Transatlantic Testing Ground

Assessing impacts of EU and US policies on accelerated deployment of alternative maritime fuels

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for Zero Carbon Shipping

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01 Executive summary

This report examines the significant potential impact of the US and EU's evolving climate policy landscape on maritime decarbonization. We investigate the investment implications of three pivotal policy developments:

1. The subsidies in the US Inflation Reduction Act (IRA) that can reduce alternative fuel costs.

2. The EU Emissions Trading System (ETS) and the FuelEU Maritime Regulation which progressively raise the costs of conventional fossil fuels.

3. The FuelEU pooling mechanism designed to reward early investment in advanced green technologies.

While EU and US policies will drive a range of behaviors including energy efficiency, this analysis is focused on the uptake of the alternative fuels identified in the Maritime Decarbonization Strategy as key pathways to reaching net-zero targets.[1] We first evaluate the impacts of each policy on key alternative fuel pathways, and then look at the combined impacts for transatlantic routes where both EU and US policies overlap and create opportunities for the shipping industry to test and scale alternative technologies. We provide actionable insights aimed at fuel producers, shipowners and operators, and cargo owners, and highlight where existing policy can drive near-term action.

We find the following key takeaways:

– Different policy approaches in the US and EU offer complementary solutions to scale up the production and consumption of alternative fuel. The IRA can provide benefits that significantly reduce alternative fuel production costs, while EU regulations increase the demand for alternatives through additional costs on fossil fuels.

– The EU ETS and FuelEU can double the cost of conventional fuels by 2030 and increase the cost of Low Sulfur Fuel Oil (LSFO) by more than 5 times in 2050. However, the cost of compliance with the FuelEU emissions intensity mandate is highly sensitive to uncertain biofuel availability.

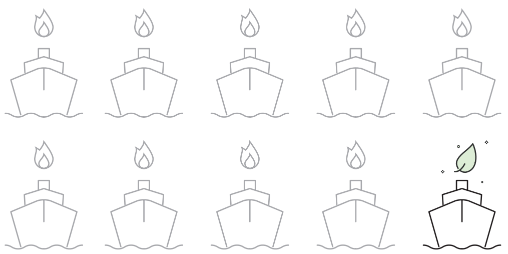
– The FuelEU pooling mechanism can provide significant time-limited benefits for alternative fuels from 2025 through 2044, incentivizing near-term investment.

– Transatlantic voyages will be impacted by both EU and US policies. The results from our analysis of container voyage costs show that the combination of EU and US policies could close the gap between LSFO and alternative fuel cost in 2030. When we factor in the additional benefits of FuelEU pooling to e-fuel costs, the gap is further reduced. For e-ammonia, the combined impacts of US and EU policy can bring total container voyage costs to 20% below conventional fossil fuels. In the case of other e-fuels, the benefits from the combination of the policies can reduce projected e-fuel costs by 45% or more in 2030, creating a potentially viable business case for sailing on alternative fuels.

02 Setting the Scene

2.1 A critical moment in the effort to decarbonize by 2050

International shipping is at a pivotal moment, with the International Maritime Organization (IMO) having set the ambition to achieve net-zero emissions “by or around” 2050 and the near-term goal to achieve “uptake of zero or near-zero greenhouse gas (GHG) emission technologies, fuels and/or energy sources to represent at least 5%, striving for 10%, of the energy used by international shipping by 2030”.[2] International shipping is reliant on roughly 300 million tonnes of fossil fuel oil annually; therefore, achieving 10% alternative energy will require replacing 35 million tonnes of fuel oil.[1]



To achieve the new targets, the IMO’s 2023 Strategy on Reduction of GHG Emissions from Ships includes a proposed “basket of mid-term measures”[2] to be assessed and agreed upon by 2025 and implemented in 2027. However, to reach the IMO 2030 target for 5% to 10% uptake of alternative technologies, investment decisions will have to be made well before 2027, as newbuild vessels can take two to three years for delivery,[3] and a full retrofit project can take over 1.5 years.[4] In the interim, existing US and EU policies can act as catalysts, strengthening the case to invest in alternative fuels. If these policies are successful in scaling alternative fuel technology in the near term, they can boost the case for strong IMO mid-term measures.

2.2 Navigating investment constraints

The substantial cost gap between conventional fossil fuels and low-GHG alternatives creates a significant financial barrier for investment in vessels capable of operating on alternative fuels (hereafter ‘green vessels’).[1] A 2023 survey of shipowners and operators found that alternative fuels’ lack of commercial viability was the main challenge for adoption.[5] In addition to fuel cost, green vessels require up to 16% higher capital expenditure (CapEx) and require higher-skilled labor. They have higher operating expenditures (OpEx) because the lower energy density of alternative fuels results in larger fuel tanks, which, in turn, results in reduced cargo space.[6]

Apart from cost, investment is constrained by uncertainty. Alternative maritime fuels are in the stage of transition between emergence and diffusion, in which technologies are proven but have not yet achieved commercial scale.[7] With alternative fuels being at a low stage of technological readiness, shipowners are hesitant to invest in alternatives with unknown future availability and cost. Facing uncertainty and a cost gap with conventional fuel can lead companies to opt for strategic delay as they anticipate more proven and cost-effective technologies in the future.

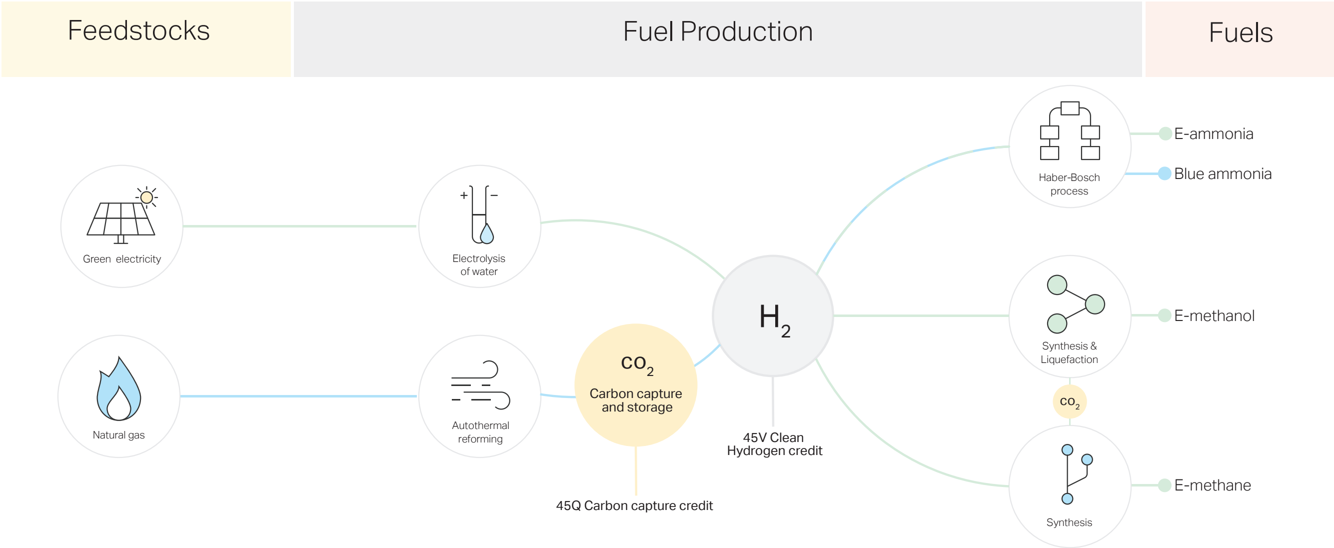
Demand-pull policies in the EU and supply-push policies in the US may provide the necessary incentives to overcome delay and incentivize near-term investment in alternative fuels. This report assesses whether current US and EU policies can motivate near-term investment in green vessels, centering on:

1. The ability of policies to narrow or close the cost gap between conventional and alternative fuels.

2. The extent to which policies encourage near-term action.

If the combination of US and EU policies can drive uptake of alternative fuels in the near term, this can create a testbed for new technologies on transatlantic voyages. Greater use of new technologies in the Atlantic may bring down costs, increase certainty, and accelerate the transition through learning and increasing returns to scale.

Figure 1. IRA tax credits in the alternative maritime fuel production process.



2.3 US Inflation Reduction Act

One of the primary aims of the US Inflation Reduction Act (IRA), signed by US President Joe Biden in August 2022, is to boost the supply of clean energy. As seen in Figure 1, alternative maritime fuels can benefit from the IRA through production tax credits (PTCs) for clean hydrogen and credits for permanent storage of carbon.

Alternative e-fuels are synthesized from hydrogen, which is made from splitting water with renewable electricity through electrolysis.

For e-ammonia, e-methanol, and e-methane, production of hydrogen through electrolysis is eligible for a Clean Hydrogen tax credit of up to USD 3 per kg, known as “45V” in the tax code. “Blue” fuels are derived from natural gas that is converted to hydrogen where carbon is captured and stored (CCS).

The IRA increases an existing tax credit of USD 50 per tonne to USD 85 per tonne of permanently stored carbon, known as the "45Q" credit. Facilities that begin construction before 2033 are eligible to receive the 45V tax credit for up to 10 years and 45Q for 12 years after production starts (more information in Table 1).

FAQ on the Inflation Reduction Act for Maritime Fuels

Which credits are available for alternative maritime fuels?

For alternative maritime fuels, the clean hydrogen credit (45V) and the carbon capture credit (45Q) are the most relevant. As seen in Table 1, all forms of hydrogen production are eligible for the 45V if they meet life cycle GHG emission thresholds. However, current emission factors associated with blue hydrogen production are greater than the 0.45 gCO_2eq/kgH_2 threshold.[8] Therefore, it's likely that only e-hydrogen will be eligible for the 45V credit.

The renewable electricity inputs for e-hydrogen production will also be eligible for production tax credits. In many cases, the electricity used for hydrogen production will come from the grid with dedicated renewable generation contracted through power purchase agreements (PPAs) that can achieve significant benefits from IRA credits.[9] However, how the renewable electricity credits will transfer from PPA to the fuel production facility is uncertain. Therefore, these credits are not included in the scope of this analysis.

Table 1. Details on the tax credits in the Inflation Reduction Act.

<table>
<tr><th>Tax credit
(IRS code)</th><th>Maritime fuel applications</th><th>Max credit value</th><th>Construction starts by</th><th colspan="2">Lifecycle CO_2eq emissions threshold to qualify</th><th>Other limitations</th></tr>
<tr><td rowspan="5">Clean Hydrogen (45V)</td><td rowspan="5">e-ammonia
e-methanol
e-methane</td><td rowspan="5">USD 3/kg hydrogen</td><td rowspan="5">2032</td><td>Threshold: $gCO_2eq/kg\,H_2$</td><td>% of more credit</td><td rowspan="5">Apprenticeship and prevailing wage requirements</td></tr>
<tr><td><0.45</td><td>100%</td></tr>
<tr><td>0.45-1.5</td><td>33%</td></tr>
<tr><td>1.5-2.5</td><td>25%</td></tr>
<tr><td>2.5-4</td><td>20%</td></tr>
<tr><td>Carbon Capture & Storage (45Q)</td><td>Blue ammonia</td><td>USD 85/tonne for captured & stored CO_2</td><td>2032</td><td colspan="2">NA</td><td>Min 12.5k tonnes CO_2 per year captured and stored. Apprenticeship and prevailing wage requirements</td></tr>
</table>

Source: US Congressional Research Service, 2022[10]

FAQ on the Inflation Reduction Act for Maritime Fuels

How do the credits work?

For the 45V clean hydrogen credit, subsidies are offered in the form of production tax credits (PTCs) and investment tax credits (ITCs). The PTC has been found to be, in almost all cases, more valuable to project developers.[11] The tax credits can be easily monetized by fuel producers through two provisions: 1) 'direct pay' provides a cash transfer at the end of the year, and 2) 'transferability' allows companies to sell the accumulated credit value to another company.[12]

To receive the full value of the credit, hydrogen production is required to use time-matched, deliverable, and incremental clean electricity.[13] Further, facilities must be constructed and repaired with labor paid at the prevailing wage and include apprenticeship hours that represent 15% of total labor during construction.[9]

Are tax credits future-proof?

The IRA passed in the US Congress with a narrow majority, raising concerns about future political support. Political uncertainty is somewhat mitigated by the fact that soon, after the bill's passage, companies began to invest in new facilities that will benefit from the IRA. While it will take a few years after the IRA's passage to know its full impact on investment, federal support has been associated with USD 271 billion in clean energy investment in the first 12 months of the program, likely creating constituencies that will advocate to keep credits in place.[14] Furthermore, a majority of funding is expected to go to states that opposed the bill in Congress, which can make it more resilient to a changing political landscape.[15,16]

Can subsidized fuel be exported or consumed outside the EU?

The IRA does not include restrictions on the export or usage of subsidized hydrogen or hydrogen-based fuels. In fact, energy producers anticipate that the IRA will contribute to the growth of e-fuel exports,[17] potentially creating a significant new export commodity for the US. There are concerns, however, over potential trade barriers in response to subsidized exports, particularly in the EU.[18] However, thus far, governments including Canada[19] and the EU[20] have chosen to respond by introducing subsidy schemes of their own.

To understand the impact of the IRA on the shipping industry's adoption of alternative maritime fuel, we estimate the potential IRA subsidy per gigajoule (GJ)[a] of alternative fuel. As seen in Table 2, we multiply the credit by the qualifying fuel content. Then we assume that investors in new production facilities will account for the limited availability of the credits (10 or 12 years) over an expected 30-year lifetime of a facility and will therefore levelize the benefit.[b]

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a) GJ is a standard unit of energy that allows us to compare across fuels with different energy densities.
b) Levelizing the benefit over the 30-year facility lifetime is a conservative approach which estimates a fixed amount over the 30-year lifetime of the facility. Alternatively, the full value of the tax credits can be applied for the years in which they are given, leading to higher benefits during the years in which credits are paid.

Table 2. Calculation of levelized credit for maritime fuels.

Maritime fuel	Tax credit	Value	Fuel content qualified for credit	Fuel credit [USD/GJ]	Credit length [years]	Levelized benefit over 30-year lifetime [USD/GJ]
e-ammonia	45V	USD 3/kg H_2	9.6 kg H_2/GJ	USD 29	10	USD 16
e-methanol			9.5 kg H_2/GJ	USD 29		USD 16
e-methane			10 kg H_2/GJ	USD 30		USD 17
Blue ammonia	45Q	USD 85/tonne CO_2	0.1 tonnes CO_2/GJ	USD 8	12	USD 5

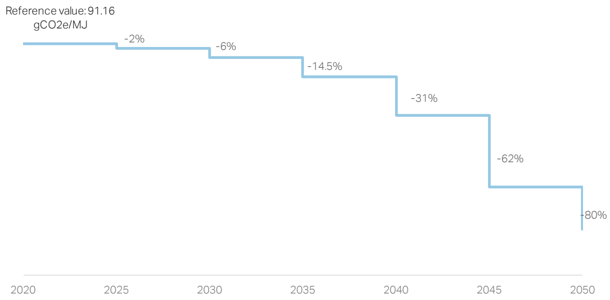
2.4 EU Emissions Trading System and the FuelEU

The EU set the legal obligation for member states to be climate neutral by 2050. The 'Fit for 55' is a suite of policies which aims to support this goal through a 55% reduction of GHG emissions by 2030.[21] We focus on two policies from this package: the FuelEU Maritime regulation (FuelEU) and the EU Emissions Trading System (ETS). We analyze their impact on conventional fuel cost as well as on early rewards for alternative fuels through a pooling mechanism in the FuelEU.

EU ETS : The EU ETS is a cap-and-trade program that was extended to include the maritime and aviation industries from 2024. In effect, the ETS adds a price on emissions through the requirement to purchase EU allowances (EUAs), or rights to emit GHGs. Shipping companies will be responsible for purchasing EUAs on vessels over 5,000 gross tonnes (GT) traveling within the EU, both at berth and in transit (intra EU) and purchasing EUAs on 50% of the emissions from voyages to and from the EU (extra EU). To analyze the impacts of the ETS through 2050, we use forecasted EUA prices from Pietzcker et al. [22] The study estimates an increase in prices from over USD 100 in 2025 to over USD 400 in 2050 to achieve goals of 55% reduction of emissions in 2030 and carbon neutrality by 2050.

FuelEU: FuelEU requires GHG intensity reduction of energy used onboard a vessel.[c] Shown in Figure 2, the law requires reduction from a reference value of 91.16 gCO_2eq/MJ, beginning with 2% in 2025 and scaling up to 80% in 2050.[23] The EU ETS vessel size and geographic coverage also apply to FuelEU.

Figure 2. FuelEU GHG Intensity Reduction Targets



To comply, vessels over 5,000 GT will be required to lower the GHG intensity of fuel (or electricity in the case of batteries or onshore power). As the FuelEU is aimed at accelerating fuel transitions, energy efficiency is not able to bring vessels into compliance; however, greater efficiency can reduce the overall burden of the regulation due to lower energy demand. In other words, less fuel consumed is less fuel that needs to be compliant.

c) In addition to fuel intensity mandates, the FuelEU will require container and passenger ships to employ onshore power in EU ports. The onshore power requirements are outside the scope of this report.

Aside from pooling (covered in Section 2.5), vessels have three main options to stay in compliance with FuelEU:

- Choose fuel type
- Use wind assisted propulsion
- Continue business as usual and pay the penalty

As the only non-fuel option for compliance, wind technologies such as rotor sails and rigid wing sails are outside the scope of this report.

Available options to comply by changing the fuel type include: 1) utilizing alternative fuels (e.g., e-methanol, e-ammonia), and 2) blending biofuel with conventional fuel. Sailing on alternatives will not be the default compliance option for most vessels, as they typically require a new or retrofitted vessel, and the fuel is more expensive than biofuel. In contrast, biodiesel, such as fatty acid methyl ester (FAME), can be blended with conventional low sulfur fuel oil (LSFO) without major vessel modifications.[24] We focus on LSFO because, along with other similar fuel oils, it represents over 80% of all fuel consumed on ships engaged in international voyages.[25]

To estimate the costs for biofuel blending to meet FuelEU mandates, we rely on methodologies by van den Berg et al.[26] This approach calculates the additional expense to blend LSFO with FAME, as it is a commercially available biofuel blend. We assume FAME from waste cooking oil, which, according to standard emissions reductions in the Renewable Energy Directive II, [27] offers an 84% reduction below a baseline of 94 gCO_2eq/MJ. For biofuel cost estimates, we draw on projections through 2050 from Transport & Environment.[28] We compare the additional costs to blend biofuel and the FuelEU penalty for non-compliance. Based on the formula in the FuelEU,[23] the penalty is calculated as the amount of non-compliant fuel in VLSFO equivalent tonnes multiplied by a penalty of EUR 2,400.

As shown in Table 3, the additional cost of the FAME and LSFO blend is always lower than the cost of the penalty. Therefore, blending biofuel is expected to be the most cost-effective compliance option and is modeled as the default.

Table 3. Estimated additional cost of FuelEU compliance options for LSFO vessels [USD/GJ].

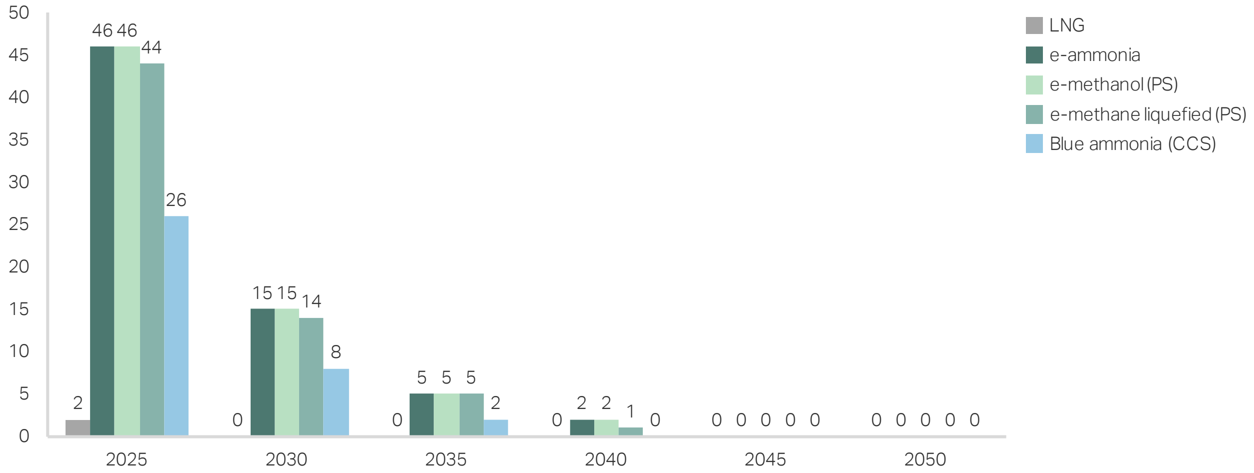
	2025	2030	2035	2040	2045	2050
LSFO costs (Europe)	USD 15	USD 13	USD 13	USD 13	USD 13	USD 13
Non-compliance penalty costs	USD 2	USD 4	USD 10	USD 22	USD 43	USD 56
Additional biofuel blend costs	USD 1	USD 2	USD 6	USD 16	USD 38	USD 55

FuelEU pooling

To incentivize companies to exceed the FuelEU GHG intensity reduction targets (Figure 2), the European Commission created a pooling mechanism. The stated goal of pooling is to provide incentives for investment in more advanced technologies,[23] which would otherwise be unable to capture value from achieving reductions beyond the requirements.

FuelEU pooling enables a vessel sailing on fuel with an emission intensity below the mandated target to establish a pool with other vessels, where the average intensity of the group of vessels is in compliance with the target.[23] The regulation further incentivizes what it calls 'renewable fuels of non-biological origin' (RFNBOs) which includes e-ammonia, e-methanol, and e-methane, with a 'multiplier' that reduces the intensity of the fuel, thereby increasing the surplus with which it can pool. Importantly, the multiplier is in effect through the end of 2033, providing a time-limited incentive. As shown in Figure 3, the potential size of pools for a qualifying RFNBO vessel is up to 46 LSFO participants with equal energy demand in 2025. The pool size then decreases rapidly through 2040.

Figure 3. Maximum number of LSFO vessels that can be covered by one alternative vessel in a pool.



FAQ on FuelEU pooling mechanism

What is the FuelEU pooling mechanism?

The FuelEU pooling mechanism aims to encourage rapid deployment of advanced technologies by rewarding overachieving vessels. The mechanism allows a vessel with emissions intensity below the FuelEU reduction target to use surplus compliance balance (CB), to compensate for other non-compliant vessels. For example, a vessel that sails in the EU on e-methanol in 2025 with an emissions intensity of 70% below the reference value can share the surplus intensity reduction with LSFO vessels if the average intensity of all the energy used across the group of vessels, i.e., the pool, is at or below the required 2% reduction target.[23]

To ensure companies of all sizes can participate, the pool can be made up of vessels within a single company or across companies, if they share the same accredited EU verifier. By 30 April of the year following the reporting year, the verifier needs to register in the FuelEU database the composition of the total pooled compliance balance for each ship. Operating procedures along with standard terms and contracts may be needed to define how the pooling mechanism will work in practice.

How are RFNBOs promoted?

To qualify as an RFNBO, a fuel must have an emissions intensity that is 70% below a comparator value of 94 gCO_2eq/MJ and follow strict criteria for sustainability and additionality.[29] From 2025 to 2033, a multiplier is applied to reward ships that use RFNBOs. The multiplier is factored into the energy denominator (MJ) of the intensity formula, thereby dividing the intensity in half, and increasing the amount of surplus intensity of the RFNBO vessel. RFNBOs are also eligible to pay zero ETS obligations.[30] In addition to the multiplier, the RFNBO's share in the maritime fuel mix must be above 1% by 2031. Otherwise, a subtarget will require all vessels to utilize 2% RFNBO from 2034.[23]

How can the potential size of pools be determined?

The number of possible pool participants is determined by 1) the target intensity in the given year, 2) the amount of CB beyond the target, 3) the intensity of other vessels in the pool, and 4) if a multiplier is used. Shown in Table 4 on two vessel types in 2025, a reward multiplier increases the CB by halving the GHG intensity. To find the highest possible pooling potential, we assume an RFNBO with maximum emissions reduction and equivalent energy consumption across all vessels in the pool. The potential size of the pool is found by dividing the compliance balance of the RFNBO vessel by the negative compliance balance of the participating vessels.

What are the banking and borrowing provisions?

Banking is a flexibility provision that allows companies with positive CBs to use surplus in the following period on the same vessel. This enables RFNBOs that did not pool with the maximum number of vessels to utilize remaining surpluses in the following year. A second flexibility provision, borrowing, can only be used for compliance, not pooling. It allows companies to utilize expected surpluses from the following year to comply in the reporting year.

Table 4. Calculation of potential pool size across alternative fuel types.

	Blue fuel with no multiplier	RFNBO with multiplier
Simplified formula for compliance balance (CB)	$(GHGIE_{target} - GHGIE_{actual}) \times E_{voyages}$	$(GHGIE_{target} - \frac{GHGIE_{actual}}{Multiplier}) \times E_{voyages}$
Values	Blue fuel $GHGIE_{actual} = 39 \frac{gCO_2eq}{MJ}$ LSFO $GHGIE_{actual} = 91 \frac{gCO_2eq}{MJ}$	RFNBO $GHGIE_{actual} = 3 \frac{gCO_2eq}{MJ}$ LSFO $GHG\ IE_{actual} = 91 \frac{gCO_2eq}{MJ}$
Compliance balance in 2025 per MJ	Blue fuel CB = (89 - 39) x 1 = 51gCO_2eq	RFNBO CB = (89 - 3/2) x 1 = 88gCO_2eq
Potential size of pool with LSFO participants	Pool size = $\frac{\text{Blue fuel CB}}{\text{LSFO CB}} = \frac{51}{-1.9} \approx 26$	Pool size = $\frac{\text{RFNBO CB}}{\text{LSFO CB}} = \frac{88}{-1.9} \approx 46$

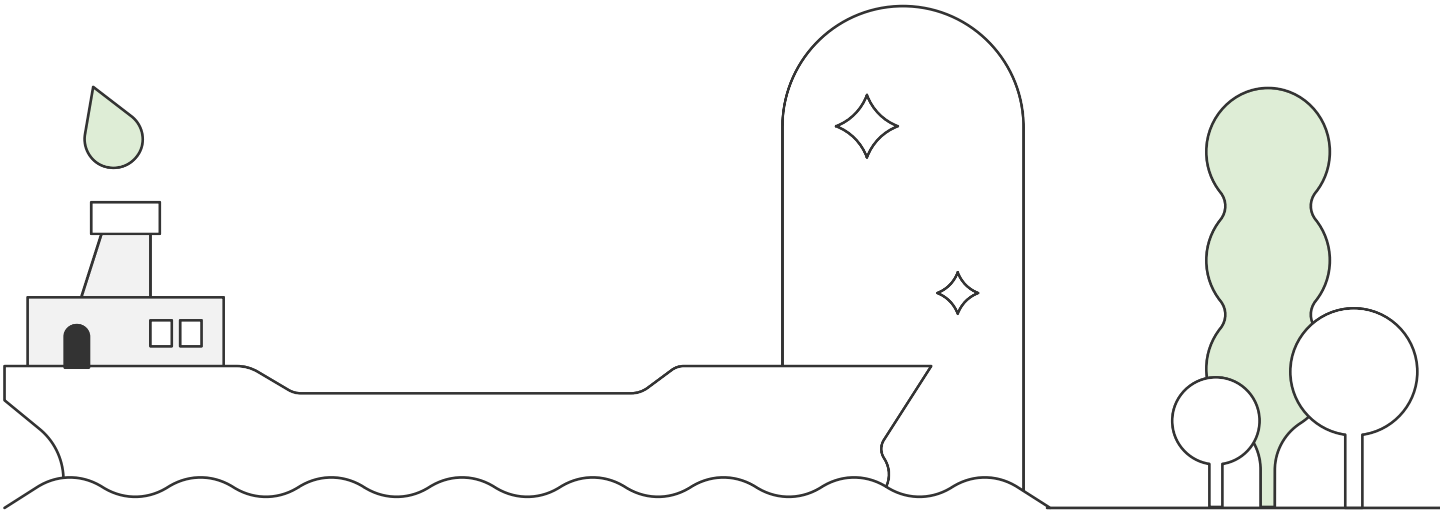
GHGIE = Green House Gas Intensity of the energy used on board by a ship.
E = Energy.

How a shipping company will determine the value of pooling for the overachieving vessel will likely depend on the default cost of compliance and the number of green vessels operating in the market. The forecasted share of green vessels calling at EU ports is expected to be below 5% in 2030.[31] Therefore, the limited number of green vessels will likely have market power and be able to set the cost of participation in pools up to the default cost of compliance, which is assumed to be the additional cost to blend biofuel (see Section 2.4). Depending on if the pool is internal to a single company or across multiple companies, the exchange in value will either take place on a company's balance sheet or through payment between companies.

In Table 5, we calculate the estimated pooling benefit that an RFNBO vessel can receive from pooling with LSFO vessels. Starting with the cost to blend biofuel, we deduct the additional cost of ETS, because vessels that offset their compliance deficit through a pool will not have achieved the targeted reduction and thus cannot claim it under ETS. Finally, we include a reduction of 10% to account for transaction costs and multiply the pool value by the maximum number of pool participants for an estimate of the pooling benefit for one RFNBO vessel. An RFNBO vessel can potentially receive up to USD 10 per GJ in 2025 and up to USD 16 per GJ by 2035.

Table 5. Calculation of pooling benefit for RFNBO collected from pool participants.

Year	FuelEU Reduction Target	Multiplier (increases pool size)	Biofuel blend compliance cost [USD/GJ]	Additional ETS costs due to not blending biofuel [USD/GJ]	Value of participating in a pool [USD/GJ]	Maximum number of pool participants	Potential pooling benefits captured by RFNBO vessel [USD/GJ]
			Additional cost to blend FAME with LSFO to meet target	Additional costs of ETS as the result of not blending biofuel	(Biofuel cost – ETS costs) x transaction cost factor	RFNBO Compliance Balance / LSFO Compliance Balance	Value of pool x number of participants
2025	2%	Yes	USD 0.47	USD 0.23	USD 0.21	46	USD 10
2030	6%	Yes	USD 2.01	USD 0.88	USD 1.02	15	USD 15
2035	14.5%	No	USD 6.16	USD 2.69	USD 3.12	5	USD 16
2040	31%	No	USD 16.05	USD 7.33	USD 7.85	2	USD 16
2045	62%	No	USD 37.44	USD 18.85	USD 16.73	0	USD 0
2050	80%	No	USD 55.24	USD 31.17	USD 21.66	0	USD 0



2.6 Methods for estimating impact

In Section 3, we analyze the impacts of US and EU policies on fuel cost, and then in Section 4, we assess their combined impacts through a case study of a transatlantic container route. We examine the impacts on a container vessel because the segment is a promising candidate for early adoption of alternative fuels. Containers operate on fixed routes and may see an increased willingness to pay a premium.[32] Transatlantic container trade between North America and Europe accounts for 5% of the world's containerized trade.[33] Despite its modest share of global shipping, this route can act as a catalyst, fostering initial scale-up of alternative fuels and potentially driving down costs globally.

We focus on four alternative fuel pathways as listed in the Fuel Pathway Maturity Map:[34] e-ammonia, e-methanol, e-methane, and blue ammonia. We utilize fuel cost projections from the Maersk Mc-Kinsely Møller Center for Zero Carbon Shipping's in-house transition modeling tool NavigaTE,[35] which is based on knowledge and insights from experts at MMMCZCS and partner organizations.[d] The cost of fuels in five regions through 2050 are modeled using a bottom-up approach, comprising three main elements: feedstock, processes, and fuels. In the analysis, we use cost estimates between 2025 and 2050 from the Americas.

In the case study, we compare alternatives to two fossil fuels: LSFO and liquified natural gas (LNG). LNG is a common alternative to fuel oil due to low cost and increasing availability,[36] despite its limited role in the transition to zero carbon shipping.[37]

d) Cost projects can be found by acquiring access to the MMMCZCS' open source TCO model.

03 Impact of US and EU policies

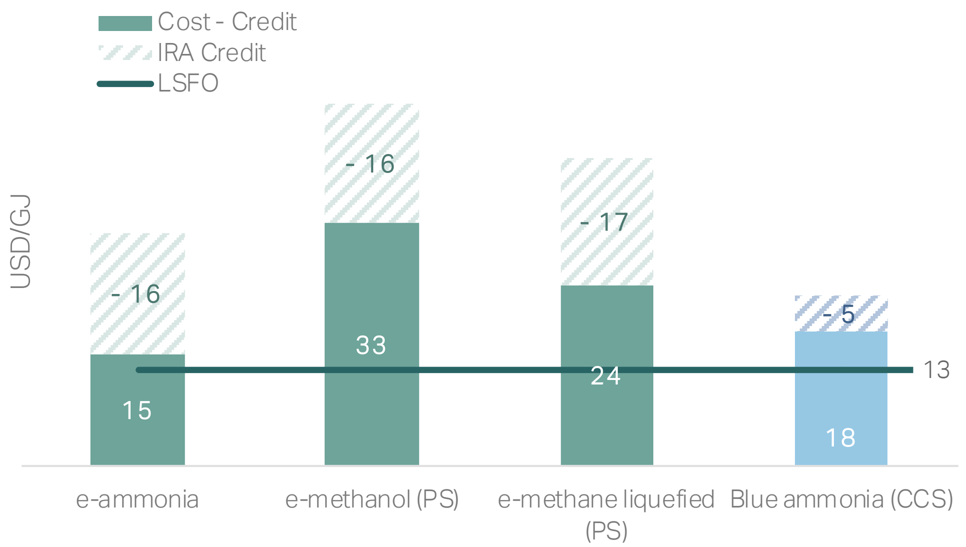
3.1 The US Inflation Reduction Act drives scaled-up supply of alternative fuels through subsidized clean energy production

The IRA subsidies for clean hydrogen and CCS can provide significant benefits for alternative maritime fuels. Figure 4 shows the impact of IRA credits on alternative fuel production costs for facilities that start production in 2030. The full height of the bars is the projected fuel cost in 2030 from NavigaTE. The striped bars show the impact of the IRA credits, and the solid bars show resulting subsidized fuel costs compared to the costs of LSFO (dark green line). The IRA subsidies have been levelized (see Table 2), and therefore, the costs and benefits extend throughout the 30-year lifetime of the facility.

Looking across alternative fuels in Figure 4, IRA credits can offer significant cost savings in 2030. In the case of e-ammonia, the USD 16 per GJ 45V credit reduces production costs by more than 50%. Blue ammonia is eligible for the 45Q tax credit, which reduces the cost by USD 5 per GJ. While the IRA does not fully close the cost gap with LSFO, it can narrow the gap to USD 2 per GJ for e-ammonia and USD 5 per GJ for blue ammonia.

In addition to the IRA, hydrogen fuels will be further supported through a USD 7 billion investment from the US Bipartisan Infrastructure Investment and Jobs Act of 2021. The Act will partially fund the development of seven hydrogen hubs, of which five are ports.[38] The combined investments of the Infrastructure law and IRA can scale up hydrogen supply to serve demand across industrial and transportation uses.[11] While the supply of clean hydrogen-based fuels is expected to increase, competition across sectors may make future prices and the availability of fuels for shipping uncertain. Despite significant potential benefits of US subsidies for alternative maritime fuels, uncertainty as well as expectation of declining future costs may limit the ability of the IRA alone to incentivize near-term investment by shipping.

Figure 4. Impact of IRA credits on production cost of alternatives in 2030.



3.2 The EU ETS and FuelEU incentivize demand for alternative fuels with costs on emissions

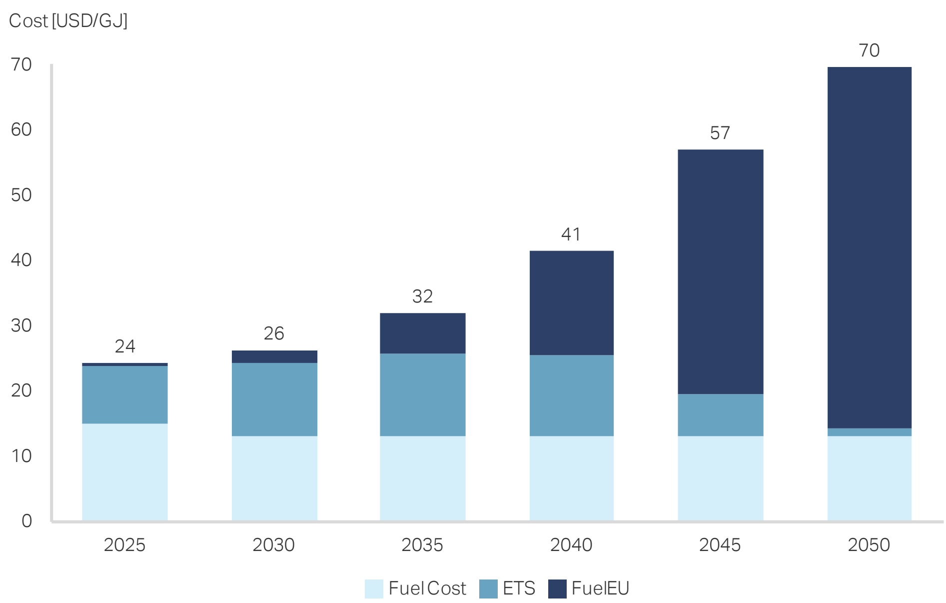
EU policy will create additional costs for sailing on fossil fuel through:

- ETS requirements to purchase European Union Allowances (EUAs), and
- FuelEU intensity reduction mandate through blending biofuel.

Figure 5 shows increasing costs for LSFO due to the EU ETS and FuelEU from the first year of FuelEU compliance in 2025 (for calculation methods see Section 2.4). After 2030, the cost of sailing on LSFO in the EU will more than double due to both the EU policies. Our estimates show that, by 2050, the fuel cost from sailing on LSFO will be over five times more expensive than it would be without the policies. EU ETS drives most of the additional cost through 2040. As FuelEU requires increasing reduction of emissions intensity, vessels will use cleaner fuel and the impact of the EU ETS will decrease. Therefore, from 2040, FuelEU will become the driving disincentive for the use of conventional fuels.

The cost of FuelEU is modeled as the additional cost to blend biofuel with conventional fuel to meet emissions intensity reduction targets. The estimates of the additional cost to blend FAME are sensitive to significant uncertainty due to limited supply, which is expected to cover only 0.3% of shipping's global energy demand.[39] Furthermore, biofuels will face competition from several industries including plastics, manufacturing, and aviation.[1] Uncertain biofuel costs may lead companies to pursue long-term contracts for biofuel or seek out non-biological alternatives.

Figure 5. The impact of FuelEU and ETS on LSFO fuel cost.



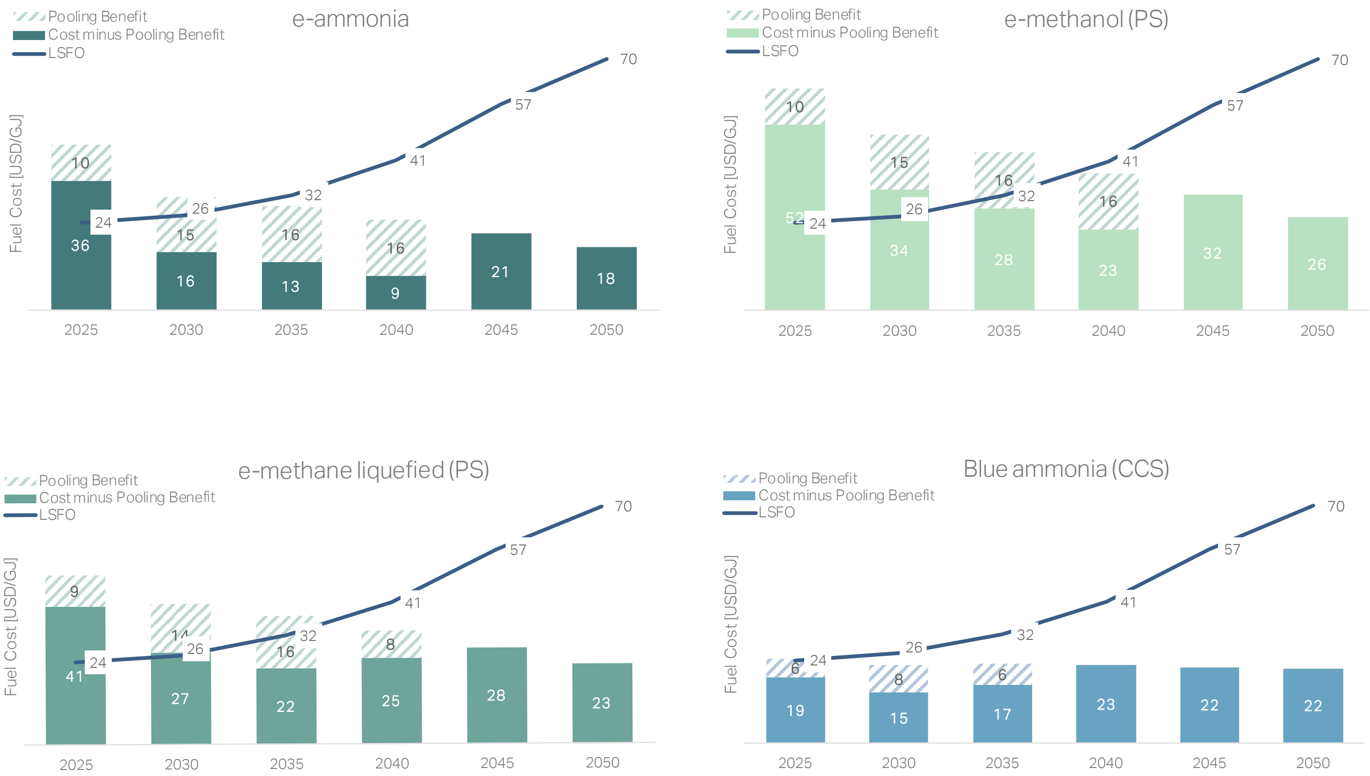
3.3 The FuelEU pooling rewards near-term investment in alternative fuels

Pooling can offer rewards for companies that invest early in alternative fuels. We apply the pooling benefits, shown as the dashed bars in Figure 6, to alternative fuel costs through 2050. We compare the alternatives to LSFO costs (dark blue line) which will rise due to the impact of EU ETS and FuelEU. We find that pooling benefits provide significant cost reduction, particularly for e-fuels.

The results show that the combination of pooling benefits and additional FuelEU and ETS costs on LSFO can close the gap between conventional and alternative fuel costs by 2035. In the case of e-ammonia, the cost is reduced by over 50% from 2035 through 2044.

Time-limited and early pooling benefits, when alternative fuel costs are the highest, create incentives for a shipowner to invest in the near term. This is clearest for e-ammonia, where early pooling benefits lead to costs being well below LSFO costs from 2030.

Figure 6. Fuel Costs with FuelEU compliance and pooling benefits [USD/GJ].



04 Case study: Commercial viability of alternative fuels on transatlantic voyages impacted by EU and US policies

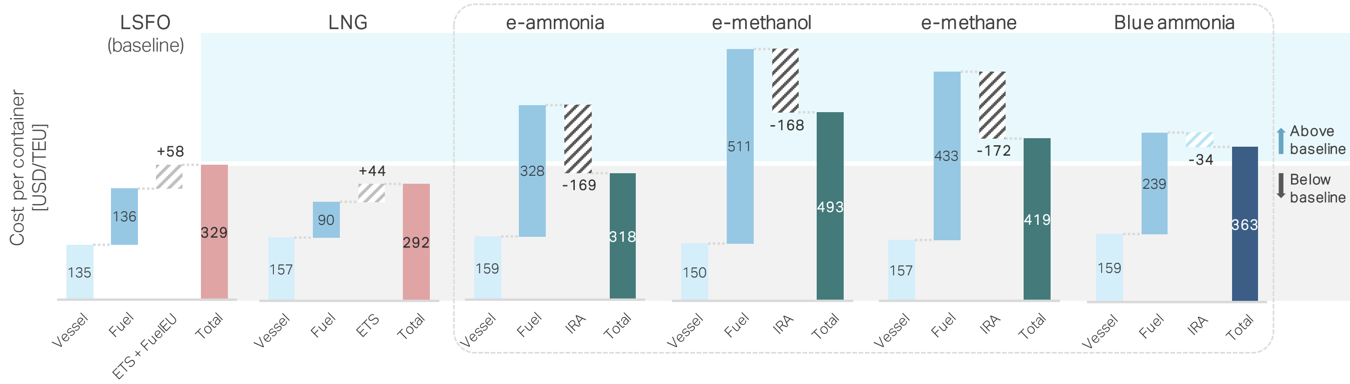
Taken individually, EU and US policies may not offer sufficient incentives for investment in alternative fuels. However, the combined impact of US supply-push and EU demand-pull policies on transatlantic routes can potentially tip the scales for green vessels. We look at a transatlantic container route in 2030 as a case study to evaluate if the combination of EU and US policies can catalyze near-term investment in green vessels (model parameters and assumptions in Appendix A). We show the impacts with and without the FuelEU pooling benefits because they are subject to the highest uncertainty.

4.1 Voyage costs with the IRA, EU ETS, and FuelEU (no FuelEU pooling)

Figure 7 compares the combined costs of transporting a twenty-foot equivalent unit (TEU) container on a transatlantic route across conventional (LNG and LSFO) and alternative fuel types. We can draw several lessons from Figure 7. First, the combination of US and EU policies has the potential to increase conventional fuel costs and reduce alternative fuel costs, thus fully closing or narrowing the cost gap between conventional and alternative fuels. Second, the difference in vessel cost which includes the vessel CapEx, financing, and onboard OpEx (crewing) is minimal across fuel types; fuel cost drives most of the gap between alternatives and LSFO. Third, by combining vessel costs, fuel costs, and policy costs and benefits, we can estimate that transporting a TEU across the Atlantic on e-ammonia is approximately 3% cheaper than LSFO, and blue ammonia is estimated to be just 10% above LSFO.

Another takeaway from Figure 7 is that LNG has the lowest estimated voyage cost, driven primarily by lower fuel costs as well as lower penalties from EU ETS and no additional costs from FuelEU. However, this result is sensitive to the engine type and operational profile of the LNG vessel being considered. Furthermore, LNG faces regulatory risk as policymakers, including in the EU[40] and US,[41] are moving towards stronger regulation of methane emissions — as is seen with the Global Methane Pledge.[42] Stronger penalties on upstream methane emissions could increase the costs of operating an LNG vessel in 2030, and therefore reduce or eliminate its advantage.

Figure 7. Impact of US and EU policies on transatlantic container voyage costs in 2030 [USD/TEU][e].



e) Results are shown in standard units used for shipping rates in the container industry, USD per twenty-foot equivalent unit (TEU), i.e., a standard container.

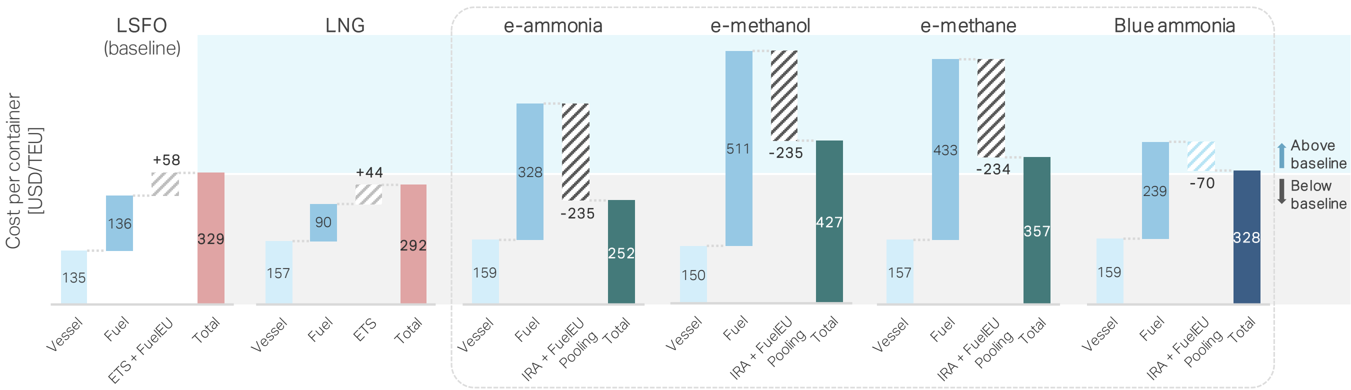
4.2 Voyage costs with the IRA, EU ETS, and FuelEU - including pooling

When the benefits of the FuelEU pooling mechanism are included in the estimated costs per TEU container, the results show significant incentives across alternative fuels. The combined benefits of the IRA, EU ETS, FuelEU, and FuelEU pooling, illustrated by the dashed bars in Figure 8, offer substantial cost savings in 2030. For e-fuels, FuelEU pooling and the IRA can provide benefits of USD 235 per TEU. This represents between 45% (e-methanol) and 70% (e-ammonia) reduction of RFNBO fuel cost. For e-ammonia vessels, the combined benefits of the IRA and FuelEU pooling can reduce the combined costs of sailing on e-ammonia on this route by nearly 50%. Compared to LSFO, the total costs for e-ammonia are 20% lower. In this scenario, e-ammonia is the most cost-effective across the six fuel types for transatlantic voyages in 2030.

While blue ammonia does not benefit from a multiplier, lower fuel costs lead to voyage costs just below parity with LSFO. Pooling also diminishes the cost advantage of LNG, as LNG is not likely to benefit from pooling in 2030. E-methane can be used without retrofits on LNG vessels.[43] Therefore, reductions in e-methane costs could incentivize companies with LNG vessels to transition to the e-fuel alternative.

The significant potential cost savings from the combined effects of the IRA and FuelEU pooling, coupled with penalties on conventional fuels, give green vessels an advantage that could drive investments. Availability of supply will also dictate which fuel is able to take advantage of policy support. Therefore, in addition to vessels, companies should consider offtake agreements or joint venture partnerships with upstream fuel producers to ensure adequate supply and lock-in benefits.

Figure 8. Impact of US and EU policies including FuelEU pooling on transatlantic container voyage costs in 2030 [USD/TEU].



Actionable insights

Cargo owners

For companies with significant freight on transatlantic routes, adjust internal Scope 3 targets to reflect the potential for an accelerated shift to alternative fuels. Seek out shipping companies that have invested in the supply of alternative fuels to ensure access to policy benefits.

Shipowners and operators

Prioritize alternative vessels in the transatlantic corridor and engage with fuel producers to ensure supply that allows vessels to maximize the benefits of sailing on alternative fuel.

Alternative fuel producers

Reach out to shipping companies that operate on transatlantic routes and showcase the business case for alternatives to secure offtake.

05 Discussion and further consideration

New climate policies in the EU and US signal a major shift for maritime decarbonization with the potential of a commercially viable pathway for transatlantic routes. Beyond cost factors modeled in this report, shipping companies could see incentives from opportunities to charge a green premium to customers for cargo transported using alternative fuels. This can be achieved through direct negotiations with customers or via a book-and-claim system.[44] European companies may also encounter growing pressure to reduce transport emissions due to the new EU policy called the Corporate Sustainability Reporting Directive.[45] This policy compels companies to report standardized environmental, social and corporate governance (ESG) data, thereby potentially driving increased demand for green shipping on EU routes. The US has proposed similar requirements on companies to submit climate-related disclosures that could further increase demand.[46]

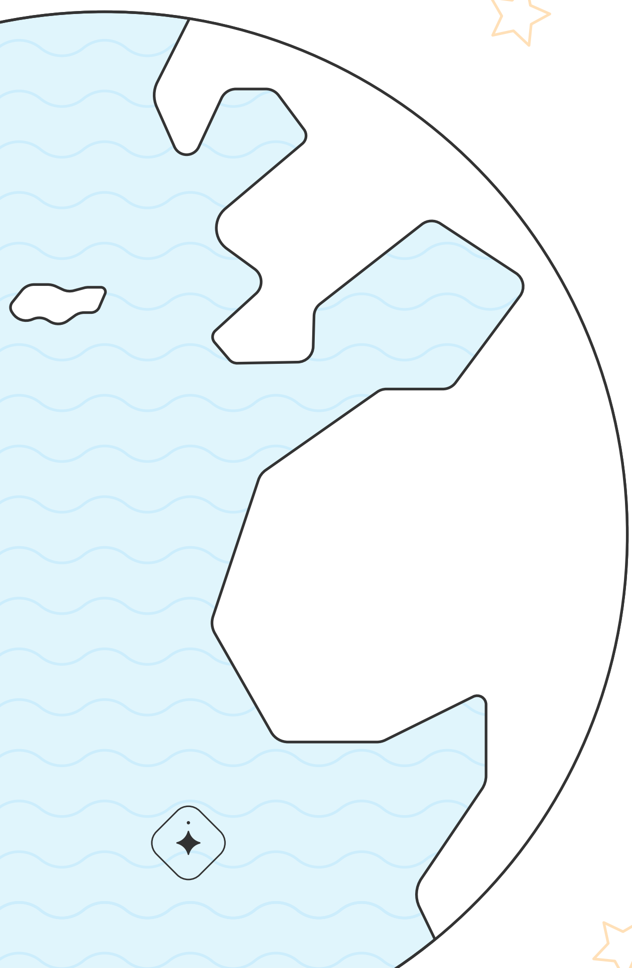
Policies from the US and EU can offer valuable insights for the development of mid-term measures at the IMO. A diversified strategy — including penalties on conventional fuels, regulatory certainty of transition, and incentives for alternative fuels — has the potential to catalyze investment in alternative fuel globally. However, without a pooling mechanism, policies may be unable to generate the urgency needed to achieve IMO ambitions, especially near-term goals. The FuelEU pooling incentives could serve as a blueprint for how to overcome delay through time-bound rewards for early adopters of new technologies.

In the interim period before the IMO implements global measures, the combination of EU and US policies on transatlantic voyages can increase demand for alternative fuels. This demand can kick off a virtuous cycle, wherein higher uptake of alternatives leads to greater economies of scale and on-the-ground learnings.[7] The North Atlantic could act as a testing ground for improving and lowering the costs of new alternative fuels, leading to higher certainty and lower costs as the production and consumption of alternative fuel increases. Transatlantic trade can therefore kickstart demand for alternative fuel globally and encourage member states at the IMO to increase their ambition.

06 Limitations

A key limitation is that, for the shipping industry, the price of fuel is subject to unpredictable market dynamics. Therefore, the production costs modeled here will not be equal to future prices. Price uncertainty could be a motivation for companies to seek long-term offtake agreements to hedge against variability and lock in cost of alternative fuel; alternatively, they could further delay investment in highly uncertain alternative fuels. The FuelEU pooling benefits are also highly uncertain. More clarity is needed for the benefits of the mechanism to have the intended effect.

We strike a balance between precision and simplifying assumptions that should be tested with sensitivity analysis in future work. One of the major assumptions is that vessels sailing on alternative fuels do not blend alternatives with conventional fuel or utilize a secondary fuel. In practice, dual-fuel vessels will likely opt to use a combination of alternative and fossil fuels depending on the customer's willingness to pay, availability of alternatives, and regulatory standards.



07 Conclusion

The international shipping industry faces the daunting challenge of achieving net-zero emissions by 2050 and 5-10% uptake of alternative fuels by 2030. High costs and uncertainty pose significant hurdles for the investment needed in alternative fuels to reach these goals. These challenges may be overcome on transatlantic routes, where US and EU policies can narrow the cost gap through subsidies on alternatives and penalties on conventional fossil fuels. Furthermore, the FuelEU pooling mechanism has the potential to provide time-limited first-mover rewards, which could overcome the incentives to delay investment.

Forward thinking companies in the maritime value chain can strategically position themselves in an evolving policy landscape to take advantage of new incentives for alternative fuels. For cargo owners, the results translate into an opportunity to accelerate upstream emissions reduction targets for cargo traded between the US and the EU. Fuel producers, meanwhile, can make a more convincing case for shipping companies to engage in offtake agreements to ensure supply on transatlantic voyages within the timeframe of FuelEU pooling incentives. Finally, for shipping companies operating in the North Atlantic, new policies with substantial first-mover rewards may shift the prevailing mindset — from the risk of action on the green transition to the risk of inaction.

08 Project team

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Abbreviations

CapEx	Capital expenditure
CB	Compliance balance
CCS	Carbon capture and storage
CSRD	Corporate Sustainability Reporting Directive
ESG	Economic, social and corporate governance
EU	European Union
EUA	European Union Allowance
EUR	Euro (currency of the European Union)
EU ETS	European Union Emissions Trading System
FAME	Fatty acid methyl ester
FuelEU	FuelEU Maritime regulation
gCO_2eq/kgH_2	Grams of carbon dioxide equivalent per kilogram of hydrogen
GHG	Greenhouse gas
GJ	Gigajoule
GT	Gross tonnes
IMO	International Maritime Organization
IRA	Inflation Reduction Act
ITC	Investment tax credit
LNG	Liquified natural gas
kg	kilogram
LSFO	Low Sulfur Fuel Oil
MMMCZCS	Maersk Mc-Kinney Møller Center for Zero Carbon Shipping
MJ	Megajoule
OpEx	Operating expenditure
PPA	Power purchase agreement
PTC	Production tax credits
RED	Renewable Energy Directive
RFNBO	Renewable fuels of non-biological origin
TEU	Twenty-foot equivalent unit
US	United States of America
USD	United States Dollar

Appendix A

Transatlantic Voyage Modeling

Parameters and assumptions used to model transatlantic voyage costs

1. Fuel cost: We use cost projections from MMMCZCS's in-house transition modeling tool NavigaTE, which is based on knowledge and insights from in-house experts and partner organizations. Cost projections can be found by acquiring access to the MMMCZCS's open source TCO model.

2. Vessel: We model policies on an 8,000 TEU Neo-Panamax container vessel with voyage parameters taken from NavigaTE and public sources: Speed of 18 knots, fuel consumption of 10 GJ/nm.

3. Utilization: We apply container vessel utilization rates of 70%.[47]

4. Vessel cost: In addition to higher fuel cost, alternative fueled vessels have higher CapEx as well as additional OpEx due to greater technical requirements. We use average newbuild vessel costs from Clarkson's World Shipyard Monitor.[48] To factor in the higher costs for alternative fuel vessels, we use a 16% premium for ammonia and methane, and an 11% premium for methanol.[6]

5. Operation cost: We extend the higher newbuild premiums to onboard OpEx daily rates taken from Moore's Report.[49]

6. EU policy impact: EU policies are applied to 50% of the distances to and from the EU, and 100% within the EU, subject to legislation.

7. Emissions factors: To estimate the cost of EU policies for this route, we rely on default emissions factors as provided by the policy from the MRV,[30] FuelEU,[23] and the Renewable Energy Directive.[27] For e-fuels, we assume they are fully renewable and have the lowest possible emissions factor.

8. IRA fuel access: We assume vessels bunker in the US and are therefore able to take full advantage of the IRA tax credits.

9. RFNBO and sustainability qualification: We assume that all RFNBOs and biofuels align with guidance for sustainability[50] and renewable generation[29] to achieve the lowest possible emissions factors.

10. Time frame: We focus on costs in 2030 because EU policies are fully in place. In the US, it is expected that renewables will dominate in the early years of IRA spending followed by investment in hydrogen production.[51] Therefore, we assume that, by 2030, eight years after the IRA was passed, hydrogen production will be in place.

11. Ammonia readiness: For the transatlantic voyage modeling, we assume that ammonia engines will be commercially available and all regulatory approvals in place before 2030.[52]

12. ETS cost: Future EUA prices are taken from Pietzcker et al.,[22] who estimate the prices needed to achieve goals of 55% reduction of emissions in 2030 and carbon neutrality by 2050.

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