only the main engine and its pilot fuel. Auxiliary engines and hotel load are not included. This simplifies the model to allow for variance between auxiliary engine installations.

Table 1. The three retrofit pathways modelled, with capital cost over a conventional vessel

Pathway	Retrofitted to engine	Main fuel	Starting fuel	Pilot fuel	Retrofit cost
LNG	X92DF-HP	Low-GHG LNG	Fossil LNG	1,424 t/yr MGO	$28m
Bio-methanol	X92DF-M	Bio-methanol	VLSFO	1,309 t/yr MGO	$24m
Ammonia	X92DF-A	Green ammonia	VLSFO	1,424 t/yr MGO	$28m

04

Fuel cost and availability assumptions

All engines begin their post-retrofit life either fully on fossil fuel or on a blend of fossil and lower GHG fuel, reflecting current understanding of alternative fuel availability. To simplify cost comparison and to highlight the impact of alternative fuel pricing, conventional fuel prices are held flat across the period while alternative fuel prices decline on the trajectories described below. For clearer visibility of the cost of fuels with very different bunkering volume requirements, comparison is made in dollars per gigajoule.

IRENA and the Methanol Institute jointly estimate bio-methanol production at US$320–770 per tonne currently, falling to US$220–560 with process improvements, at feedstock costs up to US$6/GJ. We take the midpoints – US$545 in 2030 and US$390 in 2050. Using the same publisher for both the carbon intensity and the cost keeps the pathway internally consistent.

Table 2. Fuel price assumptions

Fuel	Price (US$/t)	$/GJ	Profile
VLSFO	700	17.0	Flat to 2050
MGO	700	16.4	Flat to 2050
Fossil LNG	500	10.4	Flat to 2050
Low-GHG LNG	1,000 → 500	20.8 → 10.4	Declining 2030 → 2045
Bio-methanol	630 → 475	31.7 → 23.9	Declining 2030 → 2050
Green ammonia	500 → 400	26.9 → 21.5	Declining 2030 → 2050

Those are production costs only, whereas the other fuels are priced as delivered bunkers. We therefore add a flat US$85 per tonne covering freight to the bunker port, terminal storage, barge delivery, trader margin and the chain-of-custody administration that certified fuel requires. The resulting prices are US$630 per tonne in 2030 and US$475 in 2050.

Fig 1. Green ammonia price trajectory, with the ±25% range used in the support analysis

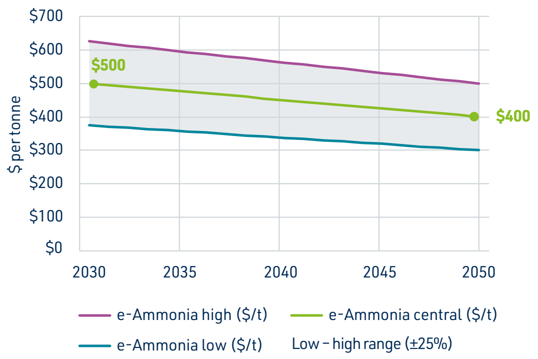


Fig 2. Low-GHG LNG price trajectory, with the ±25% range used in the support analysis

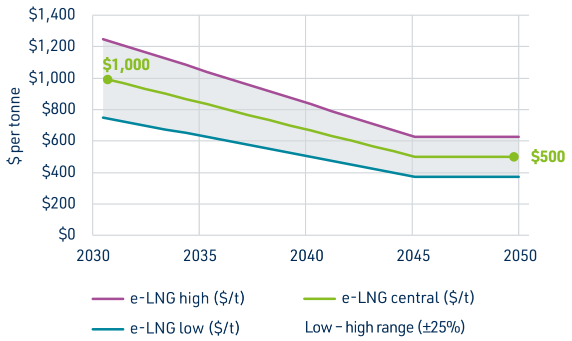
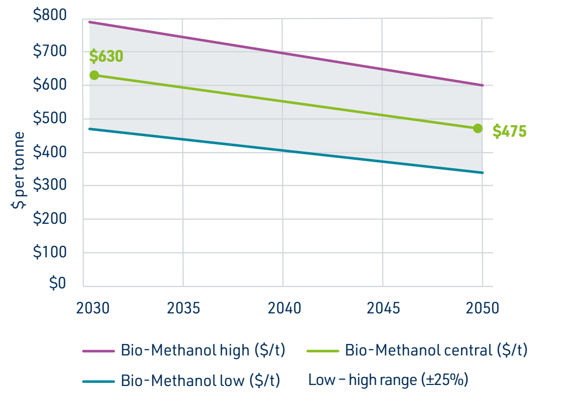


Fig 3. Bio-Methanol price trajectory price trajectory, with the ±25% range used in the support analysis



05

Emissions assumptions

Emission factors follow IMO's Life Cycle Assessment Guidelines. Tank-to-wake reflects combustion and the engine; well-to-tank reflects production, processing and delivery. Heating values and carbon factors are those specified for the IMO methodology, which differ from the European equivalents – notably a lower carbon factor for residual fuel oil and a lower heating value for LNG.

The LNG and ammonia factors are indicative rather than certified pathway values drawn from a verified fuel lifecycle declaration. Low-GHG LNG at −3.0 gCO_2eq/MJ delivers a 28% improvement on fossil LNG but is well above any threshold for a ZNZ reward, even if one were being modelled. Green ammonia at 24.2 is a generic assumption of an 80% reduction against conventional ammonia production rather than a measured figure. Results for each pathway should be read as conditional on these values – the purpose is to illustrate the impact of price and fuel GHG intensity rather than to advocate for any specific fuel.

Bio-methanol is the only pathway in this study built from published sources rather than supplied inputs. The Methanol Institute's carbon footprint work reports that most renewable pathways – biomethane, solid biomass and municipal solid waste – achieve 10–40 gCO_2eq/MJ well-to-wake, with e-methanol from solar hydrogen as low as 4.4 and manure-based routes reaching −55. We take 25, the centre of the 10–40 band, as a deliberately unexceptional pathway rather than a best case.

The published intensity figures are well-to-wake totals that already net biogenic carbon, so the 25 gCO_2eq/MJ is not split between combustion and supply chain in the same way as the other fuels. Because the Framework measures well-to-wake, the split does not affect any result.

Table 3. Emission factors, gCO_2eq/MJ unless stated

Fuel	LHV (MJ/kg)	Tank-to-wake	Well-to-tank	Well-to-wake
VLSFO	41.2	76.77	16.80	93.57
MGO	42.7	76.23	17.70	93.93
Fossil LNG	48.0	58.95	18.50	77.45
Low-GHG LNG	48.0	58.95	−3.00	55.95
Bio-methanol	19.9	see commentary	see commentary	25.00
Green ammonia	18.6	0.00	24.20	24.20

Table 4. Vessel-level GHG fuel intensity by configuration

Vessel configuration	Intensity (gCO_2eq/MJ)	Reduction vs reference
Conventional VLSFO vessel	93.57	–
LNG pathway, fully fossil LNG	79.17	15%
LNG pathway, fully low-GHG LNG	59.90	36%
Bio-methanol pathway, fully bio-methanol	31.44	66%
Ammonia pathway, fully green ammonia	31.15	67%

06

The regulatory model

Under the IMO Net Zero Framework as drafted, a ship is measured on its attained greenhouse gas fuel intensity (GHGFI) – the weighted average well-to-wake emissions of all fuel burned, in grams of CO_2-equivalent per megajoule – against two declining targets set from a 2008 baseline of 93.3 gCO_2eq/MJ. Emissions above the direct compliance target but below the base target incur remedial units at US$100 per tonne of CO_2-equivalent. Emissions above the base target incur US$380 per tonne on the excess, in addition to the US$100 tier across the band between the two. A ship below the direct compliance target instead earns tradeable surplus units.

We apply the published reduction schedule shifted one year later than originally drafted, reflecting the postponement of the Framework's adoption, so 2030 carries the factors originally set for 2029. Remedial unit values are held at US$100 and US$380 throughout the period, although in reality a review is planned after the first phase. No reward for zero or near-zero emission fuels is applied, because although a reward is specified in the drafting, none has been quantified. This makes the WinGD model a 'light' version of IMO's NZF as drafted – higher remedial unit cost post-2036 and an added reward would make all compliant fuels more attractive.

The published NZF schedule ends in 2036 once shifted for the initial delay. Beyond that only a base target of a 65% reduction is published for 2040. Under WinGD's model, the intervening years and the path from 2040 to net zero in 2050 are linear interpolations. The direct compliance target for 2040 has not been set, so we close the gap between the two targets linearly to zero by 2050. And no value has been attached to a surplus unit, so we assume US$361 per tonne, 95% of the higher remedial unit price.

The interpolated years tighten by 8.7 percentage points annually between 2036 and 2040, against 4.4 points in the published years. That step generates a large share of the regulatory cost, and therefore of the value attributed to the cleaner pathways.

Table 5. GHG fuel intensity targets applied, gCO_2eq/MJ

Year	Base target	Direct target	Basis
2030	87.70	75.57	Published schedule (deferred one year)
2033	77.63	65.50	Published schedule (deferred one year)
2036	65.31	53.18	Published schedule – final year
2040	32.66	23.99	Base target published; direct interpolated
2045	16.33	12.00	Interpolated
2050	0.00	0.00	Interpolated – net zero assumed

07

Findings

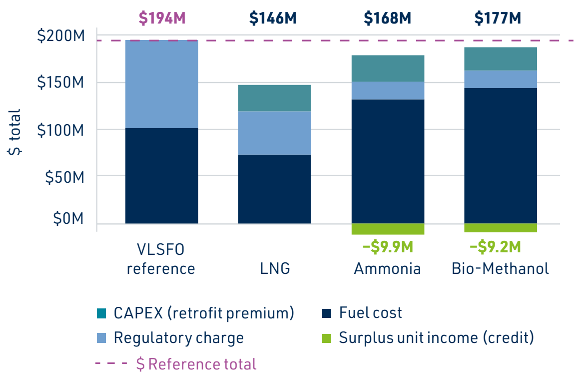
A vessel that continues to use VLSFO spends US$100.3m on fuel and US$93.4m on remedial units over the period, with a regulatory charge nearly as large as the fuel bill itself. It has no capital cost and earns no surplus. That US$93.4m regulatory cost is what every retrofit aims to remove.

LNG removes about half of it, cutting the regulatory charge to US$45.5m. Ammonia and bio-methanol remove four fifths, to US$18.6m and US$18.7m, and earn a further US$9.9m and US$9.2m selling surplus units. On the regulatory dimension alone the two deep-cut pathways are far ahead.

LNG wins on the fuel bill, not on the regulation

The reason LNG nevertheless finishes with the largest cost saving is the fuel cost itself. It is the only pathway that spends less on fuel than the conventional vessel: US$72.6m against US$100.3m, because fossil LNG at US$10.4 per gigajoule undercuts VLSFO at US$17.0, and the blend remains mostly fossil until the 2040s. Ammonia spends US$131.1m and bio-methanol US$143.3m – US$31m and US$43m more than doing nothing at all.

Fig 4. Lifetime cost by component, fixed uptake. Costs stack above the axis; surplus unit income is a credit and is shown below it. The dashed line marks the conventional vessel's total cost. All figures discounted at 8% annually over 2030–2050



CAPEX is the smallest term

The estimated retrofit premium – US$28m for LNG and ammonia, US$24m for bio-methanol – is the smallest of the four components in every case, and the US$4m spread between them changes no ranking. Bio-methanol has the cheapest conversion and still finishes most expensive in this modelling, because its fuel disadvantage is ten times the size of its capital advantage.

Conversion cost is therefore largely beside the point: the decision is driven by fuel price and regulatory treatment, not by the price of the engine work.

Fig 5. LNG retrofit pathway, fixed green uptake, lifecycle costs by cost component 2030-2050

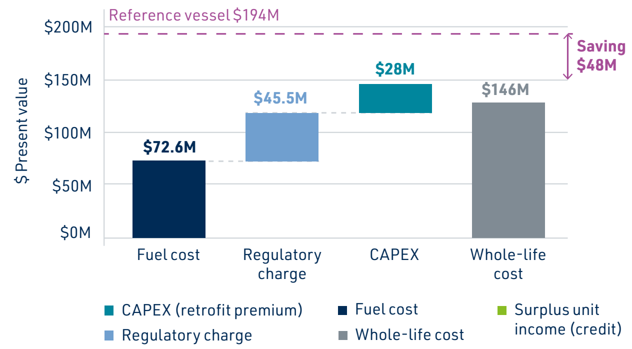


Fig 6. Ammonia retrofit pathway, fixed green uptake, lifecycle costs by cost component 2030-2050

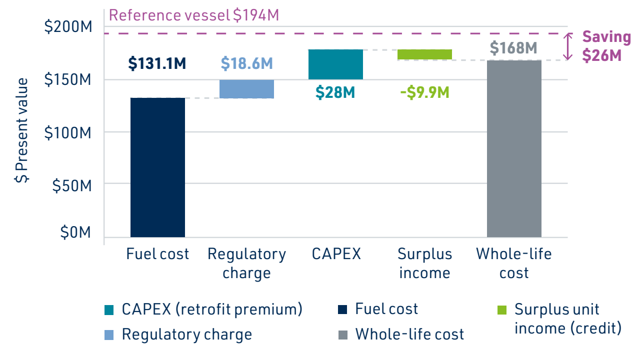
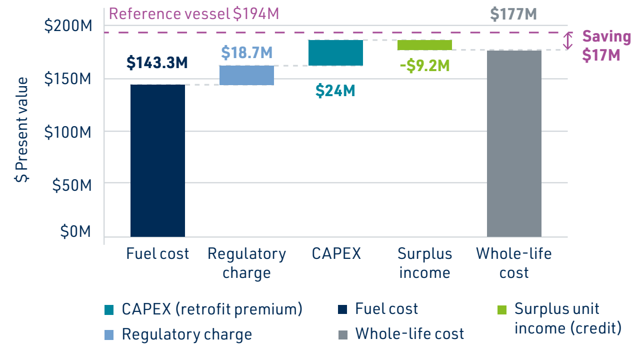


Fig 7. Methanol retrofit pathway, fixed green uptake, lifecycle costs by cost component 2030-2050



08

Return on investment and net present value

Table 6 presents the year of payback for each retrofit pathway and compliance strategy, as well as internal rate of return and net present value at 2050. Net present value relative to a conventional VLSFO-fuelled vessel is also shown at five, ten and fifteen years after conversion. The following definitions are used:

- **Net present value** includes the capital premium, taken in full in 2030, and 8% discounted annual savings.
- **Savings** are the conventional vessel's net operating cost less the alternative pathway's, in each year.
- **Net operating cost** is fuel cost plus remedial units, less income from surplus units sold. It excludes fuel and energy for auxiliary engines, consumables related to emissions abatement, and maintenance costs.
- **Payback** is the year cumulative net present value crosses zero.
- **Internal rate of return** is found by evaluating net present value at every discount rate from −15% to +45% in half-point steps, then interpolating linearly between the two rates that bracket zero.

LNG returns most, but decarbonises least

The LNG pathway delivers the strongest financial result: a 22.7% return with capital recovered in 2036. Using the variant of low-GHG LNG described here, almost none of that comes from emissions performance. Even running entirely on this low-GHG LNG the pathway reaches an intensity of 59.9 gCO_2eq/MJ, above the compliance target in every year of the period. It earns no surplus units at all and - under the fixed uptake scenario – pays remedial units from 2030 onwards.

Its advantage comes from a real but shallow emissions gain – enough to pay smaller penalties than a conventional vessel, never enough to earn surplus units, and narrowing as targets tighten.

Table 6. Net present value against a conventional vessel, US$ millions

Pathway	Strategy	5 year	10 year	15 year	2050	Return	Payback
LNG	Fixed uptake	−5.2	+14.9	+31.5	+47.6	22.7%	2036
LNG	Minimum compliance	−9.3	+11.4	+29.9	+46.2	21.3%	2037
Ammonia	Fixed uptake	−17.3	−3.2	+11.4	+25.8	15.2%	2041
Ammonia	Minimum compliance	−22.8	−8.7	+9.6	+25.0	14.1%	2042
Bio-methanol	Fixed uptake	−18.6	−8.1	+4.2	+17.0	13.1%	2043
Bio-methanol	Minimum compliance	−22.2	−12.0	+3.3	+17.0	12.6%	2043

Ammonia and bio-methanol are near-identical on emissions, and both improve as targets tighten

Ammonia returns 15.2% and recovers its capital in 2041, in a manner quite different from LNG. At 31.2 gCO_2eq/MJ when running fully green, it falls below the compliance target in the early years, earning tradeable surplus units for seven years and paying nothing until 2037.

On emissions the two 'deep-cut' pathways – using fuel intensities modelled here – are effectively indistinguishable. Ammonia reaches 31.15 gCO_2eq/MJ when fully green and bio-methanol 31.44, a difference of under 1%, giving reductions of 67% and 66% against the reference. Over the vessel's life they abate 569 and 572 thousand tonnes of CO_2-equivalent respectively, a gap of half a percent.

The choice between them turns on cost, capital and fuel availability rather than emissions performance. Ammonia is the better of the two financially under this model: it returns 15.2% against 13.1%, recovers capital two years earlier, and costs US$9m less over the vessel's life on a discounted basis. Bio-methanol needs US$4m less capital to install. Where the modelled version of ammonia wins is fuel cost per unit of energy: US$26.9/GJ in 2030 against bio-methanol's US$31.7.

Fig 8. LNG– cumulative net present value against a conventional vessel, both strategies

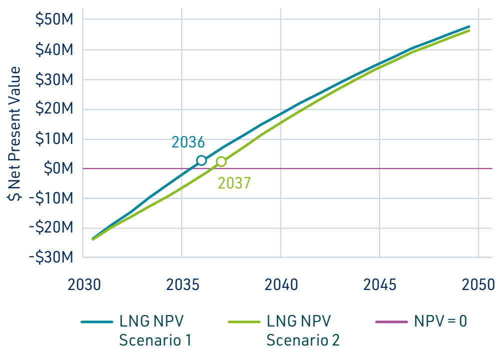


Fig 9. Ammonia – cumulative net present value, showing the later but sustained recovery

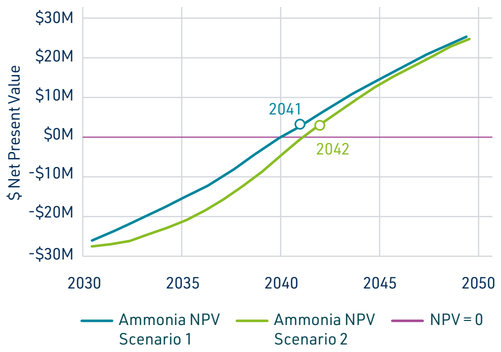


Fig 10. Bio-methanol – cumulative net present value, crossing zero in 2043

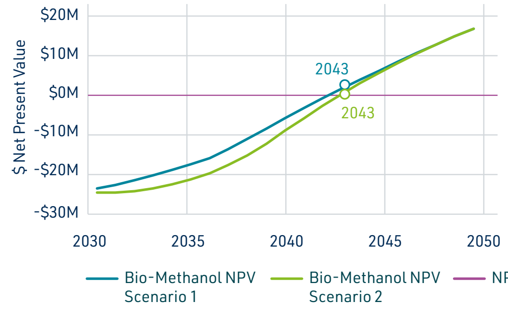


Fig 11. Annual net operating cost for all three pathways against the conventional reference, fixed uptake

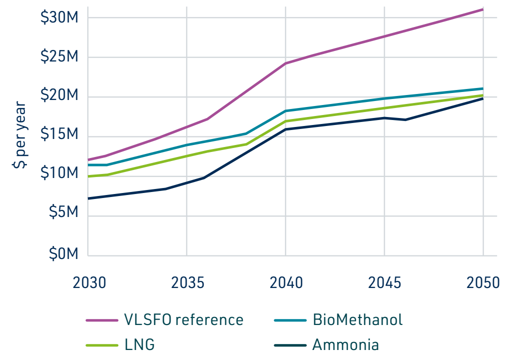
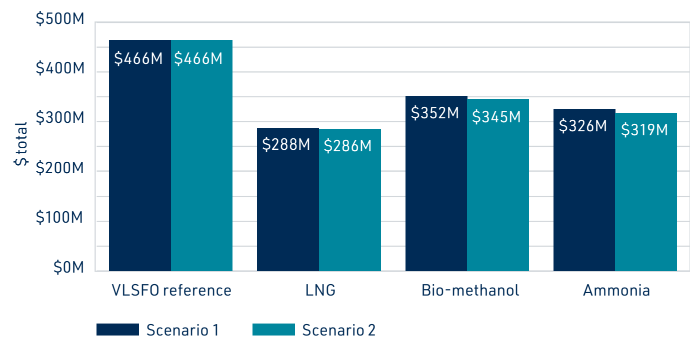


Fig 12. Cumulative net operating cost 2030–2050, both strategies



Total cost of ownership

Read as a whole-life decision rather than a return, the ranking is unchanged but the margins are clearer. Every pathway costs less to own than staying on conventional fuel once the Net Zero Framework applies, and every one abates emissions at a negative cost – the owner is paid, in avoided regulatory cost and fuel savings, to reduce emissions.

Table 7. Whole-life cost and abatement, 2030–2050, discounted at 8%

Pathway	Capital	Operating cost (NPV)	Total (NPV)	CO_2eq abated	Cost per tonne abated
Conventional VLSFO	–	$193.7m	$193.7m	–	–
LNG	$28m	$118.2m	$146.2m	324kt	−$147
Ammonia	$28m	$139.9m	$167.9m	569kt	−$45
Bio-methanol	$24m	$152.8m	$176.8m	572kt	−$30

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Support required for a five-year payback

No pathway recovers its capital within five years on these assumptions. The table (right) shows the support needed to bring each to breakeven over 2030–2034, expressed per tonne of CO_2-equivalent abated against the conventional vessel over the same period. Support is discounted at 8%; abatement is not.

LNG is the cheapest pathway to accelerate, at US$95 per tonne of CO_2-equivalent – below the US$100 remedial unit the Framework already imposes – but it buys only 55,271 tonnes of abatement over five years. Ammonia requires US$174 and bio-methanol US$186, both for around 99,000 tonnes, roughly twice the abatement for roughly twice the price per tonne. On a per-tonne basis the deep-cut pathways are no more expensive to support than LNG once the volume of abatement is taken into account.

For shipowners, the final column expresses the same support as a discount on the fuel purchased: US$268 per tonne off green ammonia, US$312 off bio-methanol, and US$647 off low-GHG LNG.

Table 8. Support required to bring each pathway to breakeven within five yrs

Pathway	Strategy	Shortfall (US$)	CO_2eq abated (t)	Support ($/t$CO_2$eq)	As a fuel discount ($/t)
LNG	Fixed uptake	5,242,470	55,271	$95	$647
LNG	Minimum compliance	9,267,934	73,641	$126	$434
Ammonia	Fixed uptake	17,268,872	99,329	$174	$268
Ammonia	Minimum compliance	22,792,599	69,165	$330	$516
Bio-methanol	Fixed uptake	18,553,571	99,892	$186	$312
Bio-methanol	Minimum compliance	22,241,306	70,736	$314	$537

The subsidy requirements to ensure payback on alternative fuel retrofits need to be an important element of discussions at IMO level – assuming a version of the NZF is passed that retains a ZNZ reward. In this model none of the fuels meet the 19 gCO_2eq/MJ threshold to qualify as a ZNZ fuel – suggesting that the subsidy requirement for low GHG intensity fuels, which are typically more expensive, would be considerably higher.

10

Impact of IMO NZF variants

As mentioned in chapter 09, the IMO Net Zero Framework has not yet been adopted. Following the postponement at the second extraordinary session in 2025, four* competing sets of amendments to MARPOL Annex VI were circulated in June 2026 as candidates for adoption at MEPC 85 or the resumed extraordinary session in December 2026. They differ widely – in two, emissions are priced through a two-tier intensity target with a tradeable surplus market, leaning on the NZF as currently drafted; in the others, emissions are priced through a universal levy or a fuel standard tied to whatever sustainable fuel is already commercially available.

The results of WinGD's modelling assume the Framework is adopted as drafted. Each of the other three options would reprice the pathways differently. The table below gives an estimation of what a vessel would save against the conventional reference in 2030, at the fuel blends modelled here, under the drafted NZF and under an indicative universal levy of US$300 per tonne.

A levy inverts the ranking

Under the drafted Framework the LNG retrofit saves the most in the early years, because only emissions above a relatively lenient target are charged and its fuel is cheap. A universal charge on every tonne removes that advantage: what matters becomes absolute intensity, and ammonia and bio-methanol move from saving US$2.1m and US$0.8m a year to US$5.4m each, while LNG falls from US$4.9m to US$3.0m.

The levy option would also fund a far larger reward pool, which IMO working group analysis expects to accelerate ammonia adoption specifically.

"Softer start, harder finish" delays every payback

Weaker targets in the early years reduce what the conventional vessel pays, and therefore reduce what any retrofit saves, precisely during the years that dominate a discounted return. The reward mechanism is also delayed to 2031 for want of funds. The steeper trajectory to 2040 partially compensates, but late savings are worth less: on our discounting, a dollar saved in 2045 is worth 32 cents. Analysis by the UK's Institute of Marine Engineering, Science and Technology (ImarEST) finds this option produces higher cumulative emissions than the drafted Framework despite the steeper later trajectory.

Fundamental redesign would favour LNG and undermine the rest

Setting the target by the intensity of an already commercially available fuel means that, under the interpretation where LNG sets the floor, the required intensity falls only from 93 to around 81 by 2050. An LNG retrofit would be close to compliant for the whole period rather than in deficit every year. But the option carries no upper-tier price, no reward and no revenue, and surplus unit prices are uncapped and expected to stay low for longer – which removes the income that makes ammonia and bio-methanol work here. It would make the cheapest-to-abate pathways the least rewarded.

Table 9. The four candidate amendment options

Circular Letter	Option	Core mechanism
5216	Net-Zero Framework "as is"	Two-tier GFI targets, remedial units at $100 and $380, tradeable surplus units, reward fund
5214	"Softer start, harder finish"	Same architecture, weaker targets early and steeper to 2040, reward delayed to 2031
5215	"As levy"	Universal charge of $300/t$CO_2$eq on all emissions below the base target; no surplus market
5213	Fundamental redesign	Target set by the intensity of a commercially available fuel; no upper-tier price, no reward, no revenue

Table 10. Annual saving against the conventional vessel in 2030, drafted Framework versus universal levy

Retrofit	Green share in 2030	Saving under "as is" (US$m)	Saving under "as levy" (US$m)
Ammonia	50%	2.1	5.4
Bio-methanol	50%	0.8	5.4
LNG	10%	4.9	3.0

* As this report was published a fifth proposal was submitted by Japan, proposing less onerous GHG Fuel Intensity reduction targets.

11

Conclusion

The clearest finding of this modelling is how little it takes to change the decision on whether a retrofit is commercially viable and under which circumstances. Every pathway examined here turns on four variables:

Whichever version of the Net Zero Framework is settled on in December – or perhaps later – a clear and robust ZNZ reward will be critical to its success in driving shipping towards net-zero emissions.

Fuel pricing

The cost of all low-carbon fuel variants used in this study – low-GHG LNG, green ammonia and bio-methanol – are based on projected price evolution from today's very short supply, and will seem low by current standards. But as the findings show, even at these relatively optimistic bunker prices, further cost evolution and/or greater policy support will be needed to strengthen the investment case.

Even with costs modelled at the relatively low end of the spectrum, the scenarios all show significant price sensitivity. As an example, the US$85 per tonne added for bio-methanol delivery to the bunker port moves its net present value by more than US$20m.

There will likely be even greater factors shifting the costs of green fuels ahead, and one role of effective legislation will be to help operators manage these fluctuations to ensure a degree of predictability around fuel costs.

Green fuel ramp-up

The rate at which clean fuel can actually be secured determines whether surplus units are earned in the years that matter to a discounted return, or whether the vessel simply pays less than a conventional one. There is a big difference between an operator choosing to maximise green fuel uptake to increase surplus revenue, and one choosing minimal uptake to ensure compliance – but both strategies rely on scaling up of production that is far from assured at present.

Fuel GHG intensity

A single emissions factor – GHG energy intensity – decides whether a fuel pathway earns tradeable surplus or pays remedial units from the first year. For operators, dealing in vague fuel types is simply not sufficient – to assess the viability of fuel choices, and of retrofits, they will need to understand the energy intensity of every fuel they choose. The difference between a certified low-intensity fuel and exposure to a supply of fuel with unspecified energy intensity is worth more than every price assumption in the model combined.

ZNZ reward

None of the three pathways modelled here recovers its capital within five years, when perhaps even that is already too long for a ship owner viewing a relatively high-risk investment. A reward set at a sufficient level to genuinely incentivise ZNZ fuels – and that is visible to an owner at the point of investment – would do two things: pull demand towards fuels that actually decarbonise, and give the required engine technology a confirmed commercial basis.

Regulation alone will not decide shipping's decarbonisation trajectory. There are already progressive ship owners showing how decarbonisation can be put into practice in the absence of a global framework. But policy can provide a decisive push.

Whichever version of the Net Zero Framework is settled on in December – or perhaps later – a clear and robust ZNZ reward will be critical to its success in driving shipping towards net-zero emissions.

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Appendix

Vessel and fuel consumption

The vessel modelled is a single WinGD customer case, carried through every pathway unchanged. Only the fuel differs between cases: the ship does the same work, over the same hours, in every year of the period.

Table 11. Vessel model profile

Parameter	Value	Note
Vessel	16,000 TEU container ship	WinGD illustrative customer case
Main engine	One 7X92-1.1, seven cylinders	Formerly the X92-B; the Diesel-cycle reference engine
Rated power (CSR)	33,300 kW	Contract service rating
Annual operating hours	6,000 h/yr	Held constant 2030–2050
Annual energy demand	589,234 GJ	Reference vessel, from 14,302 t of VLSFO at 41.2 MJ/kg
Scope	Main engine and pilot fuel only	Auxiliary engines and hotel load excluded
Retrofit year	2030	Capital premium taken in full in 2030, undiscounted
Modelled period	2030–2050 (21 years)	Net zero assumed in the final year
Discount rate	8%	Applied to all savings and support figures

Fuel consumption for each case is taken from engine performance data for the equivalent dual-fuel engine, at the load profile of the source case.

Each pathway is shown at both ends of its fuel mix: the fossil configuration it starts from and the fully green configuration it works towards. In any given year the vessel uses a blend of the two, in the proportion set by the uptake strategy, so annual energy and intensity fall between the rows shown.

Table 12. Annual fuel consumption and well-to-wake GHG fuel intensity at 0% and 100% green fuel

Case	Configuration	Main fuel (t/yr)	MGO pilot (t/yr)	Energy (GJ/yr)	GHGFI (g/MJ)
Reference	VLSFO	14,302	–	589,234	93.57
LNG	Fossil LNG	10,906	1,424	584,334	79.17
LNG	Low-GHG LNG	10,906	1,424	584,334	59.90
Bio-methanol	VLSFO (starting fuel)	14,302	–	589,234	93.57
Bio-methanol	Bio-methanol	27,260	1,309	598,372	31.44
Ammonia	VLSFO (starting fuel)	14,302	–	589,234	93.57
Ammonia	Green ammonia	29,557	1,424	610,586	31.15

The small differences in annual energy between cases – under 4% across the range – reflect differences between the fuel use in each engine case. The LNG case carries an MGO pilot in both configurations because it runs as a dual-fuel engine throughout; the methanol and ammonia cases begin on VLSFO in Diesel mode, with no pilot, and take on a pilot only once green fuel is introduced.

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