Accelleron

Asia Pacific as the proving ground for overcoming shipping's carbon neutral fuel deadlocks?

Accelerating to Net Zero December 2025

Foreword

Asia Pacific as the proving ground for overcoming shipping's carbon neutral fuel deadlocks

Asia Pacific emerges as a formative model for cross-sector energy systems shaping a net zero future.

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Asia Pacific sits at the center of global shipbuilding, global trade, and some of the world's most ambitious energy and industrial transitions. The region's unique blend of scale, industrial clustering, renewable potential, and shipping influence raises an important question. Could Asia Pacific help shape not only the future of shipbuilding, but the broader cross-sector energy transition that shipping increasingly depends on?

Shipping is entering a period when it must decide whether it will shape its own future or be shaped by forces around it. Climate impacts are intensifying. Energy systems are under pressure. Supply chains are recalibrating. Policy frameworks are still evolving. These forces are real, and they are defining what the industry is willing and able to pay for today and what we will leave as the climate bill for future generations.

Yet across this uncertainty, from COP30 to the working rooms of companies, ministries, and ports, we see a steady resolve. Decarbonization is not losing momentum, it is gaining clarity. And the message across sectors is consistent. The energy transition will continue, even if its pace and pathways vary.

Our first report, "Accelerating to Net Zero – Deadlock: What's Stopping Shipping's Energy Transition," concluded that only green hydrogen-based e-ammonia and e-methanol offer the shipping industry credible, scalable pathways to net zero by 2050.

Other fuels serve only as short-term or regional options. Nuclear, as we explore in this report, will not reach commercial viability within the required 2050 timeline.

However, when we ask where the world stands today in scaling these fuels, the answer remains the same. The ships are ready. The fuels are not.

Reaching global net zero by 2050 will require shipping to secure 100 to 150 million tons of green hydrogen per year for e-ammonia or e-methanol. And shipping is only one of several industries that will depend on green hydrogen.

Across other hard-to-abate sectors – aviation, steel, cement, chemicals, power, and agriculture – total green hydrogen demand is expected to reach 500 to 600 million tons by mid-century, supported by investment on the order of $9 trillion. But only 38 million tons, backed by $320 billion, are currently planned for development.[1]

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In addition, e-fuel accessibility appears to be severely constrained by the limited geography of early green hydrogen production.

In the emerging e-fuel landscape, production is concentrated in a small number of renewable-rich regions around the world, and early access is limited to a handful of major ports. This new geography of supply largely determines which vessels can adopt early, where they can bunker, and how operators plan their routes.

Container lines with predictable loops can build their services around these early hubs. Bulk and tramp operators cannot, because their trades depend on many smaller ports that may not have carbon-neutral fuels for years.

For the first time in shipping's history, fuel geography defines operational strategy. This is the moment when shipping must confront the abrupt shift from a world of ubiquitous, inexpensive fuel to one where carbon-neutral fuels are premium products with extremely limited geographic availability.

The magnitude of the shift from a fossil-based system to a synthetic one is why industry leaders consistently call for clear global regulation to support it.

In fact, every stakeholder we interviewed called for global carbon pricing as the single greatest enabler of carbon-neutral fuel uptake. In that light, the postponement of the International Maritime Organization's Net Zero Framework reflects practical concerns.

As Chair of the IMO Marine Environment Protection Committee (MEPC), Harry Conway, explained, states wanted clarity on economic impacts before accepting a global pricing mechanism in a market with limited carbon-neutral fuel supply.[2] Their hesitation reflected uncertainty about impacts and timing, not a reduction in ambition.

This makes regional action essential while global frameworks mature.

In this sense, Asia Pacific stands out for its distinctive political-economic conditions and the pace of cross-sector activity already underway, galvanized by conditions that make early progress on carbon-neutral fuels both desirable and possible.

The number one factor driving Asia Pacific's earlier interest in e-fuels is that they are tied directly to long-term energy security.

Several major economies in the region, including China, Japan, Korea, and Singapore, depend heavily on imported oil and gas and cannot meet their energy needs from domestic reserves alone. For these countries, green hydrogen-based e-fuels offer a path to reduce exposure to external fossil supply and to secure more resilient, regionally anchored energy as the transition accelerates.

Another major factor driving e-fuel progress in Asia Pacific is that the region holds several of the world's strongest renewable and industrial foundations for green hydrogen and e-fuel production.

Australia has some of the world's strongest natural wind and solar potential, along with critical minerals that support large-scale green hydrogen and e-fuel development.

China combines vast renewable-energy resources with unmatched industrial and manufacturing capability.

Its operating solar and wind capacity has already reached approximately 1,400 gigawatts, or 44% of the global total, more than the combined capacity of the European Union, the United States, and India,[3] and China plans to increase this to 3,600 gigawatts by 2035.[4]

On the other hand, Japan and Korea have concentrated industrial demand and advanced engineering sectors, but limited land for domestic renewable growth. Both countries must secure long-term green hydrogen and e-fuel imports to support the decarbonization of heavy industry, steel, chemicals, and power, as well as shipping.

Singapore, the world's largest bunkering hub, has even less domestic generation capability and is the only country in Asia Pacific applying carbon pricing to shipping. In addition to its national hydrogen and e-fuel strategy, Singapore is already advancing ammonia and methanol bunkering pilots, strengthening operating and safety procedures, and positioning itself to remain the leading global bunkering hub in a net zero future.

Together, these conditions create a strong cross-sector foundation for carbon-neutral fuel production, matched by a natural upstream-downstream, supply-demand dynamic for e-fuels that is unparalleled in other regions.

These regional advantages are strengthened further by modular e-fuel production that accelerates early development.

Specifically, Envision Energy in China has developed a smaller, modular e-ammonia model at Chifeng in Inner Mongolia. In commercial operation since 2025, it produces about 300,000 tons of e-ammonia per year, with plans to ramp up to 1.5 million tons by 2028.[5, 6, 7]

Building out in smaller increments reduces upfront demand from millions of tons to hundreds of thousands. This, combined with cross-sector demand aggregation across agriculture, chemicals, and shipping, makes it easier to secure the requisite offtake agreements for rapid development and delivery.

They sell directly to power and multisector companies in Korea, Japan, and Singapore, and to industrial buyers in Europe who crack e-ammonia into hydrogen.

Envision is now applying the same modular e-ammonia approach in Brazil, where it provides the integrated renewable-to-e-ammonia system for the flagship green hydrogen and e-ammonia hub at the Port of Pecém. This shows how Asia Pacific's early production models are already shaping international projects and accelerating development beyond the region.[8, 9]

Several countries in the region are also developing book-and-claim systems to overcome early gaps in e-fuel distribution infrastructure. This allows companies to access the attributes of carbon-neutral fuels even when physical delivery is not yet feasible across all ports.

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In addition, targeted government supply-side support has lowered e-fuel value-chain costs, including electricity, electrolyzer capacity, and elements of plant construction and permitting. As a result, the e-ammonia produced is already competitive enough to sell to buyers in Europe.

These emerging production capabilities offer additional impetus for port readiness and bunkering development across the region. And in fact, many ports in the region are actively preparing for e-fuels. Singapore, Yokohama, Busan, Shanghai, and others are reserving land, developing safety procedures, and preparing for future ammonia and methanol bunkering.

Asia Pacific is also beginning to establish early carbon-neutral fuel links with Europe, with Singapore acting as a connector to ports such as Rotterdam.

Despite this, demand is still not rising at the scale needed for mass production. And here is where we see the limits of isolated regional action. Asia Pacific has come as close as any region can to a working carbon-neutral fuel ecosystem, but in a global industry, that is not enough.

The two greatest factors affecting scaleup of e-fuels are the same for both Asia Pacific and the global industry: widespread carbon pricing at a level strict enough to compel change, supported by national incentives on both the supply and demand sides to enable it.

The first could be achieved either through global regulation – which every stakeholder we interviewed identified as the ideal path – or through strong regional regulation that connects the dots globally. The latter is not ideal and far more complex, but may now be the more realistic near-term route.

But carbon pricing cannot succeed alone. And that was the key lesson from the IMO NZF postponement. **The IMO can set global emissions targets and global carbon pricing policy, but it cannot produce the e-fuels necessary to achieve those targets.**

That's why achieving the necessary scale for green hydrogen and e-fuels to enable decarbonization across not only shipping but also the other hard-to-abate sectors will require national commitments and investment frameworks similar to those that enabled wind and solar to reach commercial maturity. Every country serious about their own cross-sector energy transition and meeting the International Maritime Organization's net zero goals will need to match climate ambition by adequate carbon-neutral fuel incentives.

In this respect, China has already proven that targeted incentives make smaller-scale e-ammonia production economically feasible. These incentives are reinforced by strong cross-sector demand from power generation, heavy industry, chemicals, and shipping, which together create conditions for early offtake that shipping alone cannot deliver. Australia is also developing significant early production capacity through national hydrogen programs, shared-infrastructure investments, and close alignment between energy systems, industrial users, and maritime interests, creating important future regional supply.

National supply-side incentives applied with a cross-sector perspective are what transform carbon pricing from a signal on paper into real carbon-neutral fuel production on the ground.

And on-the-ground clarity and practical action is more important than ever now.

Here, Asia Pacific proves, in very practical and sequential achievements, that when energy, industry, and maritime systems move together, carbon-neutral fuel systems become workable long before ideal global frameworks are complete.

Yet even with this progress, one gap remains unmistakable. Across Asia Pacific, national policy is enabling the supply of carbon-neutral fuels, but the conditions that would spark early maritime demand are largely absent.

Land-based sectors move because supply-side incentives reduce the cost of carbon-neutral fuels and national carbon pricing pushes early adoption.

In contrast, with the exception of Singapore, no Asia Pacific country applies carbon pricing to shipping or offers demand-side incentives. Shipping, regulated globally rather than nationally, therefore lacks the signals needed to prompt early e-fuel demand.

The regional expectation is clear: national policy can accelerate supply, but only global regulation can catalyze maritime demand at the scale required to accelerate the energy transition.

From the progress emerging across Asia Pacific to the discussions in Belém at COP30, the consensus is clear: the journey to decarbonization continues. Every obstacle and every stalled effort is another opportunity to gain the clarity needed to find a new way forward.

By working together across regions and across sectors, we can build a wider foundation for carbon-neutral fuel development in every country and find practical ways through the deadlocks ahead. We are not simply carried by global forces. We can align with them, shape them, and use them to build the net zero future we have chosen for our industry and our world.

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Executive summary

Why the world is watching the carbon-neutral fuel transition in Asia Pacific

Accelleron started the Accelerating to Net Zero initiative and report series as a way to extend support to its customers – engine designers and shipping companies – beyond its strict technological and service remit, to the biggest challenge confronting so many today: where to source the carbon-neutral fuels for the energy transition. Together, we have built the ships for net zero. But where are the fuels?

With a large concentration of manufacturing, ship engine building, and service business in Asia Pacific, Accelleron has witnessed the gradual emergence of an early e-fuel movement in the region, shaped by different motivations, industrial strengths, and energy profiles than in other parts of the world.

This regional progress is unfolding in parallel with uncertainty at the global level, following the postponement of the International Maritime Organization (IMO) Net Zero Framework. This has increased the importance of regional learning and the practical cross-sector pathways and early system designs emerging in Asia Pacific.

The Asia Pacific approach to the energy transition exhibits both similarities to, and differences from, the Western hemisphere. This has made the region's progress on green hydrogen and e-fuel development a central point of interest for understanding the deadlocks and opportunities within the global shipping energy transition.

Asia Pacific sits at the center of global shipbuilding, trade, and cleantech resources, but has modest oil and gas reserves.

The region hosts the largest share of the world's shipbuilding and service capacity and anchors many of the busiest maritime trade routes. It also contains diverse national energy systems and cross-sector industrial clusters where shipping, power generation, chemicals, steel, and global supply chains operate in close proximity.

In contrast to many Western countries, another defining regional dynamic is its substantial reliance on imported oil and gas. Domestic reserves are limited in markets such as China, Japan, Korea, and Singapore.

Commitments to renewables, green hydrogen, and e-fuels are therefore driven not only by decarbonization goals but also by an opportunity, now that green hydrogen and e-fuel technologies are sufficiently mature, to reduce dependence on external fossil supply and create more resilient energy systems.

To that end, several economies of scale arise naturally from regional strengths.

Foremost amongst those is China's commanding position in the global clean technology supply chain. In several key minerals, especially rare-earth elements, it holds among the largest reserves globally. Across an even wider set of raw materials, it also dominates refining, processing, and manufacturing capacity for renewables, electrolysis, batteries, and related systems.

The combined scale of its workforce and natural resources, together with its motivation to strengthen long-term energy security, has driven China to expand renewable power at a pace unmatched in any other region. By 2035, it aims to reach about 3,600 gigawatts of installed wind and solar capacity.[10] This figure is roughly three times the current total power generation of the United States.

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"There is a lack of synchronization between the regulations for new fuels and the incentive policies across the globe. When the rules and support schemes are different between countries, it is difficult to build a global ammonia network for ships. At this stage, ammonia fuel only works for fixed and predictable routes, for example between Australia and China. We cannot use ammonia for global flexible trading yet, because the fuel is only available in one or two locations."

Chen Xinchuan,
Managing Director, COSCO Bulk China, China

"Right now, there's a clear headwind… It has become normal for developers to delay or cancel projects… The problem is not on the production side. It is on the demand and policy side."

Frank Yu,
Senior Vice President,
Envision Energy, China

Australia also holds some of the strongest wind and solar potential in the world, making it an ideal location for future green hydrogen and e-ammonia production, with key ports connecting it to major trade routes across the region.

Japan and Korea, by contrast, have concentrated industrial demand and advanced engineering sectors but limited land for domestic renewable growth. Both countries are motivated by the need to secure long-term carbon-neutral fuel supply for heavy industry and to maintain global competitiveness in sectors such as steel, chemicals, and shipbuilding.

Singapore, with even more limited domestic renewable generation capacity, depends entirely on imported fuel and operates the world's largest ship bunkering infrastructure. Its priority is to remain the leading global bunkering hub in a net zero future and to anchor standards, certification, and early pilots for new carbon-neutral fuels.

As natural import hubs, Japan, South Korea, and Singapore, and their ports, are becoming strong demand centers for emerging carbon-neutral fuel exports from China and Australia. This is establishing a regional supply-demand dynamic for carbon-neutral fuels that has no corollary in any other part of the world.

Yet, despite possessing strong structural incentives and a pre-existing supply-demand structure, the region's development of carbon-neutral fuels is not progressing at the pace that might be expected given these conditions.

The explanation mirrors the fundamental challenge faced by other countries and regions. The ships are ready. The net zero technology is ready. But demand for carbon-neutral fuels is still not high enough to mobilize production at the scale necessary to support the shipping energy transition.

With so many favorable factors at play, this report seeks to clarify the deadlocks preventing carbon-neutral fuel development in Asia Pacific and to identify the most realistic pathways to overcoming them.

"If we look at green hydrogen as the basis for making green methanol or green ammonia, then the demand is huge."

Zhou Weizhong,
Vice CTO, CSSC Power Group;
Principal Researcher, Marine Power,
CSSC Group, China

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How do the 5 carbon-neutral fuel deadlocks identified globally impact the Asia Pacific region?

The same interconnected, systemic deadlocks affecting the global shipping industry also affect stakeholders in Asia Pacific, but with emphasis on different aspects and with differentiated approaches to resolving them.

Deadlock 1:
Fuel pathway uncertainty fragments demand and dilutes investment in scalable net zero solutions

Across Asia Pacific, as globally, every major sector is pursuing multiple fuel options at the same time. The ships are ready, but the fuels are missing. Ship readiness to run on e-fuels has far outpaced the availability of those fuels.

Although national strategies and ports across Asia Pacific envision an e-fuel-based future for shipping, hydrogen-based e-fuels remain limited, costly, and unevenly distributed.

Given their continued failure to scale, both shipping companies and ports are compelled to hedge their bets, covering all possible fuel futures and creating broad activity but insufficient convergence to unlock large-scale e-fuel investment, while maintaining a reliable supply of conventional or transitional fuels.

Key differentiator: Port preparation for e-fuels is ahead of the global curve in Asia Pacific

Carbon-neutral fuel pilots are advancing in Singapore, Yokohama, Busan, Shanghai, and other major Asia Pacific ports, driven by national green hydrogen and e-fuel strategies, as well as industrial and maritime decarbonization goals.

Stakeholders caution that these efforts are still uneven and lack the scale and predictable pricing needed to compete with conventional fuels, as well as the consistent certification frameworks required to verify fuel origin and carbon intensity. Together, these factors are essential for creating reliable demand signals across the region.

Deadlock 2:
Geographical concentration of carbon-neutral fuel limits trade flexibility

Global e-fuel development is moving toward a few green hydrogen and e-fuel mega-hubs, creating a concentrated fuel geography very different from the ubiquitous availability of conventional fuels.

In Asia Pacific, early carbon-neutral fuel production reflects a similar pattern. Inland e-ammonia and e-methanol facilities do not yet connect fully to coastal bunkering, and low energy density in green hydrogen e-fuels limits vessel range, storage volume, and refueling flexibility.

Container carriers can adapt more easily to this emerging geography, while bulk and tramp operators will face longer delays in transitioning.

Asia Pacific's potential differentiators stem from two early developments.

Key differentiator 1: Smaller, modular energy clusters accelerate early e-fuel availability.

China's emerging model of smaller, faster, modular production clusters produces competitively priced e-ammonia sooner than traditional mega-hub strategies. This approach reduces build time, spreads production across more locations, and could widen the number of ports with early access to carbon-neutral fuels.

Key differentiator 2: Book-and-claim systems broaden early fuel accessibility.

Asia Pacific is ahead in recognizing the role of book-and-claim attribute transfer, which allows ships to purchase certified carbon-neutral fuel attributes without requiring long-distance transport of scarce early e-fuels.

This mechanism can ease early infrastructure bottlenecks and reduce logistics costs and transport emissions, provided certification and accounting systems remain transparent and prevent double counting.

Deadlock 3:
Green finance paradox. The money is there, but not readily available for shipping e-fuels

Global environmental, social, and governance (ESG) capital exceeds $3.5 trillion, yet only about $14.5 billion has reached shipping because projects lack the long-term contracts, policy stability, standardized reporting, and proven technologies investors require.

Split incentives weaken the case further, since the party ordering a vessel is rarely the one paying the fuel bill, which undermines returns and slows investment.

Hedging across liquefied natural gas (LNG), methanol, and ammonia then fragments demand and limits the concentrated offtake e-fuel producers need. Green premiums work only in high-value consumer cargo.

Even then, theory is different than practice, and early offtakers expect to absorb losses for some duration, because they cannot pass on higher fuel costs.

Key differentiator: Asia Pacific's drive for fossil independence produces substantial supply-side support, while maritime demand is almost entirely unsupported.

Asia Pacific governments and ports offer finance guarantees, industrial cluster incentives, integrated ammonia and methanol programs, renewable-energy subsidies, land reservation, preferential permitting, coordinated port–energy planning, cross-sector demand aggregation, and early certification work.

On the other hand, demand-side incentives for maritime use are nearly absent across the region.

Singapore is the only economy with both a direct carbon-pricing mechanism for shipping and a true demand-side incentive through port-fee reductions.

This absence of regional demand incentives signals a clear expectations that global regulation, rather than national policy, will eventually create maritime demand and unlock e-fuel investment at scale.

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Deadlock 4:
The gap between regulatory ambition and implementation

Asia Pacific's unified message: global net zero regulation is essential to accelerating shipping's energy transition.

Across the global industry, stakeholders agree that coherent net zero regulation is essential to accelerate shipping's shift to e-fuels. Technical readiness is not the constraint.

The absence of clear global carbon pricing and incentives leaves shipowners and e-fuel producers unable to see where demand will form or scale, which slows vessel decisions and pushes e-fuel producers toward sectors like power generation, chemicals, and agriculture, with stronger policies and more reliable long-term signals.

With the International Maritime Organization (IMO) Net Zero Framework postponed and regional rules advancing at uneven speeds, companies hesitate to anchor early offtake, reinforcing a global deadlock driven by regulatory uncertainty.

Key differentiator: in Asia Pacific, green hydrogen and e-fuel policies tied to long-term energy-security goals drive earlier, although uneven, cross-sector momentum.

Singapore is the only country applying carbon pricing to shipping, but much of the region applies it to other hard-to-abate sectors.

Combined with significant government support for renewable energy, green hydrogen, and e-fuels, this creates earlier cross-sector offtake outside shipping.

The region's determination to reduce fossil-fuel dependence creates a clear regulatory trajectory, even as uncertainty limits large-scale commitments from shipowners and resulting e-fuel supply.

Deadlock 5:
Ports as infrastructure bottlenecks

Ports worldwide face structural constraints that slow readiness for carbon-neutral fuels.

Grid overcapacity, limited storage space, zoning restrictions, strict safety rules for methanol and ammonia, slow permitting, limited bunker-vessel availability, and a projected shortfall of 90,000 maritime workers by 2026 constrain the development of multi-fuel infrastructure.

With no dominant fuel pathway, ports must prepare for several fuels in parallel, which strains land, financing, and workforce capacity.

Fragmented coordination between maritime, energy, and environmental authorities keeps most activity at pilot scale and adds pressure to already overutilized ports. In this environment, only the most advanced ports, often seeking inclusion in early green corridors, pursue early e-fuel readiness.

Most others, facing high opportunity costs and uncertain returns, wait to determine when carbon-neutral bunkering will become relevant to their shipping customers.

Key differentiator: Asia Pacific ports face these same constraints, with a clear view of e-fuel not as a possibility, but as an inevitability.

This drives leading ports to prepare ahead of scaled e-fuel availability. Singapore, Shanghai, Busan, and Shenzhen test methanol and ammonia bunkering, strengthen fuel-handling capability, prepare workforces, and expand onshore power, but progress still depends on the slower scaleup of e-fuel production and delivery.

Geography and resource distribution widen regional gaps, since resource-rich areas and major trading ports advance faster than secondary ports. As a result, ports see e-fuels as inevitable but remain constrained by how much readiness is possible without reliable supply or consistent demand.

> "Long term, clear policies and stable carbon pricing are essential for investment to follow."
>
> **Tan Kian Chai,**
> Global Head, Technical Fleet Management, Eastaway Ship Management, Singapore

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Asia Pacific is becoming a proving ground for practical pathways to resolve carbon-neutral fuel deadlocks

Asia Pacific is emerging as a proving ground for coordinated hydrogen and e-fuel development. The region shows that while shipping alone cannot create viable e-fuel markets today, cross-sector alignment across power, industry, ports, and regulators is beginning to build the underlying systems that future maritime uptake will depend on.

These actions do not remove the deadlocks facing shipping, but they do create progress across the wider energy system and allow early steps that would not occur in a sector-by-sector approach.

Resolving Deadlock 1:
Clearer early pathways through energy and industrial alignment

Governments across the region have introduced hydrogen, e-fuel, and industrial decarbonization strategies that link early demand across power, steel, chemicals, and other land-based sectors. This broader demand base helps anchor early offtake in e-ammonia and e-methanol for industrial use. It also provides clearer signals to major bunkering ports, which are aligning early planning with these national strategies. These steps do not create maritime demand, but they support clarity that hydrogen-based e-fuels are the long-term direction for shipping.

Resolving Deadlock 2:
Modular production and emerging certificate systems prepare the ground for wider access

China's modular e-ammonia clusters show that smaller, inland production systems can come online early when linked to industrial demand.

These facilities remain focused on land-based users and do not yet expand maritime access, but they demonstrate a replicable model for early supply development.

At the same time, Guarantee of Origin systems in Japan, Korea, Singapore, Australia, and the European Union are developing the certificate backbone needed for future attribute transfer.

These systems do not create maritime demand today, but they form part of the future architecture for flexible, geographically distributed access once larger volumes of e-fuels are produced.

Resolving Deadlock 3:
Cross-sector offtake reduces producer risk even without maritime demand

The region provides strong supply-side incentives for hydrogen and e-fuels that support early production for power generation, chemicals, and heavy industry.

These incentives reduce risk for producers and allow early facilities to move forward. Shipping is not part of this early demand, and the region has no large-scale maritime incentives, but progress in land-based sectors keeps the supply chain evolving while maritime regulation remains uncertain.

Cross-sector offtake therefore supports early production, even though it cannot substitute for clear maritime demand signals.

Resolving Deadlock 4:
National hydrogen and e-fuel strategies align energy, industry, and port planning for future maritime fuel use

Japan, Korea, Singapore, and China are developing national hydrogen and e-fuel strategies that connect renewable production, industrial demand, import terminals, and port operations.

These strategies do not create maritime e-fuel demand today, but they provide clear direction for how energy, industrial, and port systems should plan for green hydrogen and e-fuels.

This gives major bunkering ports a structured basis for early ammonia and methanol readiness while shipping waits for stronger demand signals.

Resolving Deadlock 5:
Cross-sector planning enables early readiness at major bunkering ports

Only a few major bunkering ports in Asia Pacific are linked closely enough to national hydrogen and e-fuel strategies to justify early ammonia and methanol preparation. Singapore and Shanghai have begun methanol pilots, while Busan and Yokohama are preparing primarily for ammonia.

This cross-sector alignment helps these ports gain early operational experience, even though most ports cannot advance until maritime demand and e-fuel volumes increase.

"Many small ports simply do not have the space to carry all these alternative fuels. Without cooperation, smaller markets will have no options at all. Even inside governments, people work in silos. The energy minister and transport minister need to sit in a room together and lay out what their needs are and see where there's overlap and how they can agree on a national approach. From the port side of it, a regional approach is really necessary."

Liliane Rose Flour,
Port Management Programme Manager, UN Trade and Development (UNCTAD), Switzerland

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Asia Pacific's cross-sector model advances regional energy systems while maritime deadlocks persist.

Asia Pacific's cross-sector coordination does not resolve the deadlocks facing maritime e-fuel adoption today. Maritime demand remains limited. Carbon pricing and demand-side incentives are largely absent. E-fuel volumes are still very small. Ports outside the major bunkering network cannot justify early investment. These deadlocks persist.

At the same time, the region's progress is significant. Asia Pacific is building the technical, industrial, and port-ready foundations that the maritime transition will depend on. It also raises an important strategic question. If global maritime regulation remains delayed, or does not create early demand signals, should regions pause and wait, or continue advancing in coordinated ways?

Asia Pacific's experience suggests that progress does not need to pause.

Replicating cross-sector pathways in other regions, combined with national-level incentives and carbon-pricing measures for maritime fuels, could enable meaningful forward movement even without perfect global alignment.

Asia Pacific has demonstrated that coordinated energy and industrial systems can move first. The next step is ensuring that maritime demand strengthens in parallel.

How Asia Pacific ports position themselves in an emerging e-fuel economy

Ports across Asia Pacific are preparing for green hydrogen, and e-fuels through early bunkering pilots, safety development, and even contract coordination with national energy agencies, local industry, and maritime operators.

Their emerging roles reflect each country's resource base, industrial structure, geography, and policy direction, creating a regional pattern in which production centers, import hubs, and connector ports create a robust and shared cross-sector system.

Producer and export-source ports anchor early supply
Australia and selected Chinese coastal ports draw on strong renewable resources, industrial capacity, and export infrastructure to prepare for green hydrogen-based e-fuels. Large export terminals in Australia and major coastal hubs in China position these ports at the start of future e-fuel corridors.

Receiver and industrially aligned ports focus on import readiness
Japan and Korea, with limited renewable resources and concentrated heavy industry, configure ports for ammonia, hydrogen, and methanol import pathways. Their proximity to steel, power, and chemical users strengthens co-located demand and supports structured safety and permitting processes.

Major bunkering ports operate as regional connectors
Singapore focuses on receiving, blending, and distributing e-fuels across trade routes. Its multi-fuel pilots and regulatory coordination position it as a commercial testing ground and a key node linking regional e-fuel supply chains.

The diversity of energy systems and industrial structures across Asia Pacific creates a supply-and-demand pattern that is beginning to resemble a self-reinforcing carbon-neutral e-fuel ecosystem.

These emerging producer, connector, and receiver roles show how differentiated infrastructure, industrial demand, and renewable supply can form the backbone of scalable e-fuel corridors.

6 Key findings and recommendations

1. **National strategies in Asia Pacific are accelerating green hydrogen and e-fuel development to strengthen long-term energy security in a net zero future**

Governments across Asia Pacific identify green hydrogen and hydrogen-derived e-fuels as essential to both national decarbonization and long-term energy security. Japan and Korea are stimulating early demand for e-ammonia through power-sector procurement. Australia and China are advancing green hydrogen and e-fuel production capacity that reduces dependence on imported fossil fuels and strengthens domestic industrial capability.

These strategies establish the direction of future energy systems by anchoring them in renewable resources and e-fuels rather than fossil imports.

Recommendation:
Governments in other regions should first decide whether green hydrogen and e-fuels are central to their own net zero and energy-security strategies. If they are, then Asia Pacific's cross-sector approach, which links energy, industry, and port planning in a single green hydrogen and e-fuel vision, can serve as a reference for designing similarly coherent national strategies.

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2. Asia Pacific is becoming the most advanced regional testbed for cross-sector green hydrogen and e-fuel system development

Asia Pacific concentrates shipbuilding, global trade flows, renewable potential, and heavy industrial activity in close proximity to major bunkering ports. This co-location enables early cross-sector coordination across power generation, steel, chemicals, ports, and regulators.

Early development occurs where these sectors intersect and where national hydrogen and e-fuel strategies provide clear direction, even in the absence of a fully coherent global maritime regulatory framework.

Recommendation:

Governments and industry should expand cross-sector programs that link port planning, green hydrogen and e-fuel production clusters, and industrial offtakers.

This coordination strengthens regional system design and creates early offtake signals from land-based sectors that can support e-fuel supply development before consolidated maritime demand emerges.

3. Complementary national roles and port functions create a self-reinforcing regional architecture for green hydrogen and e-fuel supply and demand

China and Australia are advancing large-scale green hydrogen and e-fuel production. Japan and Korea form concentrated import markets for e-ammonia and green hydrogen that support power-sector and industrial decarbonization. Singapore acts as the region's primary connector and distribution hub, while Malaysia is positioned to play supporting connector roles due to its proximity to major trade routes and industrial growth. Together, these producer, connector, and receiver functions create a clear upstream and downstream structure that strengthens supply–demand alignment for green hydrogen and e-fuels across Asia Pacific.

Recommendation:

Governments and port authorities should explicitly design their green hydrogen and e-fuel strategies around the distinct roles of producers, connectors, and receivers in the region. Clear role definition allows ports, energy developers, and industrial users to plan infrastructure, storage, and future bunkering capabilities in ways that reinforce regional supply and demand dynamics. This clarity accelerates system development because each country and port invests according to its structural position in the emerging green hydrogen and e-fuel network.

4. High-traffic regional and East–West trade corridors, supported by cross-sector demand, anchor early development of green hydrogen and e-fuel systems

Asia Pacific's busiest trade routes already link renewable-rich production regions, industrial demand centers, and major bunkering ports. The Australia–Singapore–China iron corridor aligns early e-ammonia production with both maritime bunkering potential and emerging industrial hydrogen and ammonia demand in iron and steel processing, including direct reduction and high-temperature applications. This creates one of the region's strongest cross-sector anchors for early green hydrogen and e-fuel development.

The Singapore–Rotterdam route links Asia's developing green hydrogen and e-fuel supply system to European industries that already anticipate significant demand for e-methanol, e-ammonia, and green hydrogen. These include chemicals, refining, steelmaking, and high-value containerized goods where companies pursue long-term decarbonization strategies. Because these corridors concentrate maritime traffic, industrial offtake, and major bunkering ports, they provide a natural backbone for early system development.

Recommendation:

Governments, ports, and industry can use these high-traffic corridors as early deployment routes. Aligning green hydrogen and e-fuel availability, industrial offtake, and port readiness along these pathways can support efficient and scalable system development even before global maritime demand fully emerges.

5. Modular green hydrogen and e-fuel production models, supported by emerging certificate systems, can bring supply online faster and reduce early geographic constraints

Asia Pacific is advancing modular green hydrogen and e-fuel facilities that integrate renewable power, electrolysis, storage, and ammonia synthesis into smaller-scale units. China's modular e-ammonia clusters, designed to match local industrial demand, show how early supply can scale through incremental and lower-risk steps rather than relying entirely on million-ton export projects.

This modular model is already being replicated internationally, including at the Port of Pecém in Brazil, demonstrating that it can be implemented more quickly and across a wider range of locations than traditional mega-hub approaches.

In parallel, Japan, Korea, Singapore, Australia, and the European Union are developing certification systems such as Guarantees of Origin. These systems form the basis for future book-and-claim mechanisms that can separate the environmental attributes of green hydrogen and e-fuels from their physical delivery. Although these systems remain at an early stage and are not yet widely used for maritime fuel applications, they can reduce geographic constraints once larger volumes of green hydrogen and e-fuels become available.

Recommendation:

Policymakers and investors should support modular production models and robust certificate systems with safeguards for transparency, standardization, and avoidance of double counting. Together, these tools can enable earlier supply and expand the flexibility of future green hydrogen and e-fuel distribution.

6. Maritime uptake of green hydrogen and e-fuels remains stalled because carbon pricing and demand-side incentives are largely absent

Despite strong national ambition across Asia Pacific for green hydrogen and e-fuels, no major economy in the region provides meaningful maritime incentives for the use of e-ammonia or e-methanol, with the exception of Singapore. Singapore applies a national carbon tax and offers limited

Executive summary continued

port-dues and registry incentives for lower-emission vessels, although these measures are too small to close the e-fuel cost gap. All other economies in the region provide no maritime incentives at all.

Maritime fuel use is not included in national carbon-pricing systems across the region. These systems apply only to domestic emitters, which means they do not influence the cost of international bunkering or create incentives for ships to use green hydrogen or e-fuels.

Stakeholders consistently identify the absence of carbon pricing and maritime demand-side incentives as the primary reasons that shipping's e-fuel demand has not yet formed.

Early adopters expect to incur financial losses for an extended period, and cargo owners show low willingness to pay the premium associated with green hydrogen and e-fuels. As a result, maritime demand remains too weak and too dispersed to anchor early supply development.

Recommendation:
Governments can consider national or regional carbon-pricing measures for maritime fuels, along with targeted demand-side incentives that reduce the cost gap for early e-fuel use.

These steps can create clearer and more predictable demand signals while global maritime regulation continues to evolve.

Conclusion: Will shipping's net zero energy future be written where the ships are built?

Asia Pacific shows how green hydrogen and e-fuel systems can progress when energy, industrial, and port strategies are aligned around shared decarbonization and energy-security goals.

The region brings together renewable resources, large industrial demand, major bunkering ports, global trade flows, and a dominant shipbuilding base. These conditions allow energy, industrial, and port systems to advance green hydrogen and e-fuel systems in a coordinated way, even without a comprehensive global maritime regulatory framework.

A regional architecture is already forming across Australia, China, Singapore, Japan, and Korea. Renewable-rich production economies develop green hydrogen and e-fuel supply. Import-dependent economies create demand for e-ammonia and green hydrogen for power generation and industry.

Major bunkering ports act as connectors and early readiness hubs. High-traffic corridors, including the Australia–Singapore–China iron corridor and the Singapore–Rotterdam route, link industrial offtake, maritime traffic, and early e-fuel pilots. Modular production models add flexibility by enabling earlier supply in locations that match renewable resources and local industrial demand.

These developments reflect a deliberate shift toward long-term energy security in a net zero world. Fossil fuel imports cannot provide that security. Green hydrogen and e-fuels can.

However, maritime uptake continues to lag because carbon pricing and demand-side incentives for e-fuels are largely absent across the region.

This deadlock is often described by stakeholders as the linchpin that holds the others in place.

Singapore is currently the only economy applying a carbon tax that affects maritime fuels and offering limited incentives for cleaner vessels. Elsewhere in Asia Pacific, maritime fuel use is not covered by national carbon-pricing systems, and governments do not yet provide incentives that reduce the cost premium for e-methanol or e-ammonia.

The absence of both carbon pricing and demand-side incentives signals the regional expectation that global regulation will eventually create these demand signals. Many stakeholders report that, without these signals, maritime e-fuel demand cannot reach critical mass, and early adopters expect to face higher operating costs for a prolonged period.

This raises a strategic question for the global transition. If global maritime regulation is delayed or does not create strong demand signals soon, should regions wait or continue advancing?

Asia Pacific's experience indicates that progress does not need to pause. Cross-sector coordination, national green hydrogen and e-fuel strategies, modular production models, and early port pilots show that regional systems can evolve even before maritime demand strengthens.

Replicating this cross-sector model in other regions, combined with national-level carbon-pricing and demand-side incentives for shipping, could help overcome maritime deadlocks and create practical pathways for future green hydrogen and e-fuel uptake.

Asia Pacific is building the foundations now. The next step is ensuring that maritime demand can follow.

How differentiated national renewable capacities define a core supply–demand dynamic at shipbuilding's global center

Asia Pacific's four leading maritime economies, China, Japan, South Korea, and Singapore, anchor the world's shipbuilding and bunkering system. Their renewable positions determine not only how green hydrogen and e-fuels can be produced, but also how these fuels will move across the region.

Renewables already make up 59.1% of China's installed capacity, and it continues renewable deployment at unmatched global scale. In 2025, wind and solar capacity exceeded coal for the first time.[11] Its 3,600 GW wind and solar target is nearly as much as its total current power capacity. This scale gives China the strongest basis in the region for large-volume green hydrogen and e-fuel production. In effect, China is the only 1 of the 4 with long-term potential to supply significant export quantities.

Japan currently generates only 25.7% of its electricity from renewables and targets 36–38% by 2030. Its total power capacity is 10x smaller than China's, and offshore wind remains under 5 GW. This limits Japan's ability to meet its own future green hydrogen and e-fuel demand, keeping it structurally dependent on imported green hydrogen and e-fuels even under accelerated domestic build-out. This establishes Japan as a stable long-term demand center within the region.

South Korea has 144 GW of capacity and aims for 21.6% renewables by 2030, up from 9% in 2022. Coal and LNG still account for more than half of total capacity. Korea's national hydrogen roadmap and International Renewable Energy Agency assessments both conclude that the country will rely heavily on imported green hydrogen and e-fuels while developing targeted domestic production in industrial zones. This reinforces Korea's position as another long-term demand center in the region. Their standards for green hydrogen certification are some of the most advanced in Asia.

Singapore has the most limited domestic renewable potential, with only 1.5 GW of solar today and a target of 2 GW by 2030. Its 13.1 GW total capacity cannot support meaningful green hydrogen or e-fuel production. Singapore will rely entirely on imported supply, strengthening its role as a connector and distribution point in regional e-fuel pathways, consistent with its position as the world's largest bunkering hub and an early mover in ammonia bunkering trials.

These profiles are already reflected in national hydrogen strategies. China's hydrogen plan positions it as a large producer of green hydrogen and e-fuels. Japan, South Korea, and Singapore expect to rely heavily on green hydrogen and e-fuel imports to decarbonize power, steel, chemicals, and shipping. This links shipping's carbon-neutral fuel transition in Asia Pacific directly to long-term energy-security strategies and reinforces a regional pattern in which China develops export-oriented production while the other three economies remain stable demand centers.

How differentiated national renewable capacities define a core supply–demand dynamic at shipbuilding's global center continued

China

3,600 GW wind and solar target for 2035[12]

- **6×** 2020 levels[13]
- China has a total power capacity of **3,720 GW** as of September 2025[14]

Renewables already **56%** of capacity[15]

100,000–200,000 tons/year green hydrogen targeted by 2025[16]

Japan

Renewables **22.9%** of electricity in 2023[17]

- Targeting **36–38%** by 2030[18]

318.6 GW total power output[19]

- 10× smaller than China

Offshore wind target: **10 GW** by 2030[20]

- Installed capacity still under 5 GW[21]

South Korea

Clean hydrogen certification threshold:

4 kg CO_2e per kg H_2[22]

- One of most advanced green hydrogen certification systems in Asia[23]

144 GW total power output 2024[24]

Targeting **21.6%** renewables by 2030

(vs. 9% in 2022)[25]

Coal 33% and **LNG 29%** of total power output[26]

Singapore

World's **largest** bunkering hub[27]

- **54.92 million tons** of marine fuel sold in 2024[28]
- Of that, **1.34 million tons** of alternative fuels[29]

Solar: **1.5 GW** today, **2 GW** targeted by 2030[30]

Total installed capacity: **13.2 GW** (2025)[31]

First port to conduct a live ammonia bunkering operation[32]

The 5 deadlocks

Deadlock factors

1 Fuel pathway uncertainty and fragmented demand
See page 15

2 Fuel geography threatens fleet flexibility
See page 19

3 Green finance paradox & commercial structure
See page 23

4 Regulatory ambition vs. implementation reality
See page 27

5 Ports as bottlenecks of infrastructure development
See page 29

Deadlock 1:

Fuel pathway uncertainty fragments demand and dilutes investment in scalable net zero solutions

Despite a clear long-term mandate for hydrogen-based e-fuels across Asia Pacific, the region continues to mirror the global pattern of fragmented and diluted demand across many fuel pathways.

This fragmentation persists even as national hydrogen strategies, port pilots, and early cross-sector initiatives point toward e-ammonia and e-methanol as the only scalable carbon-neutral fuels.

Early cross-sector activity is visible in ammonia co-firing, emerging modular e-ammonia production in China, and targeted methanol and ammonia bunkering pilots in ports such as Singapore, Yokohama, Busan, and Shanghai. However, these developments have not yet translated into consolidated demand. Instead, fuel signals remain dispersed.

Shipping companies hedge across methanol, ammonia, LNG, LPG, and biofuels. Shipyards continue designing for multiple futures at once.

Stakeholders describe a region where technology readiness is high but e-fuels remain scarce, costly, and unevenly distributed.

In short, Asia Pacific's early hydrogen and e-fuel momentum has not yet translated into a unified demand signal.

Without stronger convergence across shipping, power, steel, chemicals, and ports, the region's structural advantages cannot overcome a fragmented fuel landscape that continues to dilute investment and delay scale.

Fragmented fuel choices dilute maritime demand

- Shipping companies hedge across methanol, ammonia, LNG, LPG, and biofuels.
- Shipyards design vessels for several futures simultaneously.
- Ports must plan for multiple pathways long before supply stabilizes.

Early hydrogen and e-fuel systems are emerging, but remain uneven

- Modular e-ammonia clusters in China and ammonia pilots in Japan, Korea, and Singapore develop in isolation.
- Ammonia co-firing and small-scale methanol/ammonia production expand, but not in coordinated ways.
- Bunkering pilots remain limited to a small number of advanced hubs.

Cross-sector demand grows, but is not yet aligned with maritime needs

- Early demand comes primarily from power generation, chemicals, and industry – not from shipping.
- These sectors create valuable early offtake, but their timelines and fuel preferences differ from maritime users.
- Cross-sector activity supports production, but it does not aggregate into a shared fuel pathway that includes shipping.

Lack of aligned demand keeps producers from committing to scale

- Producers wait for multi-sector, multi-year offtake that dispersed maritime demand cannot yet provide.
- Ports cannot invest confidently in bunkering infrastructure without clearer demand visibility.
- Uncertain demand keeps risk and financing challenges high across the value chain.

What determines the cost of e-fuels, and why do prices differ so widely across regions?[33]

E-fuels remain significantly more expensive than fossil fuels without heavy subsidies. Why?
Fossil fuels rely on extraction and refining. E-fuels require multiple feedstocks and several conversion stages.

Without strong policy and investment that lower the levelized cost of energy for e-fuels, they will not reach cost parity with fossil fuels before 2050.

Models show e-fuels will remain more expensive long-term
The International Maritime Organization published e-fuel cost trajectories showing a clear and persistent gap between fossil fuels such as heavy fuel oil, very low sulfur fuel oil, and liquefied natural gas, and e-fuels such as e-methanol and e-ammonia.

Among e-fuels, e-ammonia is most cost competitive
Carbon-based e-fuels such as e-LNG and e-methanol remain at least one-third more expensive than e-ammonia, as they require both hydrogen and captured CO_2, along with additional catalytic synthesis stages.

These steps raise electricity use, capital costs, and process complexity. Ammonia uses only hydrogen and nitrogen, which makes it substantially cheaper to produce under all modeled conditions.

Fossil fuel price declines reflect lower demand
Based on the International Energy Agency's World Energy Outlook 2023, fossil fuel prices will fall as global demand decreases, due to growing renewable energy use.

Electricity is the largest driver of total production cost
The International Maritime Organization's assessment models global averages, so it does not account for regional variation. In practice, costs vary widely by region.

A fuel-cost calculator from the Maersk McKinney Møller Center, which contributed to the study, allows users to specify electricity prices and production origins.

Studies from CONCAWE, Sapienza University of Rome, and Swinburne University of Technology show that electricity is the largest component of e-fuel production cost. Electrolyzer investment matters but contributes far less to final costs.

"Technologically speaking, either methanol or ammonia presents no problem. We have already provided the largest methanol engines and will soon put forward the ammonia engines. But we do not have enough green low-carbon fuels."

Zhou Weizhong,
Vice CTO, CSSC Power Group, Principal Researcher of Marine Power, CSSC Group, China

"Within Asia, there are some good initiatives that may help advance the conversation in this multi-fuel context… Shipping is not stopping. Efficiency and emissions reduction continue every day."

Luis Benito,
Group Business Development and Marketing Director, Wallem Group, Hong Kong

"China has shown that it is capable of producing something which at the end ends in a legally binding offtake agreement… we're talking about half a million tons per year of green methanol for a long period of time. When I say long-term offtake, it means that it's enough for them to take the financial investment decision, which in turn will allow them to start construction, and the whole thing is enabled."

Spokesperson, major shipping line

"Numerous eco-friendly fuel candidates have been proposed after LNG, such as methanol, ammonia, and hydrogen, but the ultimate one remains uncertain. Shipping companies are conservative. Many prefer slow-speed operation with existing systems until a clear candidate is identified."

Taek Kun Nam,
Chairman, Korean Society of Marine Engineering, South Korea

What determines the cost of e-fuels, and why do prices differ so widely across regions? continued

Geography influences renewable electricity prices

Countries such as Australia and Chile benefit from strong renewable resources and high capacity factors.

These conditions reduce levelized energy costs and lower e-fuel production costs compared with regions such as Northern Europe.

However, the differences remain too small to shift the overall competitiveness of e-fuels relative to fossil fuels.

Falling capital costs underpin future e-fuel production but vary by region.

Solar and wind capital costs have fallen sharply over the last 15 years.

IRENA shows that levelized electricity costs are now a fraction of their previous levels.

This decline supports large-scale renewable deployment and underpins future e-fuel production.

A similar pattern occurred in the early 2000s when Germany's feed-in-tariff program created the first large commercial markets for solar and wind and triggered global cost declines.

China achieves the lowest renewable capital costs

Cost reductions are uneven across countries.

China has the lowest cost per installed unit of photovoltaic and onshore wind capacity.

This is driven by lower labor costs, efficient materials processing, strategic sourcing, and targeted government support.

These factors have created a globally competitive renewable energy industry.

Regulatory frameworks influence which e-fuels emerge in each region

Asia focuses on e-methanol, Europe emphasizes e-kerosene

Large-scale e-fuel projects in Asia focus mainly on e-methanol. E-methane and e-kerosene projects remain limited. In Europe, more investment is directed toward e-kerosene, with e-methanol following at a smaller scale.

Policy explains the divergence

The European Union's Fit for 55 framework includes mandates for sustainable aviation and maritime fuels. These rules drive e-kerosene and e-methanol development. In Asia, aviation decarbonization has gained policy attention only recently. This explains the slower pace of e-kerosene development.

Conclusion: e-fuel costs reflect the entire value chain

E-fuel costs vary by region because each part of the value chain depends on local conditions. Electricity cost is the main driver. Capital costs for renewable installations differ widely, with China achieving the lowest levels. Regulatory frameworks in Europe and Asia shape which fuels move forward.

Cost parity is unlikely before 2050 without stronger policy and investment frameworks

Across all major studies, e-fuels do not reach fossil fuel cost parity before 2050 unless policy and investment directly lower the levelized cost of energy required for their production, while also pricing carbon out of the market.

These measures include supportive electricity pricing, faster renewable energy deployment, lower electrolyzer capital costs, and stable regulatory frameworks, including carbon pricing, that reduce risk and support large-scale financing.

Without these interventions, e-fuels remain structurally more expensive than fossil fuels, even in regions with strong renewable resources.

> "The market for low-carbon fuels for bunkering and the power sector is still not strong enough to motivate production, so the demand is not yet there. On the supply side, some companies are developing projects that are currently too big to be absorbed by the market."
>
> **Frank Yu,**
> Senior Vice President,
> Envision Energy, China

Not for net zero by 2050: Commercial nuclear ship propulsion

Potential for true zero emission propulsion[34]
Nuclear propulsion has re-entered the maritime decarbonization debate because small modular reactors, particularly molten salt reactor designs, could theoretically deliver zero greenhouse gas emissions without requiring the extensive fuel production and distribution infrastructure needed for e-fuels. The very high energy density of nuclear fuel could allow for lower operating costs, higher cruising speeds, and fewer vessels required per route, creating potential commercial advantages for ship operators.

Appeal of molten salt reactor safety concepts
Supporters emphasize that molten salt reactors are designed to be inherently safe. In the event of a failure, the fuel would drain from the reactor core into a containment structure and solidify, preventing release of radioactive material into the environment. This passive safety behavior is presented as a key advantage for offshore applications.

Fundamental technical uncertainties
Despite these theoretical benefits, significant uncertainties remain. Light water reactors used in power generation and naval applications are unsuitable for civilian merchant shipping. Molten salt reactors are viewed as the more viable alternative, but no reactor of this type has been demonstrated at the power range required for commercial vessels or tested in a maritime environment. This leaves technical feasibility, safety performance, and development timelines unproven.

Operational impracticality for ship crews
Commercial ship crews cannot operate nuclear reactors. Any practical model would require continuous remote monitoring and control by the original equipment manufacturer or significant intervention onboard from a new class of nuclear-trained maritime professionals. This introduces new dependencies in operations, maintenance, cybersecurity, and emergency response that are not part of current industry practice.

Safety, security, and proliferation concerns
Although molten salt reactors aim to eliminate the risk of atmospheric release through passive safety, these claims have not been validated in marine conditions. Concerns remain about collisions, vessel sinking, and piracy, including the possibility of radioactive release or proliferation. These risks are considered major hazards for the application of nuclear reactors at sea.

Regulatory frameworks are not prepared for civilian nuclear shipping
Civil nuclear oversight currently sits with the International Atomic Energy Agency (IAEA), while ship classification, flag state regulation, and port state control are conducted through separate systems. No international regulatory regime exists for civilian nuclear propulsion in merchant shipping. New global frameworks would be required to standardize reactor technology, vessel design, safety protocols, liability management, and port access rights.

Low public acceptance and reputational risk
Public resistance to nuclear powered merchant ships is expected to persist due to past nuclear accidents such as Chernobyl and Fukushima. Social acceptance remains a significant challenge that could influence political and commercial decisions across ports and trade routes.

Scaling challenges relative to global net zero timelines
Core Power aims to begin serial production of small modular reactors for commercial vessels around 2040, with a target rate of one reactor every ten days. However, the global newbuild market is approximately 2,000 ships per year. To achieve a meaningful share of future vessel propulsion, production would need to scale significantly beyond current plans, leaving limited time for nuclear propulsion to contribute materially to the 2050 net zero target.[38]

Economic feasibility relative to carbon-neutral fuel propulsion
Nuclear-powered newbuilds require capital expenditures several times higher than comparable conventional or ammonia-dual-fuel ships. The added costs for reactor systems, shielding, safety requirements, and regulatory compliance place nuclear vessels far outside the typical USD 120 million to USD 250 million newbuild range for large cargo ships. **Long term outlook: unlikely before 2050, possible beyond 2050**.

Based on the current level of technological readiness, regulatory maturity, and societal acceptance, nuclear propulsion is unlikely to scale in time to play a significant role in meeting the 2050 net zero target for shipping. However, over a longer time horizon, nuclear propulsion could still become viable. If molten salt reactors achieve commercial validation and if international regulatory frameworks are developed to support civilian nuclear vessels, nuclear propulsion may become an option for commercial shipping in the decades following 2050.

Deadlock 2:

Geographical concentration of carbon neutral fuel supply limits early maritime access

Asia Pacific shows clearly how geography shapes early carbon neutral fuel availability. Green hydrogen and e-fuel production is forming in inland renewable basins and industrial clusters, while early maritime access remains limited to a few major hubs. Stakeholder interviews confirm that early adoption depends primarily on where fuels can be reliably produced and delivered, not on technology readiness.

Modular e-ammonia production in China demonstrates that smaller, faster, and cheaper systems can come online earlier than large, export-scale projects. The Chifeng model allows early offtake in inland regions with strong renewable resources. However, these inland clusters are not yet connected to coastal bunkering in a way that expands access for ships. Volumes remain modest, and limited maritime demand means producers have little incentive to build distribution pathways to ports.

As a result, access remains highly uneven. Singapore, Yokohama, Busan, and Shanghai are conducting early ammonia and methanol bunkering pilots, but these represent only a small share of total port calls in the region. Container lines with fixed, predictable loops can align fuel planning with a small number of established hubs. Bulk and tramp operators cannot, because their trades rely on many ports that may not gain access to carbon neutral fuels for years. This leaves most maritime segments without predictable early supply.

Book-and-claim systems are emerging as a way to separate carbon-neutral attributes from physical fuel delivery. Guarantee-of-origin schemes in Japan, Korea, Singapore, Australia, and the European Union provide the basis for such systems. Interviews note their potential to ease the constraints of concentrated early supply. However, these mechanisms are still in early development. Transparency, standardization, and avoidance of double counting remain serious concerns, and cross-border alignment is still limited. Maritime use cases are not yet widely established.

Overall, Asia Pacific's early e-fuel landscape reflects a structural deadlock. Production is concentrated in inland and industrial clusters, maritime access is limited to a few early hubs, and shipping has not yet generated the demand signals needed to anchor wider distribution. Without stronger maritime offtake, inland production systems and coastal bunkering points will continue to develop in parallel rather than as a connected regional supply chain.

"We are seeing a big pivot towards regionalism. If regionalism is embraced properly, it will strengthen a region as a whole. A regional approach will help the shipping sector figure out new fuels and might even reduce costs for consumers."

Liliane Rose Flour,
United Nations Conference on Trade and Development (UNCTAD), Switzerland

"If we look at China, I think shipping decarbonization is seen as an enormous opportunity. And that's what lies at the heart of the matter - the extent to which the industrial supply chain within China has taken on this challenge to build plants in order to produce renewable fuels at the scale required for shipping and beyond. It's second to no other country, I think, in terms of the scale."

William Fairclough,
Managing Director,
Wah Kwong, Hong Kong

"We're working with the Ammonia Energy Association on a pilot program for the book-and-claim process. It needs to be promoted because it solves the challenge of physical delivery for green ammonia… we avoid physical shipping, reduce logistics costs, and cut carbon emissions from transport."

Frank Yu,
Senior Vice President,
Envision Energy, China

"Asia-Pacific is going to be central to the energy transition. One factor is just the number of ships that are controlled by the countries in Asia-Pacific - 50% or more. The second thing is this is where the fuel production is likely to happen. Countries in this part of the world, such as Australia, China, India, Japan, Indonesia, and Malaysia, these will be in the spotlight for ammonia, methanol, and hydrogen. It's definitely going to be the central piece in the energy transition for the production of fuels."

Niraj Nanda,
Chief Commercial Officer,
Anglo-Eastern, Hong Kong

Deadlock 2 continued

Inland production does not yet translate into coastal access

- Early e-fuel production forms in inland renewable basins and industrial clusters.
- Modular clusters like China's Chifeng system are emerging, but volumes remain modest.
- Limited maritime demand gives producers little incentive to build distribution pathways to ports.

Container lines can adapt; bulk and tramp operators cannot

- Fixed loops allow container lines to plan fuel use around these hubs.
- Bulk and tramp operators rely on dispersed ports that will not have e-fuels for years.
- Deviation for fuel access raises cost and reduces flexibility.

Early maritime access remains concentrated in a few hubs

- Only a small number of major ports conduct early ammonia and methanol bunkering pilots.
- Coastal access points are not yet connected to inland production at scale.
- Early availability covers only a small share of regional port calls.

Limited book-and-claim adoption keeps geography restrictive

- Guarantee-of-origin systems exist, but attribute trading for maritime use is still early.
- Transparency, standardization, and avoidance of double counting remain serious concerns.
- Without broader uptake, fuel geography remains a binding constraint.

"For shipowners, a lot depends on their vessel schedules. If you're a big liner container operator, with container ships on fixed routes, you can invest in a network of ports and know exactly where your ships will call in the next five or ten years. You can plan infrastructure and fuel supply around that. But for owners trading on the spot market, like tankers, oil, chemical, or LPG like us, it's different. We go everywhere."

Alain Van Thillo,
Chief Technical Officer,
Petredec Group, Singapore

"If a hydrogen or e-fuel hub is established in Korea, transportation routes, the role of ports, and even global shipping will change. Among them, it seems that the role of ports needs to change the most. If a hydrogen hub is established, ports will need infrastructure to supply, store and transport liquefied hydrogen."

Taek Kun Nam,
Chairman, Korean Society of Marine Engineering, South Korea

China's modular, cross-sector e-fuel model offers a faster, lower-cost path to early scale-up

The Asia Pacific region includes some of the world's most ambitious green hydrogen mega-hubs, designed to serve long-term, integrated demand across multiple sectors. These projects will no doubt be central to global cross-sector decarbonization.

In parallel, China is advancing an alternative model that **accelerates early e-fuel delivery** by allowing **small-scale offtake upfront**, with modular, incremental buildout over time.

Envision Energy has developed a **smaller, modular e-ammonia system** at the Chifeng Net Zero Industrial Park in **Inner Mongolia**.[36, 37]

Operating commercially since mid-2025 it produces **300,000 – 320,000 tons of e-ammonia annually** now, with **plans for 1.5 million tons by 2028**.[38]

The **design focuses on rapid build-out** and manageable volumes for early offtake in an emerging e-fuel market.

The system is fully off-grid and integrates wind, solar, battery storage, electrolyzers, and ammonia synthesis through an AI-controlled platform.

This configuration **lowers non-technical costs to enable competitive commercial delivery** for multiple hard-to-abate sectors. Envision sells e-ammonia to Marubeni, which resells to customers across several sectors and markets. Envision also supplies other buyers in Japan, Korea, and Singapore.

With reported FOB prices under US$700 per ton,[39] Envision's e-ammonia is entering the cost range for conventional marine fuels on a per-ton basis.

Accounting for lower energy density puts the ammonia at approximately double the price of conventional fuel, but it is still one of the most cost-competitive emerging e-fuel options for shipping.

Envision also designed the model to be replicated easily, with modular units scaled to local land availability, renewable resource conditions, infrastructure, and demand, enabling rapid deployment in a wide range of settings.[12]

They are now **applying the same approach at the Port of Pecém in Brazil**, providing the **integrated renewable-to-e-ammonia system** for Pecém's new flagship green hydrogen and e-ammonia hub.[45]

Yu also highlights **book-and-claim systems,** which allow producers to sell the **certified green attribute. of a fuel separately from its physical molecule**. This lets buyers in various locations access **verified carbon-neutral "claims"** even if the actual green fuel is consumed elsewhere, helping overcome early geographic and logistics limitations without long-distance transport.

"When you talk about fuel geography, two things come to mind. One is a production site; the other is a trade route... In China's inner Mongolia, we have started producing ammonia and methanol because that's where the clean energy sources are available... This will need long-term planning."

Tan Kian Chai,
Global Head, Technical Fleet Management, Eastaway, Singapore

"To supply immature markets, you cannot develop a big project. We developed a 300,000-ton-per-year green ammonia facility, which is sized reasonably to achieve viable economic scale. We can sell the molecule. We just need to find two or three customers."

"The ammonia delivered from China, landed in Europe and cracked into green hydrogen, is more competitive than hydrogen produced by electrolysis installed locally in Europe."

Frank Yu,
Senior Vice President, Envision Energy

Emerging book-and-claim certification frameworks could spur early demand signals for e-fuels, independent of geography and while distribution networks scale

Jurisdiction	Explicit book-and-claim for fuels?	Main relevant policy / scheme	How it relates to book-and-claim in practice	Status / sectors most relevant
China[40]	**No explicit book-and-claim scheme identified** for shipping or hydrogen.	National work on standards for "low-carbon hydrogen, clean hydrogen and renewable hydrogen" and a national green hydrogen strategy referenced in APEC/APERC material.	Standards and potential certificate systems could support attribute trading, but there is **no evidence yet of a formal book-and-claim framework for fuels**.	Hydrogen strategy and standards in development; focus on domestic production, industrial use and export positioning.
Japan[41]	No named "book-and-claim" scheme, but **clear moves toward Guarantee of Origin (GO) and credit systems.**	Basic Hydrogen Strategy and GX Basic Policy refer to a hydrogen "Guarantee of Origin Scheme" and the J-Credits system that certifies GHG reductions.	A hydrogen GO and J-Credits can provide the **certificate backbone** needed for book-and-claim across electricity and hydrogen use, though not yet framed specifically for maritime fuels.	Hydrogen, power sector, industrial decarbonization; early SAF and hydrogen-carrier import projects.
Singapore[42]	No formal book-and-claim regime yet, but policy explicitly flags **Guarantee of Origin** as an emerging need.	National Hydrogen Strategy notes that "standards and Guarantee of Origin certifications for low-carbon hydrogen are also in early stages" and commits to develop guidelines and standards for low-carbon ammonia and hydrogen supply chains.	This creates a **policy mandate to build certification that could support book-and-claim**, especially for imported hydrogen and carriers used in power and bunkering.	Hydrogen imports, power generation, and maritime/aviation fuel supply; MPA hydrogen/ ammonia EOIs and pilots.
South Korea[43]	No explicit book-and-claim label, but a **clean hydrogen certification system** is in place.	The government has "finalized the country's clean hydrogen certification standard of 4 kg $CO_2eq/kg\ H_2$" and established a clean hydrogen certification management system.	The clean hydrogen certification framework can serve as a **basis for attribute certificates**, allowing lifecycle performance to be tracked and potentially traded, consistent with book-and-claim logic in future.	Hydrogen production and imports, power generation, industry; early ammonia and hydrogen hub concepts.
Australia[44]	**Yes – closest to a full GO framework for hydrogen and electricity**, usable for book-and-claim.	The Guarantee of Origin (GO) scheme is described as "a voluntary framework for emissions accounting of products, and certification of renewable electricity" and "tracks the emissions intensity of products – like hydrogen – and verifies renewable electricity."	GO certificates are **explicit emission-attribute instruments**. Buyers can purchase the certificate and claim the associated emissions profile, even if physical molecules are blended – this is functionally a book-and-claim-ready system.	Hydrogen and renewable electricity, with extension to green products such as steel and ammonia; relevant for export and cross-border trade.
European Union[45]	**No cross-sector book-and-claim system yet**, but ReFuelEU Aviation explicitly mandates the Commission to assess a **"system of tradability"** for SAF.	ReFuelEU Aviation introduces a SAF flexibility mechanism and requires the Commission to "assess and report on possible improvements or additional measures", including a "system of tradability" for SAF.	Mirrors book-and-claim. Environmental attributes to be traded independently of physical SAF, enabling buyers in different locations to claim attributes, creating demand signals without physical distribution.	Aviation, hydrogen, and renewable electricity.

Deadlock 3:

The green finance paradox – capital supports e-fuel production in land-based sectors, but almost none reaches maritime fuel demand

Across Asia Pacific, financing for green hydrogen and e-fuels flows primarily to land-based sectors such as power, chemicals, and heavy industry, where national incentives create clear early demand. These supply-side measures make small-scale production possible, although volumes remain limited and far below what maritime use would require.

In contrast, maritime fuel demand receives almost no financial support. Shipping sits outside the national carbon-pricing systems that benefit domestic sectors, and no major economy in the region—except Singapore—offers meaningful incentives for ships to purchase higher-cost e-fuels. This leaves shipping without stable price signals or direct financial support for fuel switching.

Split incentives deepen the deadlock. Shipowners invest in dual-fuel vessels, but charterers and cargo owners decide whether to buy the fuel. Bulk and tanker operators, who dominate Asia Pacific volumes, cannot recover higher fuel costs in spot markets.

Interviews confirm that cargo-owner willingness to pay is low, even among first movers, and that early adopters on the shipping side expect ongoing financial losses without aligned cost-sharing.

As a result, producers see no bankable maritime e-fuel offtake. Investors avoid funding e-fuel use in shipping because demand is weak, incentives are absent, and cost responsibility is unclear. This leaves capital concentrated on land-based sectors and prevents investment from reaching maritime e-fuel deployment, reinforcing a structural financing deadlock across the region.

"There's a huge queue of capital waiting to enter the hydrogen and e-fuel space. The barrier is not liquidity but risk and returns. Most green fuel production investment that's moving forward today relies on some degree of concessional finance – state-backed, policy-backed, or philanthropic. Not everything needs to be fully subsidized; even modest gearing between concessional and commercial capital can unlock investment if someone provides the facility."

James Forsdyke,
Managing Director, Lloyd's Register Maritime Decarbonisation Hub, Singapore

"Election cycles are short, and it's causing regulatory changes to happen all the time, with policy mechanisms that aren't long term. It hinders the unlocking of big finance. We need an insane amount of money, and it needs to be a global, national, and regional effort."

Liliane Rose Flour,
Port Management Programme Manager, UN Trade and Development (UNCTAD), Switzerland

"We're immersed with the green premium and try to pay our bit, but also pass some on. The simple logic is to say that when we do act – let's say pay a higher price for green fuel – we're dealing with our scope one emissions, but at the same time, we're dealing with our client's scope three emissions."

Spokesperson,
Major shipping line

"At the moment, nobody is really making money from these projects. We are investing as shipowners, and the financial pressure on the fund is very high in this early transition stage. The market and the support mechanisms are not yet strong enough for us to recover these investments easily. It is a huge cost. It cannot be done by one company alone, even a big company like COSCO. Shipowners, charterers, shippers and receivers, everybody in the supply chain needs to join together and share the cost."

Chen Xinchuan,
Managing Director, COSCO Bulk China, China

Deadlock 3 continued

Supply-side incentives support early production

- Several economies provide incentives for hydrogen and e-fuels in power, chemicals, and heavy industry.
- These incentives allow small-scale production to move forward, although volumes remain limited.
- Producers focus on sectors with clear domestic offtake, since shipping demand has not yet proven to scale.

Split incentives weaken e-fuel uptake

- Shipowners invest in dual-fuel vessels, and early movers invest in e-fuels, but charterers and cargo owners decide whether to buy higher-cost fuels.
- Most bulk and tanker operators cannot recover higher fuel costs in spot markets.
- Real-world willingness to pay remains low on the cargo side, even among first movers.

Maritime e-fuel demand receives almost no financial support

- No major Asia Pacific economy (except Singapore) provides demand-side incentives for maritime e-fuels.
- Shipping's global regulation leaves shipping outside national carbon-pricing systems that drive demand in land-based sectors.
- Maritime e-fuel use receives no stable price signals and no direct financial support.

Early financial mechanisms remain limited and unaligned with maritime uset

- Sustainable finance frameworks, credit guarantees, and aggregation ideas remain early-stage.
- Without predictable maritime offtake or shared cost responsibilities, investors avoid funding e-fuel use in shipping.
- This keeps risk high and prevents investment from reaching maritime e-fuel deployment.

"To avoid relying solely on subsidies, we have created the 'Yokohama Port CNP Sustainable Finance Framework' and are working to make it easier for companies to access green loans and other financing."

Hitoshi Nakamura,
Director for Carbon Neutral Port Promotion, Port and Harbor Bureau, City of Yokohama, Japan

"There are small incentives happening, things like recognition for green performance, green awards, or reduced port fees. Not everyone is doing it, but it is a start in the right direction."

Eswynn de Souza,
Head of Fleet, Pacific International Lines (Pte) Ltd, Singapore

"Unlocking finance in an industry like ours is not the most straightforward. There's no certainty on the offtake agreements; there's no certainty on the time periods. The trade is itself dynamic. There is no 100% assurance on a return on any of it... It's not a very easy decision for a financier to take a hedge or a bet on something into the future without any collateral or any certainty on the return on investment."

Niraj Nanda,
Chief Commercial Officer, Anglo-Eastern, Hong Kong

"You need some sort of incentives. To ask shipping companies to do this from their own will and wallet is a big ask. One way or another, it needs to come from regulation."

Johan Zander,
General Manager & Head of Singapore, Stena Bulk, Singapore

The absence of maritime carbon pricing and e-fuel demand incentives shows a region waiting for global regulation

Across Asia Pacific, the policy pattern is clear: the supply of carbon-neutral fuels is being enabled across all sectors, while maritime demand is not.

Governments have created a wide range of supply-side incentives that support renewable energy, green hydrogen and e-fuel production for power, industry, and chemicals.

Because these land-based sectors are regulated nationally, they also operate under national carbon pricing measures, which help convert supply-side support into early industrial demand.

For shipping the situation is entirely different.

Shipping is regulated globally, not nationally, and the region clearly reflects that by offering neither carbon pricing nor demand-side incentives that would create early maritime offtake for e-fuels.

National/regional carbon pricing and incentives relevant to e-fuels and green hydrogen

Country/region	Mechanisms	Targets, and Deadlines
IMO 2023 GHG Strategy and postponed Net Zero Framework (NZF)	• 2023 Strategy sets direction for global pricing and calls for a "basket of measures" including a market-based mechanism and revenue recycling. • Details remain under negotiation.	• Target: Reduce annual GHG emissions in global shipping by at least 20%, striving for 30% by 2030.[46] • Target: Zero or near-zero energy sources to reach at least 5%, striving for 10% of energy used by 2030. • NZF aims for global carbon pricing; several proposals reference approximately USD 100 per ton CO_2. • Prior to its postponement, the NZF was to be implemented around 2027–2028.[47]
European Union: EU ETS (maritime)	• Maritime emissions included from 2024 with gradually increasing coverage. • ETS revenue partially funds hydrogen and e-fuel projects through the Innovation Fund. • The EU ETS 62% emissions reduction target for maritime emissions by 2030 vs. 2005 is **more than double** the IMO's 2030 "striving for" target of a 30% reduction in global maritime GHG emissions vs. 2008.	• Coverage: 40% of 2024 emissions in 2025; 70% in 2026; 100% from 2027 onward. • Scope: 100% of emissions on intra-EU voyages; 50% of emissions on EU–non-EU voyages.[48] • ETS allowances must be surrendered annually by 30 September.[49] • ETS cap aligned with 62% ETS-specific sectors (power, heat, heavy industry, aviation, and now maritime) reduction by 2030 vs 2005.[50]
European Union: FuelEU Maritime	• Requires progressive reduction of well-to-wake GHG intensity in fuel used in ships; penalties apply for non-compliance. • Supports uptake of RFNBOs (e-methanol, e-ammonia).	• Applies from 2025 with a 2% reduction in GHG intensity vs. 2020, tightening in subsequent years, with stronger requirements in 2030 and 2040.[51] • From 1 January 2030, container and passenger ships over 5,000 GT must use on-shore power supply or a zero-emission alternative in TEN-T ports; extends to all relevant EU ports from 2035.[52]

The absence of maritime carbon pricing and e-fuel demand incentives shows a region waiting for global regulation continued

National/regional carbon pricing and incentives relevant to e-fuels and green hydrogen continued

Country/region	Mechanisms	Targets, and Deadlines
China	• No national maritime carbon price yet. • "30–60" climate targets drive industrial scaling of low-carbon fuels and renewable power. • Incentives through national and provincial strategy/policy. • Provinces and municipalities finance tax, land, and infrastructure subsidies for hydrogen, ammonia and methanol industrial clusters, and port-clusters. • These clusters could supply shipping fuels.	• National target: Peak emissions by 2030 and carbon neutrality by 2060.[53] • China's national ETS currently covers the power sector, with expansion to cement, steel and aluminum announced. • Shipping is not included.[54]
Japan	• Introducing mandatory carbon pricing under Green Transformation Emissions Trading System (GX-ETS). • Strong policy focus on hydrogen and ammonia supply chains. • GX-ETS focuses on domestic emissions in covered sectors. • International shipping and aviation bunkers are not currently included; aviation coverage is limited to domestic flights.	• Mandatory GX-ETS begins April 2026 for several hundred large emitters (typically >100,000 tons CO_2).[55] • Carbon tax on fossil importers planned from FY 2028.[56] • National target: 46% reduction in GHG emissions by 2030 vs 2013; net-zero by 2050.[57]
South Korea	• Operates an economy-wide ETS. • Clean hydrogen certification and power-sector procurement obligations indirectly lower costs of carbon-neutral fuels for shipping. • Shipping not yet covered, but K-ETS raises cost of electricity and key materials needed to make carbon-neutral fuels, which increases the price of those fuels for shipping.	• Hydrogen certification threshold: ≤4 kg CO_2e per kg hydrogen.[58] • Clean Hydrogen Power Generation obligations planned through auctions and long-term contracts.[59] • National ETS covers major industrial emitter. • Shipping has been studied and proposed, but is not yet covered.
Singapore	• Applies national carbon tax plus targeted maritime incentives (port-dues reductions clean-engine incentives for ships). • Hydrogen and ammonia strategies under Maritime and Port Authority of Singapore (MPA). • National Hydrogen Strategy frames Singapore as a future ammonia import and bunkering hub.	• Carbon tax: SGD 25 per ton CO_2e in 2024; rises to SGD 45 in 2026 and SGD 50–80 by 2030.[60] • Incentives for vessels using low- and zero-carbon fuels expanded for 2025–2027 under MPA's programs.[61]

Singapore is the only economy with a carbon-pricing mechanism that directly affects shipping and a single demand-side incentive through port-fee reductions for low- and zero-carbon vessels. Its motivation is clear: to convene early e-fuel users at its port and define its leadership as a net-zero bunkering hub, protecting its status as the world's largest refueling center.

Every other major economy in the region offers zero demand-side incentives for maritime e-fuel use and zero direct carbon-pricing signals for international shipping. This sends a unified message to shipowners, ports, e-fuel producers, and financial institutions: Asia Pacific is waiting for global regulation to do the other half of the job.

In the absence of both global and regional demand-side support or elevated maritime carbon pricing, early movers must absorb higher fuel costs that they cannot pass on, and stakeholders note that early adoption entails financial loss for an undefined period, with no clear advantage.

The region is therefore advancing the enabling conditions for supply, while intentionally deferring the enabling conditions for demand. The expectation is that global rules, not regional policy, will ultimately drive maritime demand, anchor offtake, and unlock investment at scale.

Deadlock 4:

High regulatory ambition, but weak carbon pricing and absent demand-side incentives prevent maritime e-fuel demand from forming

Across Asia Pacific, regulatory ambition for hydrogen and e-fuels is high.

National strategies in China, Japan, Korea, Singapore, and Australia position green hydrogen and its derivatives as essential for both decarbonization and long-term energy security.

Both policy documents and interviews describe hydrogen-based e-fuels as the only realistic path to net zero for shipping, and as an eventual inevitability rather than a speculative option.

Despite this, the two conditions that stakeholders identify as most important for maritime e-fuel demand are largely missing in the region.

> "There are already a lot of frameworks in place. EU ETS and FuelEU work regionally, but we need something global and even. The rules are not perfect, but they need to be set so everyone has a level playing field and we refine from there."
>
> **Tan Kian Chai,**
> Global Head, Technical Fleet Management, Eastaway Ship Management, Singapore

First, robust carbon pricing for international shipping is absent. Outside the European Union's Emissions Trading System and FuelEU Maritime regulation, which apply only on EU-related routes, there is no strong, predictable carbon price on international bunker fuel.

In Asia Pacific, some national systems, such as Korea's Emissions Trading System and Japan's emerging GX-ETS, price emissions in land-based sectors and parts of domestic transport, but they do not yet create a clear, sector-wide carbon price signal for international shipping.

Singapore is the only economy in the region that applies an economy-wide carbon tax together with port and registry incentives for cleaner ships, and even these measures are modest compared with the cost of e-fuels. Interviews consistently describe the lack of a meaningful global or regional carbon price for shipping as the single biggest barrier to e-fuel uptake.

Second, dedicated demand-side incentives for maritime e-fuels are effectively absent. No major Asia Pacific economy offers broad e-fuel demand subsidies or mechanisms to reward ships for actually burning e-methanol or e-ammonia. Singapore's port dues reductions and registry concessions for low- and zero-carbon vessels are the only notable regional example, and stakeholders emphasize that these incentives are far too small to close the cost gap. As a result, shipping companies that invest in e-fuels now do so at a loss, hoping that future regulation will eventually reward their position, while most operators wait on the sidelines.

Interviews make clear that multiple fuel pathways in the region do not reflect a belief that all candidates can scale to net zero. Instead, they reflect a landscape where e-fuels are recognized as the endgame, but where weak carbon pricing and absent demand-side incentives prevent that endgame from becoming commercially rational today. High ambition at the policy level has therefore not yet translated into the implementation conditions needed to create predictable maritime e-fuel demand.

> "If the IMO finally approves its Net Zero Framework, the market will be there and demand will rise. The problem is not on the production side. If there is a policy, there will be demand. The production problem can be solved immediately. As long as there's margin and profit, people will invest... As long as the IMO can approve a zero or near-zero emission incentive, it will be very good for the shipping lines."
>
> **Frank Yu,**
> Senior Vice President, Envision Energy, China

> "Had the framework been passed as envisaged, there was a clearer pathway towards fuels becoming available, which is now quite uncertain. A lot of the plants that were looking to make alternative fuel in China may start to backpedal. What could unlock the investment is just the regulation."
>
> **William Fairclough,**
> Managing Director, Wah Kwong, Hong Kong

> "COSCO has actively responded to the implementation requirements of the IMO net-zero framework. Although it has already planned methanol and ammonia dual-fuel ships in advance, the uncertainty of the incentive indeed has a significant impact on the company's subsequent investment decisions. After all, new energy ships are expensive to build, and the prices of new energy fuels are also high."
>
> **Chen Xinchuan,**
> Managing Director, COSCO Bulk China, China

Deadlock 4 continued

E-fuels are recognized as the endgame for shipping

- National strategies in China, Japan, Korea, Singapore, and Australia highlight hydrogen and e-fuels for net zero and energy security.
- Interviews and earlier analysis identify e-ammonia and e-methanol as the only scalable net-zero fuels for deep sea.
- Stakeholders understand that transitional fuels cannot deliver net zero alone.

No meaningful demand-side incentives for maritime e-fuels

- No major Asia Pacific economy offers broad demand-side support for ships actually using e-fuels.
- Singapore is the only economy with direct financial incentives for low- and zero-carbon ships through port dues and registry concessions, and stakeholders view these as too small to offset the fuel premium.
- Early movers in e-fuels expect losses without shared cost-sharing mechanisms.

Carbon pricing for international shipping is weak or absent in Asia Pacific

- EU ETS and FuelEU Maritime create a strong demand signal only on EU-linked routes.
- In Asia Pacific, national ETS systems such as K-ETS and Japan's GX-ETS focus on domestic emitters and only partially touch transport; they do not create a clear, region-wide carbon price for international shipping.
- Interviewees repeatedly describe global carbon pricing under the IMO as the single biggest enabler of maritime e-fuel demand.

Result: regulatory ambition does not translate into maritime demand

- E-fuels are seen as inevitable, but not yet commercially rational for most owners.
- Owners hedge across several fuels, while producers and ports do not see the predictable maritime offtake needed to justify dedicated e-fuel supply chains.
- High-level ambition and strategy do not yet produce the regulatory conditions required for e-fuel scaling in shipping.

"EU regulations exist now, and we still hear about other regional schemes. You could have the world divided into different areas. In practice, people will spend more time optimizing exposure toward the EU because that is the market in front of us. Whether that is big enough to unlock balance sheets remains to be seen."

William Fairclough,
Managing Director,
Wah Kwong, Hong Kong

"All the IMO had to do was put the one hundred dollar per ton CO_2 fine on every bunker transaction. When the cost of fuels goes up enough, switching to green fuels becomes a no-brainer."

Khalid M. Hashim,
Managing Director,
Precious Shipping, Thailand

"Where is the incentive? If we could be given an incentive for being the first to move, it would help. Lower fees from ports, flags or class for early adopters would send a clear signal to those sitting on the fence."

Eswynn de Souza,
Head of Fleet, Pacific International Lines (Pte) Ltd, Singapore

"An international framework is essential for the global shipping industry. The IMO Net Zero Framework was a very good concept because it was limited to the shipping sector and designed to collect contributions from shipping companies and reinvest them in decarbonization. Such an industry-specific system would send a strong signal to the market and our customers. International regulation is therefore extremely important."

Spokesperson,
Japanese shipping line

"The industry can't progress in isolation; even the best solutions must be discussed, agreed, and shaped with regulators. If these governance forums can merge industry and administration perspectives, they could become positive accelerators for net zero."

Luis Benito,
Group Business Development and Marketing Director,
Wallem Group, Hong Kong

Deadlock 5:

Asia Pacific's uneven e-fuel port readiness and limited maritime demand keep early bunkering capability confined to a few major ports

Many large Asia Pacific ports are actively trying to prepare for carbon-neutral fuels. Major bunkering ports along the region's busiest trade routes, particularly the iron corridor from Australia to Singapore and China, recognize that e-ammonia and e-methanol are inevitable. These ports have begun early pilots, safety assessments, and operational reviews for ammonia and methanol handling.

However, these efforts highlight a structural deadlock. Only a small number of major bunkering ports can move early because maritime demand for e-fuels has not yet emerged and regional e-fuel volumes remain extremely small. Without predictable fuel offtake, most ports cannot recover the cost of early e-fuel infrastructure. For ports operating on tight budgets or handling mixed traffic profiles, early investment is financially impractical.

At the same time, the wider regional network is still developing the basic prerequisites for handling new fuels.

Many smaller and developing ports are stabilizing electricity systems, upgrading digital infrastructure, or initiating zoning and permitting specifically for ammonia or methanol storage, transfer, and bunkering. They do not yet have the inter-agency coordination, trained personnel, standardized procedures, or ammonia and methanol capable bunker vessels required for safe operations.

Operational capability, rather than land or tank space, is cited as the central bottleneck. Stakeholders emphasize that handling readiness, including safety frameworks, green hydrogen and e-fuel certification, and specialized bunker vessels, remains concentrated only in a few major bunkering ports.

The result is a clear structural deadlock. Early preparedness is confined to a few major bunkering ports while most ports across the region lack both the operational capability and the economic case to advance. For shipping segments that depend on a wide range of ports, especially bulk and tramp operators, practical access to carbon-neutral fuels remains extremely limited regardless of vessel readiness or upstream production.

"I think there will be a few ports in the world that will have everything; vessels that go to those ports know they will have it available. Singapore is really keen and investing money to remain in the position they have right now, bunkering the fleet of the world."

Susana Germino,
Chief Sustainability & Energy Transition Officer, Swire Shipping and Swire Bulk, Singapore

"My concern is that you've got the Singapores and the Rotterdams on one hand… but the gap is just too wide {for many smaller ports}. It's not realistic… we love engaging with the largest ports as best practice, but I try not to advise anyone to copy them because it's not realistic…"

Liliane Rose Flour,
United Nations Conference on Trade and Development (UNCTAD), Switzerland

"What the industry is probably not touching on enough is the people, the acceptance in the society, and the safety and skills training. This is a core element of success for all these new fuels to be adopted on a wide scale."

Niraj Nanda,
Chief Commercial Officer, Anglo-Eastern, Hong Kong

"In most countries, the installation costs are multiple times higher than the same cost scope in China. The permit and licensing process in other countries is very long, difficult and costly, and the time to build the plant in most countries is also much longer than it is in China. All of these non-technical factors are killing the projects."

Frank Yu,
Senior Vice President, Envision Energy, China

Deadlock 5 continued

"I think the governments have to step up and invest in port infrastructure and bunkering facilities for alternate fuels. They have to invest in green energy – an abundance of green energy – to produce these alternate fuels because you cannot take away from the grid... we are talking about four to five times the energy supply in each place where they will produce these fuels."

Surajit Chanda,
Vice President - Technical,
Hafnia, Singapore

"Asia itself is China, Japan, Korea, India, Australia. I believe all these countries actually have their own strengths. For example, China has scale, which leads to cost leadership. Japan and Korea bring technology and innovation. India has solar potential for low-cost green hydrogen, and Australia is strong in ammonia. If these countries combine their capabilities, the impact could be transformative."

Tan Kian Chai,
Global Head, Technical Fleet Management,
Eastaway Ship Management, Singapore

"The Hong Kong government is already designating an area in the current port to create fuel storage. They're opening this to the market and will begin selecting operators next year. The government is also offering green incentives for those involved in green bunkering. Everything is moving fast... Given the geopolitical backdrop, it's likely this will scale up rapidly. It's written into government plans, and when Hong Kong writes plans down, they act on them."

Luis Benito,
Group Business Development and
Marketing Director, Wallem Group,
Hong Kong

"In Asia-Pacific, everybody wants to be the green port hub for bunkering and the fuel trading, but in terms of the production location of greener fuels, they need to use renewable power, which is either solar or wind, so usually the production site is located in quite remote inland places."

Yuan Yuan,
Regional Strategy Director,
Bureau Veritas Marine & Offshore,
Singapore

Deadlock 5 continued

A few major bunkering ports advance early

- Singapore, Shanghai, Busan, and Yokohama conduct early ammonia and methanol bunkering pilots.
- These hubs are directly linked to national hydrogen and e-fuel strategies that prioritize early ammonia and methanol handling.
- Experience handling complex fuels, as well as established safety and regulatory systems, allows them to pilot ammonia and methanol earlier than other ports.
- To move forward, some hubs lean on national hydrogen strategies connecting e-fuel needs to land-based industrial demand, especially power-sector ammonia use (e.g., Japan, Singapore).

Most ports cannot progress beyond basic readiness for e-fuels

- Smaller and developing ports are still working to provide onshore power and digital systems, before addressing e-fuel needs.
- Many ports are at the very beginning of zoning and permitting for ammonia and methanol storage, transfer, and bunkering, which require complex safety reviews.
- Smaller ports lack the inter-agency coordination needed for e-fuel approvals across maritime authorities, energy ministries, and local regulators.
- Many small ports have no linkage to broader hydrogen or e-fuel strategies, leaving them isolated from cross-sector development priorities.

Key operational enablers are not yet in place for many ports

- Bunker vessels capable of ammonia or methanol transfer are scarce across the region, limiting any port's ability to serve ships.
- Standardized safety procedures and trained personnel for handling ammonia and methanol are concentrated in a few large hubs.
- Most ports do not yet have the emergency response systems required for ammonia or methanol incidents, which limits their ability to support safe bunkering even at small scales.
- Without alignment between port operations and broader energy-system plans, readiness advances slowly and remains fragmented.

Result: many ports cannot justify early e-fuel infrastructure investment

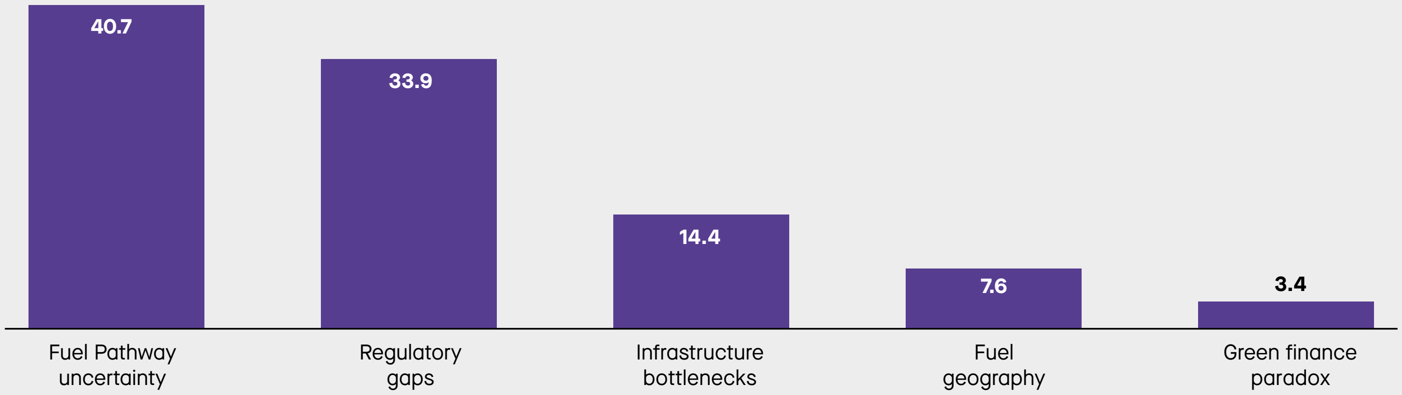
- With e-fuel volumes extremely limited and maritime demand undeveloped, most ports cannot recover infrastructure costs.
- Ports dependent on tight budgets, or with limited land and throughput, cannot justify early investment without firm fuel demand.
- Bulk and tramp operators, who rely on many smaller ports, face no practical e-fuel access and remain locked into conventional fuels.
- Early progress stays confined to a handful of hubs until cross-sector demand and national strategies begin driving shared infrastructure.

Survey confirms cost and uncertainty are the biggest perceived barriers to shipping's energy transition

To complement the interviews and qualitative analysis in this report, we conducted a short survey of 120 senior stakeholders from the maritime, energy, finance, industrial, and port sectors. How do decision-makers view the core barriers behind shipping's energy transition? The responses highlights three consistent themes: 1) uncertainty about future fuels, 2) cost and policy pressures around hydrogen and electricity, and 3) the need for clearer regulation.

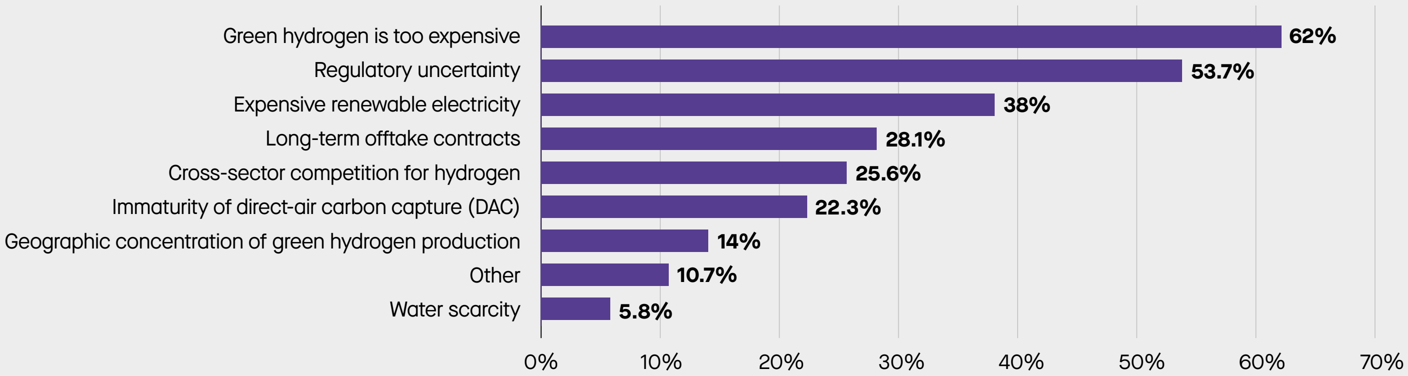
Respondents support a green surcharge, see value in the IMO Net Zero Framework, and recognize the potential of cross-sector demand aggregation. While confidence varies, there is meaningful alignment on the actions needed to accelerate the transition.

Uncertainty about which future fuels will scale is perceived as the biggest barrier to the maritime energy transition



Hydrogen cost, regulatory uncertainty, and renewable electricity pricing seen as the top barriers to scale-up of e-fuels

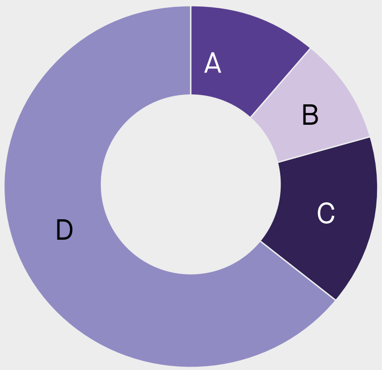
Percentage of respondents



Survey confirms cost and uncertainty are the biggest perceived barriers to shipping's energy transition continued

Most respondents support a net zero fuel surcharge/green premium

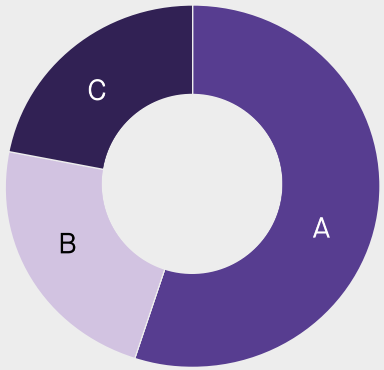
Costs cannot be carried by shipowners alone, so broader willingness to pay remains essential to scaling.



A	No, bulk and commodity markets cannot absorb additional costs under current structures	**11.32%**
B	Partially, only containerized high-value goods where cost impact is minimal	**9.43%**
C	Unsure	**15.09%**
D	Yes, cargo owners should share the cost of the energy transition through a green premium, that can be passed on to customers and dispersed across many transactions, making the impact negligible	**64.15%**

Interest in cross-sector demand aggregation is high, but confidence is not yet firm

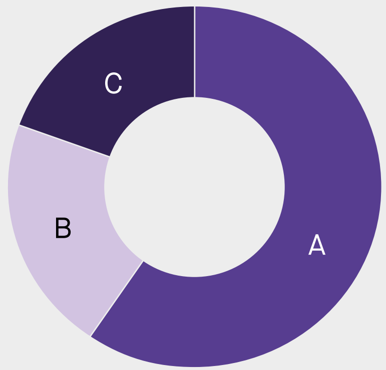
Would your organization join a port-led, cross-sector offtake model?



A	Unsure	**55%**
B	No	**23.3%**
C	Yes	**21.7%**

The IMO net zero framework is recognized as vital for shipping's energy transition, with caveats

Most respondents described the IMO Net Zero Framework as essential. Many noted that value depends on how national authorities translate it into operational rules.



A	Unsure	**66.7%**
B	No	**18.2%**
C	Yes	**15.2%**

Asia Pacific's cross-sector hydrogen and e-fuel development offers practical pathways to address the region's maritime fuel deadlocks

Asia Pacific is emerging as a proving ground for coordinated green hydrogen and e-fuel system development. Although maritime e-fuel demand remains weak, the region is building the energy, industrial, and port foundations that future maritime uptake will require.

Cross-sector coordination does not remove the deadlocks facing shipping today, but it enables progress where alignment already exists and creates structured early steps that would not occur in a siloed approach.

The following sections describe how Asia Pacific's energy, industry, and port systems are working together to address the constraints identified across the five deadlocks.

Asia Pacific's cross-sector hydrogen and e-fuel development offers practical pathways to address the region's maritime fuel deadlocks continued

Resolving Deadlock 1: Cross-sector energy and industrial strategies help consolidate early hydrogen and e-fuel pathways

Governments across the region have introduced integrated strategies for green hydrogen and e-fuels, including Japan's Basic Hydrogen Strategy, Korea's Hydrogen Act and hydrogen procurement rules, Singapore's National Hydrogen Strategy, and China's provincial programs for e-ammonia production. These strategies link renewable power development to industrial decarbonization, ammonia-for-power, and chemical feedstock demand.

This cross-sector alignment clarifies early expectations about which green hydrogen and e-fuel pathways will matter most for the region. It directs planning at major bunkering ports toward ammonia and methanol rather than a long list of alternatives. It also strengthens early demand in land-based sectors, which supports initial green hydrogen and e-fuel production capacity even though shipping is not yet part of that demand.

Cross-sector alignment narrows early fuel uncertainty and helps consolidate regional focus toward e-ammonia and e-methanol as long-term maritime fuels.

Resolving Deadlock 2: Cross-sector production models and emerging certificate systems prepare the ground for wider access

China's modular e-ammonia clusters show how green hydrogen and e-fuel production can scale in stages when linked to inland renewable resources and nearby industrial users. The Chifeng system integrates wind, solar, battery storage, electrolysis, and ammonia synthesis in a single off-grid platform that supplies industrial buyers in Japan, Korea, Singapore, and Europe. The same model is now being applied in Brazil.

Most of these clusters are not yet connected to coastal bunking for shipping, but they demonstrate how green hydrogen and e-fuel supply can advance through incremental, commercially realistic steps rather than relying solely on million-ton projects.

Parallel to this, Guarantee of Origin systems in Japan, Korea, Singapore, Australia, and the European Union are laying the foundation for credentialed attribute transfer. These systems support cross-sector use of green hydrogen and e-fuels by giving buyers confidence in carbon intensity data. They are not yet widely used for maritime applications, but they represent a future mechanism that can soften early geographic constraints.

Together, modular production and early certification and book-and-claim frameworks help establish the building blocks for regional e-fuel uptake.

Resolving Deadlock 3: Cross-sector offtake reduces producer risk even without maritime demand

Asia Pacific energy and industrial sectors receive strong national incentives for domestic green hydrogen and e-fuel use. These include Japan's ammonia-for-power procurement plans, Korea's hydrogen power auctions and industrial hydrogen clusters, and various Chinese provincial incentives for e-ammonia production. These incentives support early production capacity by guaranteeing offtake from power generators, chemical producers, and heavy industry.

Shipping is not part of this early offtake. However, cross-sector demand from land-based users reduces project risk for producers and keeps supply chains developing while maritime regulation remains uncertain. This allows early green hydrogen and e-fuel projects to progress at scales that match industrial demand, even though maritime demand remains absent due to weak carbon pricing and a lack of demand-side incentives.

Cross-sector offtake cannot substitute for maritime demand, but it keeps supply growing and maintains critical momentum.

> "The idea of different industries sharing a common clean-energy source at specific ports is very good. Each region has unique conditions that make certain renewable energies more viable, for example, solar power in some areas. If an area has a comparative advantage in a particular energy type, its industries could focus on using that energy collectively. Collaboration between sectors such as aviation, trucking, and shipping could therefore make sense, provided the initiative is coordinated regionally. However, each industry is also a competitor for limited energy resources, so it is difficult for companies to initiate such cooperation on their own… ports and regional governments can play a key role in sending these signals and facilitating collaboration across sectors."
>
> **Spokesperson,**
> Japanese shipping line

Asia Pacific's cross-sector hydrogen and e-fuel development offers practical pathways to address the region's maritime fuel deadlocks continued

Resolving Deadlock 4:
National hydrogen and e-fuel strategies align energy, industrial, and port systems for future maritime fuel use

Japan, Korea, Singapore, and China are building national hydrogen and e-fuel strategies that link renewable power development, green hydrogen production, industrial decarbonization, import infrastructure, and port operations. These strategies support domestic energy transitions and energy security, and they define the role of ports as import terminals and distribution points for green hydrogen and e-fuels.

This alignment gives major bunkering ports a clear direction for early preparation. Japan's ammonia-for-power program requires ports such as Yokohama to plan for ammonia import and storage. Korea's hydrogen industrial clusters guide port preparation in Ulsan and Busan. Singapore's National Hydrogen Strategy positions its port as a receiver and distributor of green hydrogen carriers. China's industrial decarbonization programs support inland e-ammonia production and encourage coastal ports to plan for bunkering.

Resolving Deadlock 5:
Cross-sector planning supports early readiness at major bunkering ports

Progress at ports such as Singapore, Shanghai, Busan, and Yokohama is closely tied to national hydrogen and e-fuel strategies. Power-sector ammonia demand, industrial hydrogen use, and national import plans require these ports to plan for future ammonia and methanol handling. Singapore and Shanghai have taken early steps on methanol through live bunkering pilots, while Busan and Yokohama are preparing for ammonia based on national energy priorities.

This cross-sector alignment allows major bunkering ports to develop operational experience through controlled pilots and early procedural work.

Asia Pacific's cross-sector model creates meaningful progress even as maritime deadlocks persist

Asia Pacific has not resolved the deadlocks that limit maritime e-fuel uptake. Maritime demand remains absent. Carbon pricing and demand-side incentives are still limited. Green hydrogen and e-fuel volumes are small. Most ports cannot justify early infrastructure. These deadlocks persist.

At the same time, the region has made substantial progress in developing the energy, industrial, and port foundations that future maritime e-fuel use will depend on. Crucially, this progress does not rely on global maritime regulation. It reflects regional capability, national energy-security priorities, and coordinated cross-sector planning.

This raises a strategic question. If global maritime regulation remains delayed, should regions wait or continue building the green hydrogen and e-fuel systems that domestic and industrial transitions already require?

Asia Pacific's experience shows that coordinated regional action can advance the energy transition even without perfect global coherence. The next step is ensuring that maritime demand can follow.

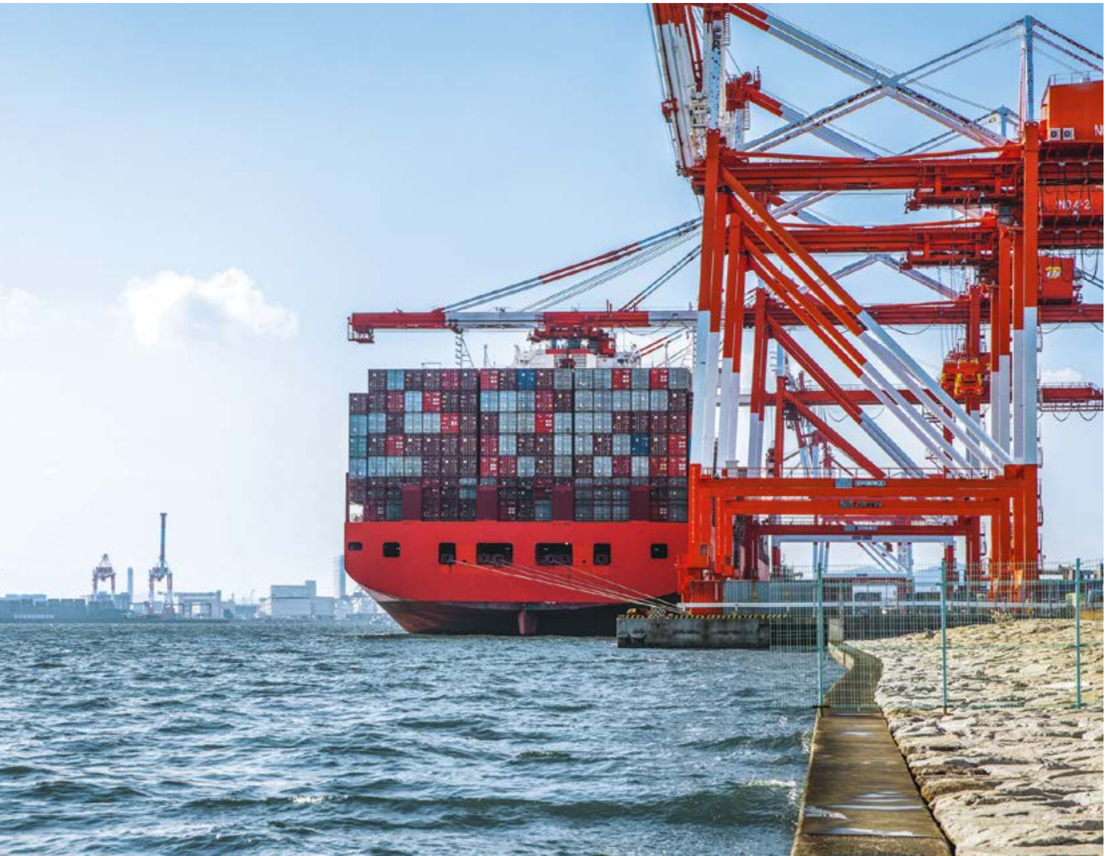
> "It will not be easy for companies to establish a carbon-neutral fuel network across different industries. Therefore, local government initiatives and central government support will be necessary to interconnect local industries and establish a carbon-neutral fuel network. Shared investment in producing eco-friendly fuels… would be a highly effective way to reduce GHG emissions."
>
> **Taek Kun Nam,**
> Chairman, Korean Society of Marine Engineering, South Korea

> "The anchor spot is the heavy industry location first where you will have multiple industries, in certain regions in Southeast Asia. That starts to allow you to look forward to saying we have a certain baseload of energy requirements, power generation requirements, and then link up with the ports and shipping from there."
>
> **Subajan Sivandran,**
> Director, Strategy, M&A and Sustainability, Bureau Veritas Marine & Offshore, Singapore

Asia Pacific's cross-sector hydrogen and e-fuel development offers practical pathways to address the region's maritime fuel deadlocks continued

Deadlock	Cross-Sector Pathway	What Asia Pacific Is Actually Doing	Why It Matters for Future Maritime E-Fuel Use
Deadlock 1: Fragmented demand and unclear fuel pathways	Align energy, industry, and port strategies around green hydrogen and e-fuels.	National hydrogen and e-fuel strategies in Japan, Korea, Singapore, China, and Australia link renewable power, industrial demand, and import planning.	Creates clearer early expectations that e-ammonia and e-methanol are the long-term fuels and narrows uncertainty for shipping, even before maritime demand forms.
Deadlock 2: Concentrated production limits early port access	Advance modular production and certificate systems for green hydrogen and e-fuels.	China's modular e-ammonia clusters supply industrial customers and show scalable early production. Japan, Korea, Singapore, Australia, and the EU build GO systems for future attribute transfer.	Builds supply foundations and future flexibility for distributing green hydrogen and e-fuels once maritime demand increases.
Deadlock 3: Financing bypasses maritime demand	Cross-sector offtake reduces risk for early green hydrogen and e-fuel production.	Power generation, chemicals, and heavy industry create early offtake through national procurement and industrial decarbonization programs.	Keeps green hydrogen and e-fuel projects moving forward so shipping is not starting from zero when demand-side incentives arrive.
Deadlock 4: Weak maritime regulation and absent demand signals	Use national hydrogen and e-fuel strategies to align energy, industrial, and port planning.	Japan links ammonia import planning to power. Korea aligns hydrogen clusters to port development. Singapore's National Hydrogen Strategy integrates port roles. China's industrial zones anchor early e-ammonia supply.	Ensures ports and energy systems build early green hydrogen and e-fuel readiness even without maritime regulation or carbon pricing.
Deadlock 5: Uneven port readiness and economic barriers to early infrastructure	Cross-sector energy and industrial priorities drive early ammonia and methanol capability at major bunkering ports.	Singapore and Shanghai conduct methanol bunkering pilots. Busan and Yokohama prepare primarily for ammonia based on national energy strategies.	Provides early operational experience, safety learning, and procedural clarity that smaller ports can adopt once maritime demand grows.

How Asia Pacific ports are driving the cross-sector energy transition



Port of Yokohama: advancing Japan's Carbon Neutral Port (CNP) initiative

The Port of Yokohama is one of Japan's designated Carbon Neutral Ports under the national program led by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The initiative aims for **net zero emissions by 2050** and focuses on **decarbonizing port areas** through **lower-emission terminal operations**, expanded shore power, electrified equipment, and **infrastructure readiness for future fuels**. Yokohama aligns with this scope by **linking port operations with nearby industrial users and emerging hydrogen and e-fuel demand**.

Its structured roadmap identifies **121 public–private partnership projects** that advance this transition, including **digitalized fuel-handling systems** and **coordinated development of hydrogen, ammonia, and methanol supply chains**.

The port is also pursuing blue-carbon initiatives, underwater carbon capture targeting 250 tons of CO_2 per year by 2050.

In addition, Yokohama is working to improve early-stage financing conditions.

> "To avoid relying solely on subsidies, we have created the 'Yokohama Port CNP Sustainable Finance Framework' and are working to make it easier for companies to access green loans and other financing."
>
> **Hitoshi Nakamura,**
> Director for Carbon Neutral Port Promotion, Port and Harbor Bureau, City of Yokohama, Japan

Cross-municipal cooperation is another core element of Yokohama's approach. The port is coordinating closely with neighboring Kawasaki City to better align fuel-supply planning, industrial energy needs, and regional decarbonization efforts. As Nakamura notes,

"The City of Yokohama has been working to promote a broader energy transition by deepening cooperation with neighboring Kawasaki City in pursuit of the Carbon Neutral Port initiative."

This program shows how local governments can prepare port infrastructure for hydrogen and e-fuels while supporting the long-term transition of shipping, logistics, and the surrounding industrial zone.

Official site: Carbon-Neutral Port Initiatives 横浜市 [62, 63]

How Asia Pacific ports are driving the cross-sector energy transition continued

Singapore: testing the viability of ammonia for power and bunkering

Singapore is assessing whether **ammonia can serve dual roles as both a low-carbon power-generation fuel and a bunkering fuel**. Under Singapore's **National Hydrogen Strategy, hydrogen and hydrogen-carrier fuels** are positioned as **essential to "accelerating the transition to net zero emissions by 2050 and strengthening energy security**."[64]

As part of this strategy, the Energy Market Authority (EMA) and the Maritime and Port Authority of Singapore (MPA) launched an Expression of Interest to evaluate an **end-to-end ammonia value chain covering import, storage, power generation, and ship-to-ship bunkering**.

The project will assess the feasibility of using **green ammonia to generate 55–65 MW of electricity** and **at least 100,000 tons per year of ammonia bunkering**.

> "The aggregation part applies more to shipping in a way than it does to other industries because our demand is so fragmented."
>
> **William Fairclough,**
> Managing Director, Wah Kwong, Hong Kong

Located on **Jurong Island, Singapore's largest industrial energy hub**, the study also **evaluates how ammonia can support industrial power and heat demand across petrochemicals, refining, and heavy manufacturing**. This **cross-sector integration is a core feature of the program: industrial demand provides long-term offtake stability**, while **power generation and bunkering together create a shared pathway for scaling new fuel infrastructure**.

The most recent step in the project has been the appointment of a consortium to conduct Front-End Engineering Design (FEED) studies on the power generation proposal and the bunkering proposal. Findings are expected to guide future policy, infrastructure sequencing, and pilot demonstrations, as the project moves towards Final Investment Decision to formally proceed.[65, 66]

> "If implemented, this would be among the world's first direct-ammonia combustion power plants - and Singapore's first - setting a new benchmark for clean fuel solutions and global decarbonization."[67]
>
> **Cindy Lim,**
> CEO, Infrastructure Division, Keppel Ltd (lead consortium partner)

> "Across Asia, Japan and China are creating major momentum, and Singapore always adapts quickly to complete the trade lane. Singapore is a nation that adapts to the market; its flexibility allows it to connect these new green-fuel trades with Europe and ports like Rotterdam. This ability to adapt and close the trade loop could expand these regional initiatives into a more international model."
>
> **Luis Benito,**
> Group Business Development and Marketing Director, Wallem Group, Hong Kong

> "The concept of cross-sectoral aggregation is eminently sensible in theory. The practicality is, okay, how do I buy? How much volume do I need? With what timeline do I want to procure? How do I manage the logistics where I need it, in what priority, how do I resolve conflicts between the aggregated buyers in the pool. So how do we make the theory real?"
>
> **James Forsdyke,**
> Managing Director, Lloyd's Register Maritime Decarbonization Hub, Singapore

How Asia Pacific ports position themselves in an emerging e-fuel economy

Ports across Asia-Pacific are preparing for hydrogen, ammonia, and methanol in ways that reflect each country's resources, industry base, and national energy strategy. The region follows a clear pattern.

Australia and selected Chinese ports are moving toward producer and export-source roles because they have strong renewable resources and large industrial systems. Japan, Korea, and Singapore are developing receiver and connector roles due to concentrated industrial demand, limited domestic resources, or strategic positions in global trade.

These roles mirror the four functions outlined in our global report: **producers** that generate hydrogen-based fuels, **connectors** that move them between clusters, **receivers** that import them for domestic use, and **export-source** ports that supply global markets.

Front-runner ports are testing bunkering, digital systems, and safety frameworks, while production-linked ports are developing export pathways. Import-oriented hubs are strengthening standards, terminal readiness, and links to local industries.

Together, these approaches show how coordinated action between ports, regulators, and industries can support early adoption and shape the first regional hydrogen and e-fuel corridors.

How Asia Pacific ports position themselves in an emerging e-fuel economy continued

"Specialized vessels for ammonia are critical. We have seen investments from Singapore involving the Japanese in tenders for building ammonia bunkering vessels. If that supply side picks up, there are not enough transfer vessels now. This is still at pilot stage and will remain so for several years, but you cannot build a production plant and not have transfer vessels. That is not going to work."

Niraj Nanda,
Chief Commercial Officer,
Anglo-Eastern, Hong Kong

"If you compare us with the big liner companies or the big car carriers, they know that once every loop they will call at Singapore and Rotterdam, so they are fine. Whatever fuel they choose – methanol, LNG, ammonia – they know they will have access in those major ports. There are only a handful of such ports globally with steady supply of different bunkers."

Johan Zander,
General Manager and Head of Singapore,
Stena Bulk, Singapore

"If we pivot to a more collaborative approach, and use the energy transition as the vehicle, it could help the region and the shipping companies at the same time. For small islands, if the port transitions properly, you could almost transition the whole country because ports consume so much energy and communities are built around them."

Liliane Rose Flour,
Port Management Programme Manager,
UN Trade and Development (UNCTAD),
Switzerland

"Different fuels require different storage methods. Ammonia and LNG are in gas form and need to be cooled. Storage facilities are already there, because they are part of the cargo, so boosting bunker supply is not difficult. What is more critical is the transfer mechanism. When demand is unstable, the cost to build and operate bunker barges is high, and takes years before projects take off."

Tan Kian Chai,
Global Head, Technical Fleet Management,
Eastaway Ship Management, Singapore

"The ports in China are some of the most advanced in decarbonization, and the highest ratio of onshore power supply installation is in China. I think China has over 90 ports with OPS. And in terms of greener fuel bunkering facilities and capabilities, China is also among the leading countries. Just this year alone there have been a few new trial bunkering activities. Unfortunately, it is mostly from trailer to ship because of the missing bunker vessels for green methanol and ammonia."

"The major factors determining bunkering activity are the bunker vessel and the availability of the fuel itself, because it is not difficult to build storage tanks. Shanghai is the first and so far the only port licensed for ship-to-ship green methanol bunkering. Shenzhen is also building capability; Hong Kong faces more constraints."

Yuan Yuan,
Regional Strategy Director,
Bureau Veritas Marine & Offshore, China

How Asia Pacific ports position themselves in an emerging e-fuel economy continued

China

Producer, connector, export source

China combines large coastal industrial clusters with inland renewable resources, high steel and chemical demand, and extensive manufacturing and shipbuilding capacity.

Its ports sit at the center of domestic supply chains and global trade routes, enabling production, distribution, and export.

Ports:

Qingdao, Dalian, Tianjin, Ningbo-Zhoushan, Shanghai, Guangzhou, Shenzhen

- **Producer:** coastal industrial hubs linked to nearby ammonia and methanol pilots.
- **Connector:** integration with inland renewable zones and cross-sector industrial belts.
- **Export source:** large-scale outward flows of fuels to Asia-Pacific and global markets.

Japan

Receiver with cross-sector industry co-location

Japan has limited land for large renewable deployment and relies heavily on imported energy.

Its heavy industries–steelmaking, power generation, chemicals–sit adjacent to major ports, making them natural fuel receivers rather than producers.

Carbon Neutral Port initiative further anchors this import orientation.

Ports:

Yokohama, Kawasaki, Kobe, Osaka, Nagoya

- **Receiver:** focused on ammonia, hydrogen, and methanol import readiness.
- **Industrial co-location:** strong alignment between ports and nearby industrial users.
- **Safety and standards:** structured regulatory approach to handling new fuels.

Korea

Receiver and regional connector

Korea's geography concentrates shipyards, steelmakers, and power plants along its coast, creating high domestic demand for imported fuels.

Korea has strong regulatory coordination and a national hydrogen strategy, making its ports natural connectors between import terminals and industrial users.

Ports:

Busan, Ulsan, Incheon, Gwangyang

- **Receiver:** preparing for multi-fuel capabilities for domestic industry.
- **Connector:** linking imported fuels to shipyards, refineries, and industrial clusters.
- **Safety-first approach:** strong emphasis on safe handling of hazardous fuels.

Singapore

Receiver and global connector

Singapore is the world's largest bunkering hub, located at the center of the Asia-Europe trade route.

With no domestic renewable resource, it depends on imports and focuses on distribution efficiency, digital systems, and commercial viability.

Its competitive position relies on being the first mover in fuel readiness.

Ports:

Singapore Port / Tuas Mega Port

- **Connector:** receives, blends, and distributes fuels across regional supply chains.
- **Receiver:** Import hub, no domestic production; relies on diversified global imports.
- **Commercial testing ground:** site of early ammonia and methanol bunkering pilots.

Australia

Producer and export source

Australia has abundant solar and wind resources, low population density, and strong project pipelines for hydrogen, ammonia, and methanol.

Its ports sit at the ends of large mineral and commodity trade routes and are already configured for bulk export, making them natural origins for green hydrogen-based fuels.

Ports:

Port Hedland, Dampier, Geraldton, Kwinana, Gladstone, Newcastle

- **Producer:** large-scale co-located renewable energy driving hydrogen and ammonia projects.
- **Export source:** established export infrastructure for bulk commodities.
- **Global source:** aligns with national strategies targeting fuel exports to Asia-Pacific markets.

Acknowledgements

The following individuals, representing shipping companies, ports, supply chain leaders, fuel producers, technology leaders, policymakers, classification societies, decarbonization think tanks, industry councils, and intergovernmental bodies, provided expertise and insights that informed the analysis and recommendations in this report.

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