GETTING TO ZERO COALITION
GLOBAL MARITIME FORUM

IMO policy measures: What's next for shipping's fuel transition?

IMPLICATIONS OF THE IMO'S NET-ZERO FRAMEWORK

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Executive summary

- Based on total cost of ownership (TCO) modelling by UMAS and UCL and more than 30 stakeholder interviews by the Getting to Zero Coalition, this insight brief dives deeper into the implications of the International Maritime Organisation's (IMO) mid-term policy measures for the sector's capital and operational strategies, costs and risks, highlighting how the measures and the industry's responses to them can ensure that scalable, zero-emission technologies reach commercial maturity as soon as possible.
- The policy measures set global fuel intensity (GFI) factors and the price levels of penalties or remedial units (RUs) for non-compliance. While some questions remain, the measures already create a significant basis for long-term action looking ahead at 2040. The measures as currently defined can be complied with by many different ship specifications and fuel pathways, but the steepening GFI curve and likelihood of increasing RU prices narrows the potential compliance options in the future to scalable zero-emission fuels such as e-fuels like e-ammonia and e-methanol.
- Yet the development of the value chain for e-fuels cannot be delayed until the late 2030's to ensure it reaches technological and commercial viability in time. This requires a growing portion of the fleet to adopt such fuels already in the first years of the measures.
- In the immediate aftermath of the agreement, over 30 interviews with industry stakeholders emphasised the challenges for long-term strategic investment and the greater clarity of short-term cost of compliance optimisation.

- The TCO analysis indicates a long-term competitiveness investment in dual-fuel ammonia vessels. The analysis shows that liquefied natural gas (LNG) and ammonia dual-fuel ships are the most competitive options before the mid-2030s, and that ammonia is the cheapest from then on. However, this is mostly driven by blue fuels, as e-fuels remain insufficiently incentivised before 2040. E-fuel use can be made competitive through appropriately designed rewards.
- Non-compliance penalties should also be expected to increase in future years to align with the IMO's absolute emissions reduction objectives. These regular adjustments will create "cycles" for compliance in which other parameters, including surplus unit (SU) pricing dynamics and rewards for zero- and near-zero-emission fuels, will adjust. This complicates choices for fuel pathways and their relative competitiveness.
- The guidelines and upcoming revisions will play a critical role in ensuring the transitional period is characterised by a growing adoption of scalable zero-emission fuels to prepare for the long term. This requires sufficiently high rewards, revisions of the RU prices, high values of the SUs, and stringency of emission factors.

Introduction

In July 2023, the International Maritime Organization (IMO) adopted its revised greenhouse gas (GHG) strategy that provided the shipping sector with an important, non-binding roadmap that required translation into binding policy measures under the International Convention for the Prevention of Pollution from Ships (MARPOL). MARPOL's decision-making body, the Marine Environment Protection Committee (MEPC) and its Intersessional Working Group on GHG Emissions from Ships (ISWG-GHG) then worked to develop such measures, which were agreed at MEPC 83 in April 2025 and are set to be formally adopted in October 2025.

Going into MEPC 83, three main issues were at stake: establishing regulations for the greenhouse gas content of fuels in a global fuel standard (GFS), designing an economic instrument for maritime GHG emissions pricing, and developing mechanisms, including those for revenue-sharing, that ensure a just and equitable energy transition. This resulted in two sets of GHG fuel intensity (GFI) targets between 2028 and 2040, combined with a flexible compliance mechanism in the shape of surplus credit trading. The meeting also set initial thresholds for zero- and near-zero emission (ZNZ) fuels and technologies, and areas for revenue disbursement.

These measures are a watershed moment for the industry. Amid global economic and political turmoil, member states came together to regulate a global sector. Following adoption, shipping will be the first industry with globally binding greenhouse gas regulations combining mandatory emissions limits and GHG pricing. While progress has been made in the sector, as also illustrated within the Getting to Zero Coalition, it is clear that more significant progress is needed to fully prepare for and align with the regulation.

Based on a total cost of ownership (TCO) modelling by UMAS and UCL, and more than 30 stakeholder interviews from across the maritime value chain, this insight brief dives deeper into the policy measures and highlights their implications for the sector's capital and operational strategies, costs, and risks, with a special focus on how the measures and the industry's responses to them can ensure that scalable, zero-emission fuels and the vessels that use them reach commercial maturity in time to minimise overall risks and disruption.

Policy measures adopted at MEPC 83

The agreed policy architecture is based on a tiered global fuel standard that sets limits on the GHG intensity (GFI) of fuels for every year for 2028-2035 and 2040. Two trajectories are set: a less stringent "base" line that divides undercompliance into different tiers, and a more stringent "direct compliance" line that vessels need to meet to avoid penalties. Vessels can either comply, under-comply, or over-comply in different tiers for any given year. Shipping companies can comply in several ways—by switching fuels, paying penalties to the IMO through remedial units (RUs), or for GHG intensity above the base compliance trajectory buying surplus units (SUs) from ships that have overshot the targets. Vessels using ZNZ fuels also receive a financial reward that is yet to be defined. For more details on the targets, the design, the maximum GFI of ZNZ fuels, and revenue disbursement, see Appendix I.

Based on this system, vessels can find themselves in four compliance positions related to the two tiers:

Penalty	Base	Direct compliance	Overcompliance
Vessels with emission intensities higher than the baseline pay RU2 of $380/tonne CO2e for their deficit to the baseline or buy SUs, as well as pay RU1 of $100/tonne CO2e on their base to direct compliance deficit.	Vessels that hit the base targets pay RUs of $100/tonne CO2e (RU1) for their deficit to direct compliance. SUs cannot be purchased from this position.	Vessels with emissions intensity equal to the direct compliance targets do not need to make payments nor generate a surplus.	Vessels that emit less than the direct targets generate SUs that can be sold once, banked for two years, or cancelled. Vessels may also be eligible for a reward.

Companies' compliance positions will thus be driven by fuel choices and their emissions intensity, the abatement costs of these fuels, and the relation between these abatement costs and the levels of RUs, SUs, and rewards.

Guidelines that define the emissions intensities of various fuel options, and thus which fuels are eligible for rewards, will be developed before the IMO measures enter into force. The guidelines will also set further guidance on the calculation of the GFI and the surplus/deficits compared to the baseline, as well as rules that determine the reward levels for eligible fuels. RU prices have now been set for the first period (2028-2030) but are expected to increase in future periods to ensure that GFI targets are met.

Implications for the e-fuel transition

- The measures as currently defined can be complied with by many different ship specifications and fuel pathways, but the steepening GFI curve and likelihood of increasing RU prices will narrow the potential compliance options in the future to scalable zero-emission fuels such as e-fuels. The development of the value chain for e-fuels cannot be delayed until the late 2030s if it is to reach technological and commercial viability in time for full scale up. This requires a growing portion of the global fleet to adopt such fuels already in the first years of the measures.
- Many shipowners indicate that they are likely to focus on near-term cost-optimisation strategies during the initial compliance period (2028-2030), while those who already have a long-term strategy for scalable zero-emission fuels will seek to leverage the compliance system to maximise early opportunities and gains from their investments.
- The TCO analysis, however, shows that ammonia is likely to be the most competitive pathway from the mid-2030s onwards, even without rewards and increased RU prices. This suggests that ammonia dual-fuel vessels could be a preferred option already today. Rewards, revenue generation to fund them, and higher future RU prices are required to generate a first-mover business case for e-fuels rather than their blue alternatives.
- Industry interviews indicate a mix of approaches. Many companies cite e-fuel supply uncertainty and commercial risk as challenges hindering their planning even post-MEPC 83.
- The ability to bring forward the maturity of scalable options such as e-fuels and reach the milestone of 5% scalable zero-emission fuel use by 2030 will depend on how many companies are willing and able to integrate a long-term view on e-fuels into their short-term compliance strategies, which in turn hinges on critical further work from the IMO.

The transition period to full decarbonisation allows for multiple fuel options that will narrow as targets become more stringent over time. In the early years, conventional vessels can comply either by using an increasing share of drop-in biofuels or onboard carbon capture and storage (CCS). Vessels running on liquified natural gas (LNG) can avoid a significant volume of penalties to be paid in the beginning and could potentially run on bio- or e-LNG or later be retrofitted to run on ammonia. E-fuels can reduce more emissions but generally require higher capital investments throughout the value chain and are not yet competitive.

At the same time, the set GFI reduction factors give a clear indication of where the sector needs to be in the long run. Extrapolation from the regulations suggests that the GFI will require an approximate 80% reduction of the carbon content of fuels in 2040, so that only biofuels with a very low carbon footprint and e-fuels are likely to meet the targets. Where biofuels might hit scalability constraints due to scarce feedstocks and competition from sectors such as road and aviation, e-fuels have a high scalability potential.

While 2040 is relatively far away, the lifespan of vessels and the scale of fuel production and bunkering infrastructure needed globally mean that immediate investments are needed to put the sector on the right track. The development of the value chain for e-fuels cannot be delayed

until the late 2030s - the technology is in its early stages, key challenges to scaling up remain, and building production or compatible vessels can take several years.

An early push to commercialise e-fuels is crucial. This does not require the whole fleet to switch to e-fuels right away but does require a growing portion of the fleet to explore and use these fuels already this decade. Reaching around 5% e-fuel uptake in 2030 can provide a key tipping point for the larger scale-up of the value chain in the following years. An early uptake enables cost reductions through innovation and economies of scale, allows the workforce and supply chains to evolve in tandem with demand, and helps avoid costly investments in technologies that may soon be obsolete. In this way, early action lays the groundwork for a smoother, more efficient, and lower-cost shift away from fossil fuels.

Ammonia and LNG are the most competitive options from the start, with ammonia taking a competitive advantage from 2037 onwards, but more is required to achieve an early transition to e-fuels

While short-term uncertainties on the further development of policy elements remain, TCO modelling gives a clear indication of the likely development of technologies' comparative competitiveness and the competitiveness of ammonia in the long run.[1] Figure 1 shows that even without rewards, conventional fuel would already be significantly more expensive than LNG and ammonia. LNG has a near-term lowest comparative cost between 2030 and 2035, which can be extended to 2037 with onboard CCS. Ammonia, specifically blue ammonia, appears to be closely competitive with the two LNG options initially, and then significantly more competitive from 2037. Blue ammonia is expected to generate surplus credits until around 2037. After its lowest-cost compliance position changes from overcompliance to base position, it stops generating surplus credits in 2037 but remains the lowest cost option. Under the modelled fuel price projections, e-ammonia becomes the lowest cost compliance position after 2045.

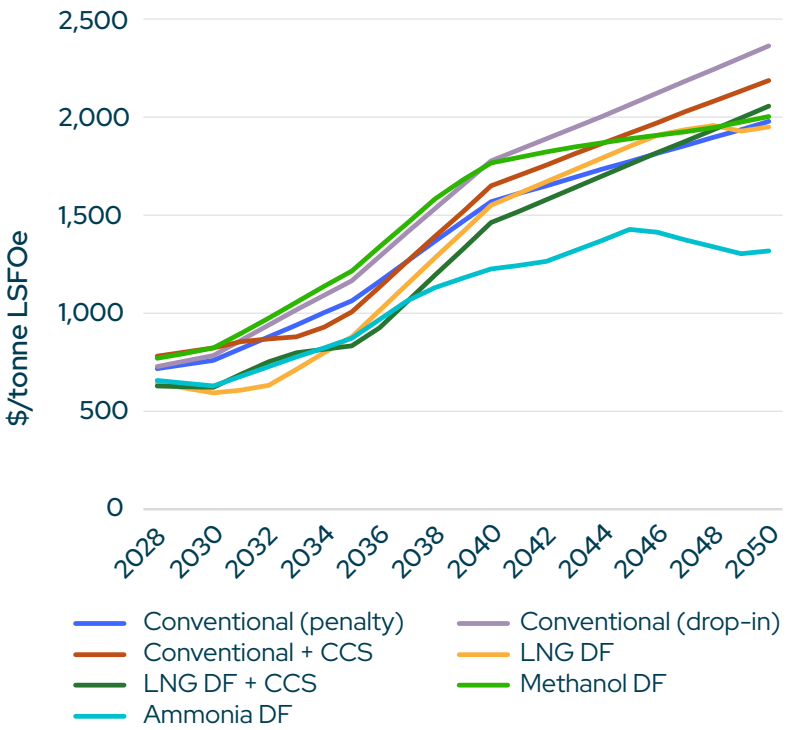


Figure 1: *TCO for the lowest cost compliance options based on static RU/SU development without rewards*

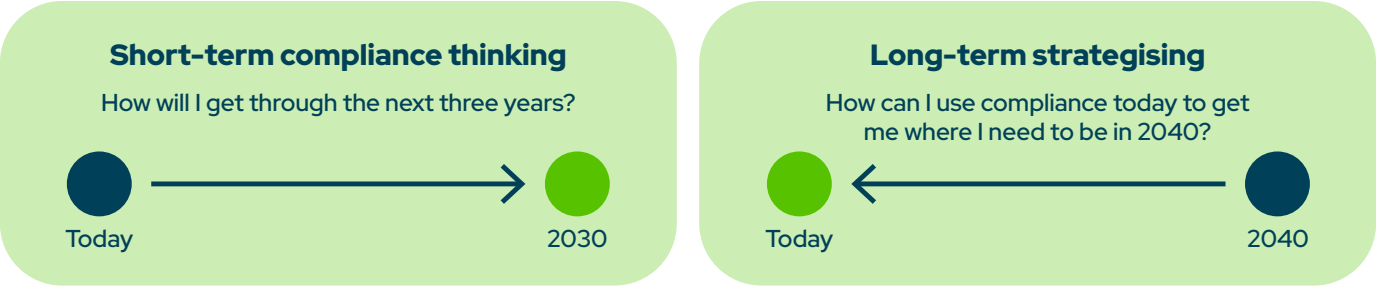
The analysis shows that while the steepening curve of emission reduction factors combined with the current RU prices is sufficient to achieve competitiveness for e-ammonia in the long run, it is insufficient to ensure an early transition to such fuels and incentivise uptake during the first years of this framework.

1 *Price assumptions are the same as in the report* How the IMO's mid-term measures might shape shipping's energy choices and transition to e-fuels*, which in turn is based MEPC 82/INF.8/Add.1.*

The transition will require a combination of near-term cost optimisation and long-term strategic investment

The policy measures drive the sector's long-term fuel shift but also influence which transitional technologies have potential and for how long. This is largely driven by the GFI reduction factors, the level of the RUs and the zero-emission fuel rewards. The RUs are set for the first three years of the transition until 2030, with details on the review methodology to be agreed by 2028, and the price levels will seek to balance emission reductions (driven by a high RU2 price) and revenue generation to a central IMO fund (through a relatively low RU1 price). The RU prices will in turn drive the volumes and prices of the SUs, and the level of rewards needed to stimulate ZNZ fuel use. The development of RU prices is therefore critical for shipowners to determine which compliance type best fits their fuel choice. With each review, the parameters for what optimal compliance looks like will be reset, impacting vessel choices, fuel choices made by dual-fuel vessels, viability of offtake agreements, etc. Interviews with stakeholders from across the value chain highlighted two approaches to the early stages of the transition:

1. **Short-term cost optimisation:** Shipowners focus on the newly set parameters and calculate which fuel blends or types give them the lowest-cost path to comply with the regulation. This approach focuses on using the existing fleet and available strategies to reduce costs rather than heavy capital investments in new technologies.
2. **Long-term strategic planning:** Shipowners focus on a longer time horizon and the fuels they'll need in the long run. Shipowners use the short-term cycles to make their long-term strategy work. This approach is characterised by higher capital investments in alternative fuels and leveraging compliance strategies to cover the cost gaps. For example, a shipowner may have a long-term ammonia strategy and orders for ammonia dual-fuel vessels. To support this strategy, it may apply short-term compliance strategies that include strategic deployment related to companies' exposure to European Union (EU) rules or the banking/selling of SUs.



Each approach has its own benefits and risks for individual shipping companies and impacts the shape of the global transition. Short-term cost optimisation strategies may delay capital investment, enhance immediate competitiveness, and reduce investment risk in today's uncertain market environment. However, they expose operators to fuel price volatility (especially in the spot market) and a risk of stranded assets or accelerated vessel depreciation as the regulations tighten.

In contrast, long-term transition planning—such as early adoption of e-fuels or securing long-term offtake agreements—can ensure certainty of fixed pricing and reduce the likelihood of stranded assets in the future. Securing a long-term offtake agreement today can protect against higher future operating costs due to price fluctuations. However, this approach may complicate short-term competitiveness and has higher upfront risks, as it requires committing to emerging

fuel types and supply chains that are still maturing. Furthermore, it hinges on finding a compliance position that can reduce the cost gap as much as possible, for example through SUs or rewards.

More shipowners here promotes an early transition

	Short-term cost optimisation	Long-term strategic planning
3-year position	Fuel choice and volumes used are driven by competitive costs, flexibility, and risk reduction.	Early planning of the fuel mix is driven by a combination of costs and long-term asset value. Compliance position is designed to maximise gains from proactive investment.
Long-term position	Fuel choice and compliance strategies are increasingly constrained by available options and costs as RU prices are likely to go up.	Fuel mix is established by early planning for future cost and risk, driven by risk reduction and competitive costs.

More shipowners here promotes an incremental transition

Table 1: *Trade-offs between short-term cost optimisation and long-term planning*

If all shipowners opt for short-term cost optimisation, it is likely to drive the lowest-cost transitional fuels and therefore may lead to an incremental transition whereby the global fleet only switches to scalable zero-emission fuels when the GFI measures have reduced alternative options In contrast, a significant number of companies integrating long-term planning into compliance strategies is more likely to lead an early transition. This does not exclude transitional fuels such as LNG or drop-in biofuels but rather ensures e-fuels become part of the fleet's fuel mix and reach commercial maturity sooner. These strategic choices have ripple effects beyond individual companies. They directly influence the readiness of the broader system, including fuel production, bunkering services, and supporting infrastructure.

Shipowners may focus on short-term cost optimisation in the first cycle while working on their long-term strategies

While the TCO modelling shows that ammonia is likely to be the lowest-cost option from the mid-2030s and beyond builds a strong case for early investments in e-fuels, shipowners face remaining uncertainties in the interim period, reinforced by the likelihood of changing parameters.

Interviews with stakeholders from across the maritime value chain give an indication of how companies are approaching the pre-2040 transition period, particularly the first cycle in which RUs will remain relatively low and rewards remain relatively unclear until implementation. It is important to note that these reflections from shipowners are preliminary: they were collected in the immediate aftermath of MEPC83. Both the market landscape (e.g., prospects for fuel availability) and understanding of the likely future development of the measures (e.g., the likely increase of SU prices and the challenges in meeting the steep GFI decline from 2035 to 2040), suggest that more shipowners will re-assess their long-term requirements in their early approach to compliance.

Due to the limited ability to project where the measures were headed prior to agreement, and the remaining lack of clarity around the rewards and emission factors, the 2028-2030 period is likely to be characterised by short-term compliance optimisation as shipowners prepare their longer-term strategies. However, some shipowners are already considering integrating their long-term strategy into this initial cycle. Roughly, shipowners indicated four strategies for their existing and ordered fleet for the coming years:

1 Conventional vessel	2 Conventional vessel	3 LNG vessel	4 E-fuel dual-fuel
Increase the share of drop-in biofuels to reach the base line and then pay RU1. Companies with EU exposure avoid penalties of FuelEU Maritime	For vessels with EU exposure: Increase the share of drop-in biofuels to direct compliance and generate SUs in the EU to offset extra costs.	Full use of LNG to reach direct compliance first and then baseline. For EU vessels, overcompliance can be banked to offset future emissions or defray RU1 costs under IMO for a few years.	Use methanol or ammonia to generate a surplus, preferably also in the EU. The IMO surplus units can be sold to offset the cost, while EU surplus is more likely to be banked or pooled internally.

E-fuels can also be a tool for short-term cost optimisation. However, this hinges on the value of the SUs they can generate, the availability and size of rewards, and owners' ability to cover their additional cost and risks (see sections below). Shipowners not yet committed to dual-fuel vessels that can use e-fuels pointed to several perceived constraints.

- **High uncertainty:** The regulatory and market landscape remains fluid. While shipowners may make informed assumptions, uncertainty around SU supply and pricing, future RU adjustments, and the evolution of mechanisms like FuelEU Maritime (e.g., treatment of banked overcompliance) make it challenging to commit to a specific technology or fuel pathway with confidence.
- **Fuel availability constraints:** There are persistent concerns about access to alternative fuels at key bunkering hubs. Without confidence in supply, shipowners are hesitant to invest in vessels or systems tied to specific fuels.
- **Exposure to commercial risk:** Long-term offtake agreements are seen as financially risky. While many fuel producers require long commitments to secure investment, shipowners often cannot commit beyond five years, creating a significant mismatch in planning horizons and limiting market development
- **Timing and readiness:** Many stakeholders have taken a wait-and-see approach, choosing to delay major decisions until regulatory measures are fully adopted. Additionally, the lack of zero-emission vessels in current order books means immediate efforts are focused on short-term compliance rather than strategic fuel transitions.

How many shipowners move towards long-term planning early on will be critical to the prospects for the early commercialisation of e-fuels. While the interviews highlighted a remaining uncertainty around the transition period, especially the first years of implementation, the TCO modelling shows that competitiveness for e-ammonia as a scalable zero-emission fuel is within reach.

Key considerations from across the value chain

The way shipowners view the balance between ensuring short-term cost optimisation and investing in their long-term strategy directly affects energy and infrastructure actors in the value chain. For example, fuel producers indicated the continued importance of offtake agreements with significant duration (five to ten years as a minimum) to reach final investment decisions, and persistent challenges in reaching such agreements. While forthcoming clarity on rewards for ZNZ fuel use will reduce uncertainty around the business case (as further highlighted below), producers nevertheless expect a delay between signing agreements and volumes becoming available. Whereas new vessels can be delivered within two to three years, depending on shipyard capacity, fuel production sites will likely require offtake agreements to reach final investment decisions, and multiple years from those agreements to supply. It is therefore critical for the fuel supply side that offtake agreements quickly follow the resolution of remaining policy uncertainties.

The TCO modelling similarly indicates some challenges for fuel production considering the current state of the measures. While it does point to a significant demand for ammonia as a shipping fuel, especially in the next decade, uncertainty remains on the demand for production pathways for synthetic fuels (as opposed to blue ammonia). For example, fuel producers focusing on e-ammonia face significantly more uncertainty without additional support from the rewards.

From a bunkering perspective, many ports indicated a more reactive position as early low volumes of e-fuels can rely on flexible bunkering solutions that do not require as much capital investment. Their investments will become more relevant once the first offtake agreements come into place. At the same time, the TCO analysis highlights an important role for blue ammonia early in the transition due to its close competitiveness with LNG and higher competitiveness than conventional fuel oils. While the use of e-ammonia may be relatively low in the early years, the demand for blue ammonia bunkering is likely to increase significantly between now and 2035.

What is still required from the IMO to support an early transition?

- Kickstarting the transition to scalable zero-emission options such as e-fuels and achieving the objectives of the 5% goal requires that enough (not all) shipowners incorporate these fuels into their compliance strategies as soon as possible.
- The TCO analysis shows that early adoption hinges on further refinements of the measures through rewards, higher RU prices, etc. The number of shipowners who make their fuel choices will be impacted by strategic views on these fuels and market developments, but primarily by the relative competitiveness and compliance positions likely to be available to various fuels in successive periods. The evolution of optimal compliance positions over time will dictate the relative competitiveness of different options.
- The steep decline of the GFI from 2035 to 2040 and the likelihood of significant increases to RU2 may already underpin the case for investing in e-fuel pathways today. While ordering dual-fuel vessels seems to be the best bet for the long term, the weaker short-term business case for e-fuels opens the way for multiple compliance options in the transition period.
- The business cases for fuels depend on the interplay between rewards, value and availability of SUs, and the level of RUs. Changing these parameters comes with significant opportunities for—and risks to—an early energy transition.

Optimal compliance positions for different fuels will evolve over time

Fuel choices will be impacted by their total cost of ownership, which includes both capital and operational expenditures, as well as any potential penalties, rewards, or surplus generation. The TCO of a given fuel depends on the volume used, which in turn is impacted by what is most optimal within the compliance framework.

The tiered GFS creates various positions in relation to the base and direct compliance lines. Each position comes with its own additional costs and potential benefits. This means that each fuel has a lowest-cost position, or "optimal compliance position". Shipowners not only have to decide on which fuel to pick but also the optimal compliance position of the chosen fuel. This is driven by the fuel and its emissions intensity in relation to the reduction targets, as well as the abatement cost of the fuel in relation to the individual or combined RU prices and the SU price. This influences the volumes of the alternative fuels used and, at a system level, how much revenue is generated through RUs and how many SUs are generated. There are four possible positions, depending on key criteria:

Compliance position	Explanation	Criteria
Penalty	No low emission fuel use. RU2 (or SUs) is paid until the Base line and RU1 between Base and Direct Compliance.	Requires for the penalties/SU cost for a conventional ship to be less than the TCO of the alternative fuel. Low RU and SU prices trigger this position.
Base	Minimum volumes of low-emission fuel used to reach base trajectory. RU1 is paid for the difference until the Direct Compliance line.	Requires the abatement cost of the low-emission fuel (potentially adjusted for rewards) to be lower than RU2.
Direct Compliance	Higher volumes of low emission fuel used to reach direct trajectory.	Requires a high RU1 and for the SU price to be high enough to avoid a penalty position, but low enough to keep overcompliance more expensive.
Overcompliance	Maximum volume of a low-emission fuel used. SUs are generated when the emissions intensity is below the direct trajectory.	Requires high SU prices to compensate for the abatement cost of the alternative fuel.

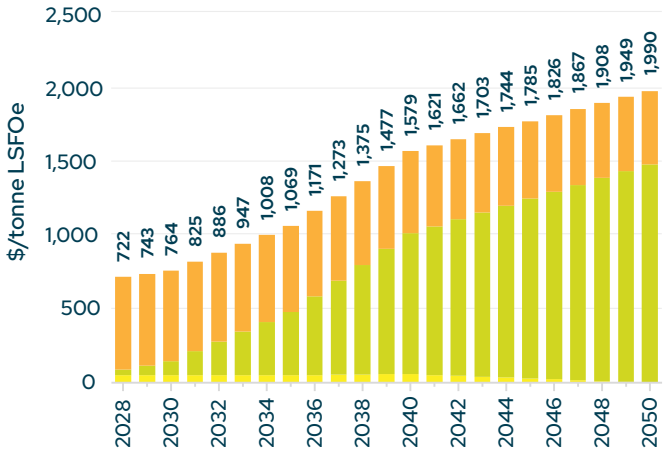
Table 2: *The optimal compliance position for each fuel depends on factors such as the RU/SU prices and abatement costs of low-emission fuels.*

The optimal compliance positions are not static for each fuel. As the emissions reduction targets become more stringent, it may become more difficult to reach over-compliance when using a maximum amount of a transitional fuel. For example, a shipowner running a vessel fully on a fuel with 50% emission reduction and a relatively low cost may find that generating surplus units is the cheapest option to begin with, but as the targets become more stringent, full consumption of this fuel will eventually only get the vessel to direct compliance, declining eventually to the baseline or below.

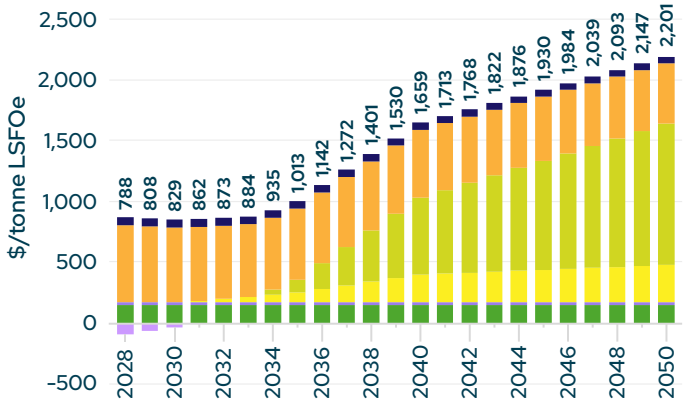
Besides the emission reduction factors, four key parameters will change the compliance position of a given fuel: rewards, SU value, SU volumes, and RU levels. Before diving into how these parameters may change the fuel outlooks, the figures below present the likely developments of the TCO of different fuel options by following their optimal compliance positions throughout the years. **These projections exclude rewards and assume static RU/SU levels—assumptions that are not realistic in practice, but which provide a starting point for how changing the parameters will affect these outlooks.**

Without rewards and increasing RU prices, e-fuels are unlikely to be part of the early fuel mix

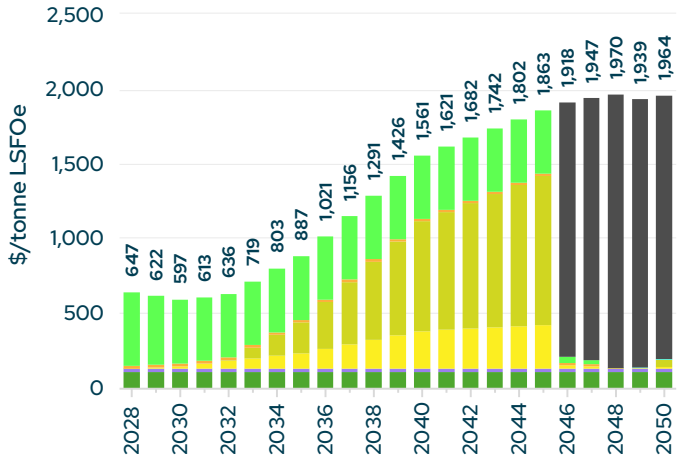
Based on fuel price projections and conservative IMO assumptions (e.g., assuming no reward mechanism and no strengthening of RU prices), this analysis highlights each technology type's optimal compliance position. This is derived from the fuels' abatement costs and then compared to the RU and SU levels as outlined above. This leads to an optimal position at which the TCO for that fuel is lower than any other potential compliance position in any given year. The figures below outline the TCOs for the fuels at their optimal compliance position between 2028 and 2050. The TCO is represented as an operational cost, calculated in US dollar per tonne of low-sulphur fuel oil equivalent (LSFOe), but also includes the capital costs of any required modifications to the ship. These findings highlight the tension between near-term optimisation and long-term fuel choices. All vessel specifications can be used to comply, but the choice of vessel type will both define short-term relative competitiveness of operations and come with significant risks and opportunities for the long-term approach to the transition.



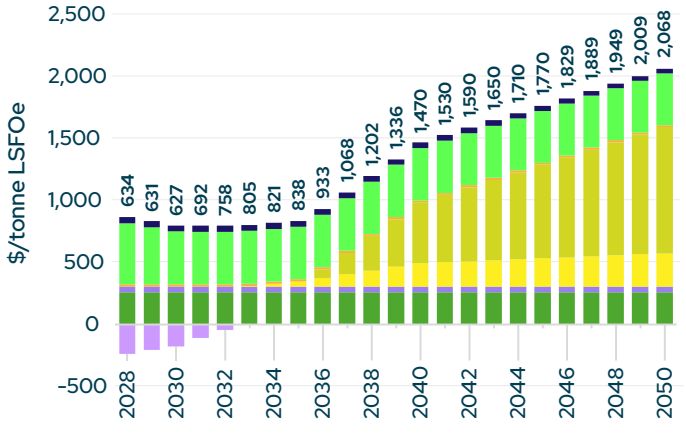
Pay to pollute: A conventional vessel running on LSFO and paying RU2 and RU1. This vessel can also buy SUs for the same or slightly lower price than the RU2 value.



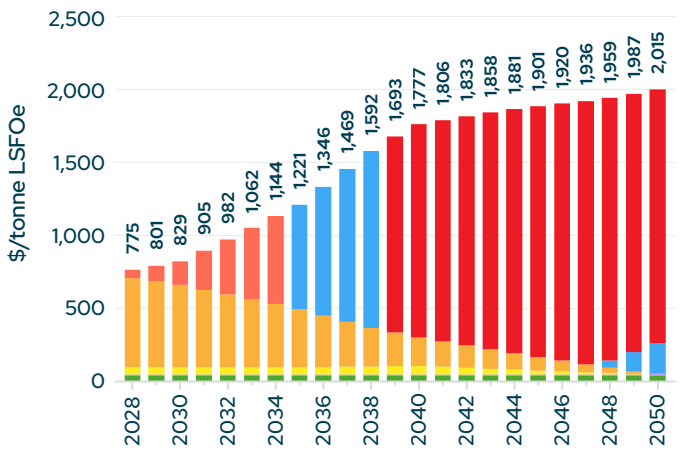
Conventional vessel with CCS: This vessel can first generate SUs and once it can no longer generate these it switches to baseline compliance.



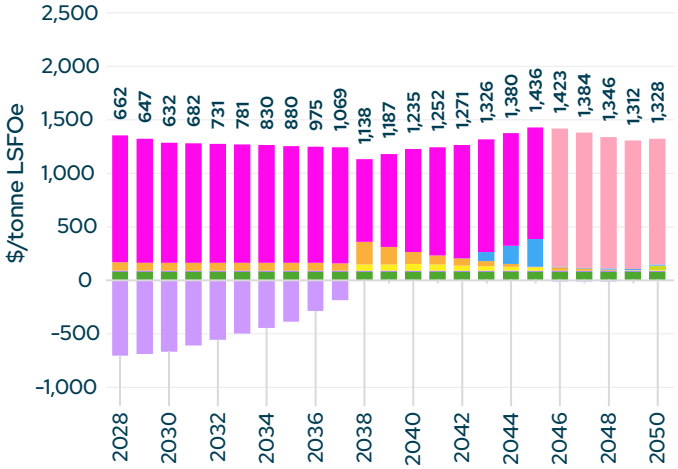
LNG dual-fuel vessel: This vessel can reach direct compliance in the first year and then switches to baseline compliance when the high targets cannot be reached.



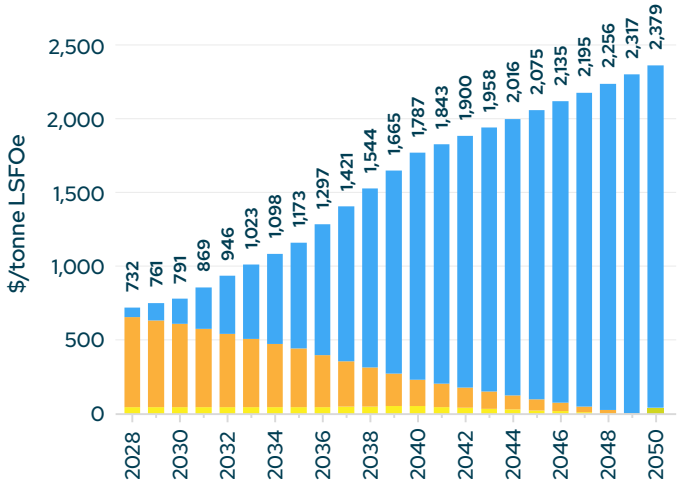
LNG dual-fuel vessel with CCS: This vessel generates SUs in the first year and slowly moves from direct to baseline compliance as the targets become more stringent.



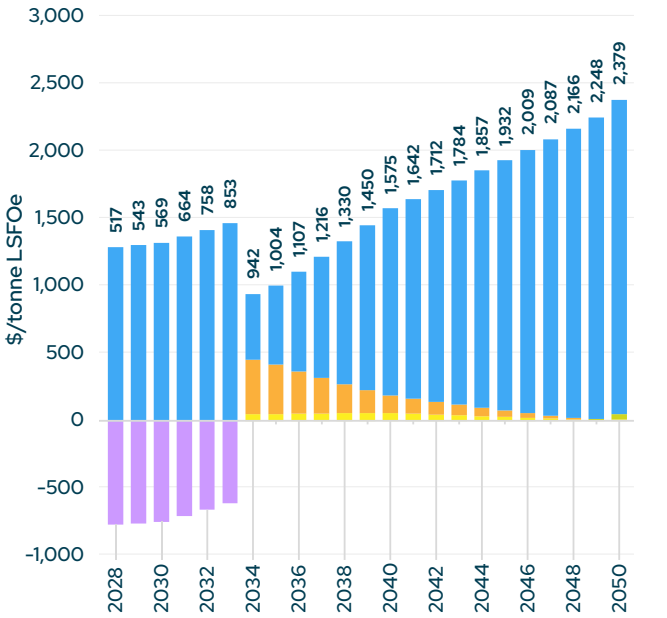
Methanol dual-fuel vessel: Due to the costs of methanol, the cheapest option is to be at baseline and switch from bio to e-methanol as the price of e-methanol comes down.



Ammonia dual-fuel vessel: Due to blue ammonia's relatively low costs and emissions factor, this vessel will first generate SUs before moving to a baseline position in 2038.



Conventional vessel with drop-in biofuel: Based on the cost of biofuels in comparison to the RU levels, the optimal position is to use a bio blend to move to the baseline and pay RU1 until direct compliance.



Conventional with a "new" drop-in bio blend: Bio-blends are likely to respond to the market to generate new compliance options. One possibility is a blend with a lower cost but higher emissions intensity that generates SUs until 2034 and then returns to a baseline trajectory with RU1 payments.

- Vessel CAPEX
- Vessel OPEX
- IMO tier 1 RU
- IMO tier 2 RU
- CCS costs
- IMO SU credits
- Fuel cost (LSFO)
- Fuel cost (LNG)
- Fuel cost (Bio-MGO)
- Fuel cost (Bio-LNG)
- Fuel cost (Bio-methanol)
- Fuel cost (Blue ammonia)
- Fuel cost (e-MGO)
- Fuel cost (e-LNG)
- Fuel cost (e-methanol)
- Fuel cost (e-ammonia)

Targeted rewards will reduce the TCO for e-fuels and support the early development of the value chain

The figures above indicate the TCO for different possible fuel pathways based solely on fuel and vessel costs, RUs and SUs only. Financial rewards, however, will play a critical role in defining which compliance position is the optimal position for a fuel. To increase the volume of scalable zero-emission fuels in initial compliance strategies, rewards for such fuels should help make overcompliance through maximum consumption of the fuel the optimal position. This can be done by **bridging the gap between the TCO of the optimal, lowest-cost compliance position of the fuel and the TCO of that of a reference fuel**. For example, this could mean covering the TCO cost gap of e-ammonia vs LNG for each year. This way, the rewards include the cost of modifying ships and account for variances in the volumes of fuels required.

The TCO analysis shows that without rewards, LNG and ammonia dual-fuel ships are the most competitive options before the mid-2030s. Regardless of the scope and level of the rewards, ammonia is likely to have a long-term competitive advantage. However, e-fuels remain insufficiently incentivised before 2040 and are unlikely to outcompete blue fuels without a reward. The reward mechanism, as well as subsequent revisions to RU prices, can be expected to have a significant impact on this outlook. A reward that closes the cost gap between e-ammonia and LNG would require around $14 per gigajoule (GJ) or $190 per tonne of carbon dioxide equivalent (tCO2e). This would make both LNG and e-ammonia the lowest-cost options from the start. Alternatively, using the reward mechanism to close the gap between blue and e-ammonia would require a reward of $12 to$13/GJ. While this would close the gap between these two ammonia production pathways, it would not close the gap between ammonia and LNG, which would remain the lowest cost option until 2035. **A reward that helps close the cost gap for e-ammonia can play an important role in ensuring that scalable e-fuel production is developed in time**.

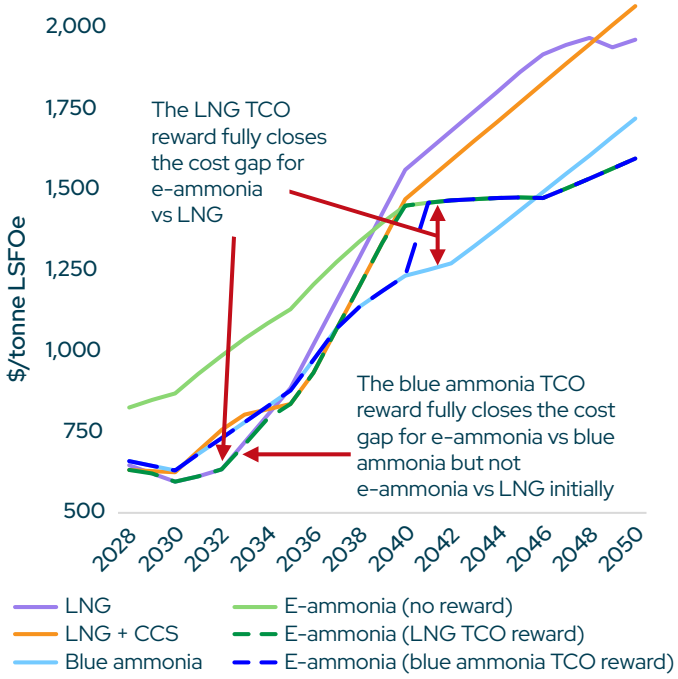


Figure 3: *TCO for the lowest cost compliance options based on static RU/SU development and with rewards covering various gaps*

The price of the SUs is critical for the business case for scalable zero-emission fuels

The competitiveness of different ship specifications and their compatible fuel options depends not only on the reward but also on the economic benefit through the price of SUs.

If the price is low,

1. the fuels' penalty positions involving non-compliance with the GFI trajectory will be more competitive. This is because a low SU price (meaning significantly lower than the ceiling price set by the RUs) will make it cheaper to compensate for the deficit over the baseline.
2. the fuel's over-compliance positions that involve the selling of SUs become less competitive as it reduces the incentive to overperform beyond direct compliance. Ensuring a business case for e-fuels thus requires higher rewards to enable their uptake.

However, the price of SUs is a matter of supply and demand: if the supply of SUs is low and more vessels take a penalty compliance position, the closer the price will be to that of the RU2. Conversely, higher levels of over-compliance will create stronger downward pressure on the price of the SUs.

From this TCO analysis, very few ships look likely to generate SUs in the first three years. Compliance looks most likely to be achieved through conventional or LNG-fuelled ships, and with some amount of 'pay to pollute', e.g., paying both RU prices. However, this may change if new fuel products enter the market. For example, the biofuel industry may respond to the regulations by offering a bio-marine gas oil (MGO) that has a higher emission factor but a cheaper abatement cost. The lower cost may push the optimal compliance position for bio-MGO from base to over-compliance in the first few years, when GFI levels are less stringent and can be met without very low-emission options. In turn, this may generate enough SU credits to push the price of the SUs down. While the downward pressure on the SU price would likely diminish over time, this could reduce the attractiveness of over-compliance through ZNZ/e-fuels. This would require a higher reward for e-fuels to ensure they have a business case. For example, if the SU price falls below $300/tCO2e, the reward required to ensure over-compliance as the optimal position for e-ammonia could be around $20/GJ, which would fund abatement of only roughly 6.8 million tonnes of LSFOe if a-ammonia meets the ZNZ fuel criteria, or just over 2% of the total energy mix.

To minimise a downward pressure on the price of SUs and support the business case for e-fuels, the IMO has a few options:

1. **High integrity on the Life Cycle Assessment (LCA) Guidelines and sustainability certification:** The LCA Guidelines on emission factors and sustainability criteria are critical to define which fuels may generate SUs and which are eligible for rewards. The risk of lowcost biofuels' impact on investment in long-term solutions can be mitigated if the IMO's LCA guidelines and sustainability criteria do not sufficiently consider impacts on food crops and manage land use change risks. Existing regulations, such as FuelEU Maritime, aim to limit incentivisation of biofuels to sustainable bioenergy sources by focusing only on waste feedstocks or other scalable/non-competing feedstock supplies, an approach that could be replicated through stringent guidelines.
2. **Targeting rewards to scalable zero-emission fuels:** The availability of rewards for both e-fuels and biofuels increases the potential supply of SUs and therefore lowers their price and creates greater pressure on the revenues for rewards. Limiting rewards to fewer fuels (e.g., those with key long-term scalability and potential) can contribute towards higher SU prices, which would then close a greater proportion of the overall cost gap for long-term options such as e-fuels. This would also amplify the ability of the (limited) revenues to support scalable zero-emission fuels.

3. **Covering the difference when the SU price falls below certain levels:** A part of the revenues could also be used to set a flexible floor price, meaning that revenues from the central fund would be used to cover the gap between the actual price and the floor price as a guarantee.

Figure 4: *The RU2 level functions as a ceiling price for the SU price. Increasing RU2 means a potentially higher SU price.*

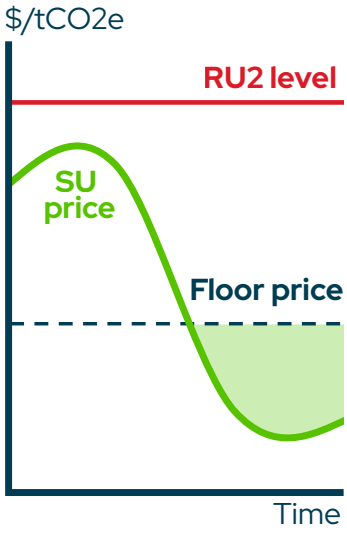


Figure 5: *The IMO could provide guarantees for the SU price to ensure a minimal level for the sale of surplus.*

Increasing RU levels in the long run is required to progressively remove the option of 'pay to pollute' and ensure a sufficiently high SU price, but might lead to a reduction in total revenue generated

The levels of RU2 automatically set a ceiling price for the surplus units, as no SU would be sold if it were cheaper to simply pay directly to the IMO. Therefore, adjusting the penalties for non-compliance not only changes the TCO for fuels that are likely to end up requiring RU payments, but may also affect the prices of the SUs, affecting the TCO for fuels relying on the sale of surplus units.

E-fuels require a high penalty price to stay competitive and depend on selling SUs to remain viable in the long term. The RU2 level may need to rise significantly over time to ensure this. Over time, and as the targets become more stringent, further emissions reductions require fuels with higher reduction levels but also a higher abatement cost. This means fewer SUs may be generated, resulting in a price closer to RU2. However, as the abatement cost of the remaining options is high, generating SUs will become less attractive due to their relatively lower value. The IMO has agreed to include a review mechanism for the RU prices with an adjusted RU2 from 2031 onwards. This is likely to also lift the SU ceiling price, which should help fuels with high abatement costs to increase their competitiveness (by selling SUs), regardless of the support

provided by the reward mechanism. A further effect should be a lowering of the required reward levels as it reduces the remaining cost gap for the reward mechanism and makes the compliance positions of lower-cost fuels more expensive.

RU1 can also be adjusted upwards. This changes the TCO for all fuels whose optimal compliance strategy is for GHG intensities above the direct compliance trajectory, as they will be required to make the RU1 payments. If RU1 increased significantly, the optimal cost position for these fuels might shift, and this in turn can affect the total revenue generated and rewards required.

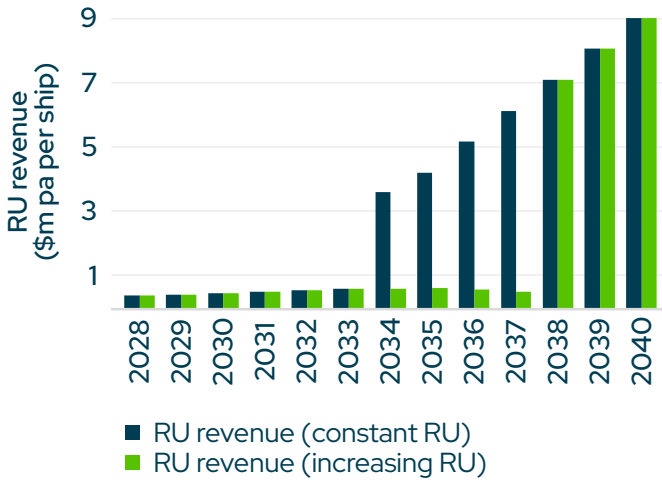


Figure 6: *Potential impact of the RU prices on the total generation of revenue.*

Enabling a just and equitable transition

A just and equitable transition requires that no country is left behind and mostly depends on financial support through a central fund that enables, for example, technology transfer, capacity building, fuel and infrastructure development, support for wider climate mitigation and adaptation, and mitigation of disproportionate negative impacts. Achieving this is critical for several reasons:

- Shipping's energy transition and accompanying climate regulations can increase trade costs that disproportionately impact smaller nations, particularly small island developing states (SIDS) and least developed countries (LDCs).
- The shipping industry employs over 1.8 million seafarers from around the world, many from developing countries. The transition to zero-emission shipping will affect jobs, training needs, and working conditions.
- Shipping is a truly global sector that is interconnected with many different energy, port infrastructure, finance, and trade systems. To achieve a global transition and avoid fragmentation across these systems, industries in less developed countries will also need to decarbonise.

Sufficient revenue is required to achieve this. With the IMO measures expected to generate annual revenue of roughly $11 billion annually in the first three years, areas for a just and equitable transition are competing with reward requirements and funding to build out the global fuel supply chain. As the measures drive shipping's energy system towards long-term, scalable zero-emission fuels like e-fuels, many developing countries with renewable energy potential can potentially benefit as long as the right support is provided. This could come from IMO funding, as well as other multilateral funds, including development banks. The guidelines on disbursement and the IMO's cooperation with other funds will be critical.

Recommendations

Industry

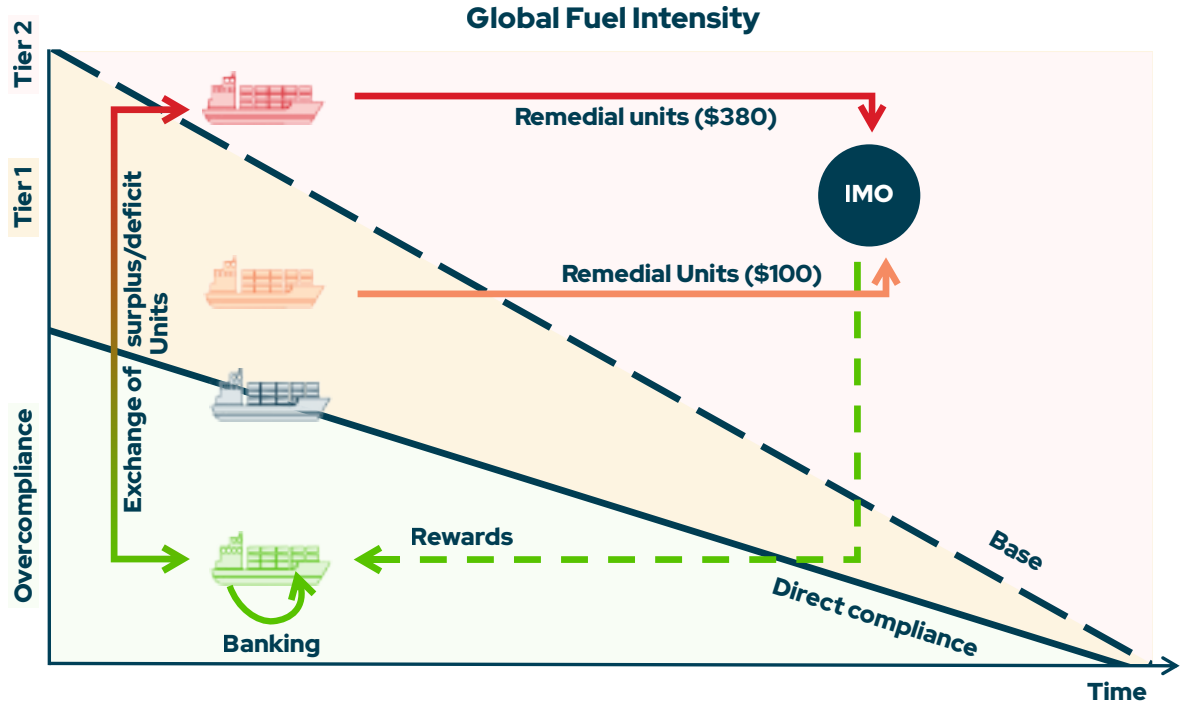
- Take time to understand and study the agreed-upon framework and its potential implications for competitiveness. There are some clear implications for ship specification competitiveness already, even if these will benefit from clarifications arising as IMO adopts various details in guidelines over the next two years.
- Consider how the likely long-term fuel pathways can be integrated into short-term compliance strategies. Analysis suggests that, due to the steep GFI curve, ammonia will have the lowest TCO from 2037 onwards, even without rewards. Given the agreement to include a reward mechanism and the likelihood of increasing RU prices, there is significant potential to comply via e-fuel adoption already in the first period (2028-2030).
- With much detail still needing to be finalised, continue engaging with policymakers on the definition of zero- and near-zero emission fuels, LCA guidelines, rewards, RU levels, etc. Using these to maximise the alignment of the regulation with the long-run business case will be key.
- Actively support revenue disbursement requirements that support rewards and ensure a just and equitable transition to maximise a rapid evolution of widespread global fuel availability and minimise the risk of a geographically fragmented technology, energy, and decarbonisation landscape.
- Continue exploring alternative approaches to reduce cost gaps and share the risks associated with the early offtake of e-fuels: joint ventures, innovative financing / blended finance, joint offtake/demand aggregation for fuels, etc.
- Find and work with other sources of funding, including accessing existing multilateral funds and engaging with national governments for national funding and support.

Policymakers

- Ensure that guidelines maximise the potential for the fuel mix of the future to compete with lower-cost transitional fuels by using the reward mechanism to focus support for e-fuels, which are the only subset of fuels currently available that can scale to achieve IMO's 2040-2050 GHG reduction expectations, but that require bigger upfront investments.
- Set a sufficiently high reward for e-fuels within the IMO Net-Zero Framework to ensure they can compete early on and be part of the fuel mix.
- Monitor and manage the value of the SUs by restricting their volumes, lifting the price ceiling, and potentially setting price guarantees. Because the SU price hinges on the RU prices, it is key to develop a rigorous, fact-based, and predictable basis for the RU price review, responding to the changing and expected marginal cost of compliance and overall scale of revenue needed to drive an effective, just, and equitable transition.
- Ensure strict emission factors in the LCA Guidelines that factor in any sustainability criteria and external impacts, such as land use change.
- Consider and develop national policies to further drive the uptake of e-fuels, given some of the gaps in support that exist in IMO regulation, at least in the near term. This could include national subsidy schemes, support for fuel production and storage, risk sharing, etc.

Appendix I - IMO's Policy Measures MEPC 83

The **tiered global fuel standard** sets limits on the GHG intensity of fuels between 2028 and 2035, with indications for 2040. Two lines are set: a "base" line that divides undercompliance in different tiers, and a "direct compliance" line that vessels need to meet. Vessels can either be compliant, undercompliant in different tiers, or overcompliant compared to these targets for any given year. This is combined with a flexible compliance mechanism, including fees of non-compliance (Remedial Units) or credits trading (Surplus and Deficit Units) between overcompliant and Tier 2 undercompliant vessels. Vessels using zero- and near-zero-emission fuels also receive a reward, which is still to be defined.



Zero- and near-zero emission fuels

These fuels are defined by their GHG intensity: under 19.0 gCO2eq/MJ until 31 December 2034, and thereafter no more than 14.0 gCO2eq/MJ.

Revenue disbursement

Areas for revenue spending include rewards, development of ZNZ fuels and technologies, training for seafarers, technology transfer, support for capacity building, and addressing disproportionate negative impacts.

	Reduction factor, base	Reduction factor, direct compliance
2028	4.0%	17.0%
2029	6.0%	19.0%
2030	8.0%	21.0%
2031	12.4%	25.4%
2032	16.8%	29.8%
2033	21.2%	34.2%
2034	25.6%	38.6%
2035	30.0%	43.0%
2040	65.0%	To be determined