The Aotearoa Circle

Mā te Kaitiakitanga ko te Tōnuitanga
Prosperity Through Guardianship

Future Fit Shipping

Decarbonising the Aotearoa New Zealand Maritime Industry

Vicki Watson | Chief Executive, The Aotearoa Circle

Foreword

The connection between land and sea has shaped Aotearoa New Zealand since the arrival of the first waka. Over generations, this relationship has deepened, linking our identity and economy, and the way we interact with the wider world.

Shipping remains the backbone of that connection.

Today, 99.7% of New Zealand's trade by volume and 81%[2] by value moves by sea. Our nearest trading partner – Australia – is more than 1,500 kilometres away, roughly a week's voyage by cargo ship.

The vast ocean highways across the Tasman and South Pacific carry a continuous flow of two-way trade. As of March 2025, our annual goods exports were valued at over $74 billion, with imports surpassing $80 billion[4].

Keeping these maritime channels open and resilient is critical for New Zealand's economic growth, as is reducing future costs. But increasingly, it's not just the goods we trade that are being scrutinised – how they are transported matters more than ever before.

Global markets, regulatory frameworks, and consumer expectations are all shifting toward low-emissions supply chains, as also incentivised by the incoming levy from the IMO. Retaining competitive access to export markets demands meaningful progress toward maritime decarbonisation and that work is needed now.

Vicki Watson | Chief Executive, The Aotearoa Circle

Foreword

The International Maritime Organization (IMO) has established a legally binding framework to cut greenhouse gas (GHG) emissions from global shipping, with a target of reaching net-zero emissions around 2050.

This Net-Zero Framework introduces mandatory emissions limits and a pricing mechanism for GHGs across the entire shipping sector. Key measures include a fuel standard for ships and a global carbon pricing system.

Set for formal adoption in October 2025 and implementation in 2027, the new rules will apply to large ocean-going vessels over 5,000 gross tonnage – responsible for about 85% of international shipping's CO_2 emissions.

The framework, which has multiple tiers and some complexity to navigate, would impose a carbon price of up to $380 USD per tonne of CO_2 equivalent on ships above 5,000 gross tonnes. For New Zealand, the risk exposure to this cost impost is very real.

The Future-Fit Shipping workstream, led by The Aotearoa Circle with secretariat support from Deloitte, is a response to this opportunity – it explores how New Zealand can decarbonise its maritime supply chains, maintain and strengthen access to global markets – and also models the risks of inaction.

By investing in green shipping, New Zealand can strengthen its international competitiveness, deepen partnerships across the Pacific, and build a resilient, future-ready maritime economy. Achieving this vision will require genuine collaboration, open dialogue, and a willingness to look beyond individual interests in pursuit of shared economic and environmental outcomes.

We extend our sincere thanks to Deloitte for delivering this important report, and to all those who generously contributed their time, expertise, and insight. Your collective effort has laid a vital foundation for New Zealand to chart a steady course toward meaningful action towards maritime sustainability and continued economic prosperity.

Vicki Watson
Chief Executive, The Aotearoa Circle

2 Why maritime matters to Aotearoa | New Zealand – Maritime NZ

4 Overseas merchandise trade: March 2025 | Stats NZ

"By investing in green shipping, New Zealand can strengthen its international competitiveness, deepen partnerships across the Pacific, and build a resilient, future-ready maritime economy."

Vicki Watson
Chief Executive
The Aotearoa Circle

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Executive Summary

ES | Overview

Change is on the horizon. Shipping lines are poised to lead a maritime decarbonisation transition. Aotearoa New Zealand and others will be technology takers, relying on international shipping to guide aspects such as future fuel mix, vessel configurations, and deployment.

However, New Zealand has the opportunity to play an active role in decarbonising its international maritime supply chain, potentially leading the way on key shipping routes. This leadership could bring significant commercial and reputational benefits, acting as a catalyst for wider domestic decarbonisation initiatives.

Decarbonising New Zealand's maritime supply chain is a complex challenge, further complicated by the global scale and interlinked nature of the shipping industry and New Zealand's geographic isolation. The international shipping industry, which serves as the backbone of international trade, is emissions intensive. If considered as a country, the international shipping industry would rank as the sixth largest emitter globally.[1] International shipping is recognised as a 'hard-to-abate' sector. A multifaceted international approach that enhances ship efficiency, optimises logistics, and replaces fossil fuels with lower-emission alternatives is essential.

Despite these complexities, the transition from fossil fuels in the maritime sector is achievable through targeted policymaking and coordinated action among key supply chain actors, noting that everything does not need to be solved immediately.

New Zealand, as a small open trading nation situated in the South Pacific at the end of long supply chains, relies heavily on shipping for trade, with 99.7% by volume and 81% by value transported by sea,[2] significantly more than the world average of around 80% by volume.[3]

With annual goods exports valued at just over $74b and imports over $80b for the year ended March 2025,[4] the urgency to decarbonise shipping is driven by both environmental commitments and the need to maintain competitive access to global markets. International regulations and heightened expectations from trading partners and customers necessitate swift action towards decarbonisation. The window of opportunity for achieving net-zero is closing fast, making it imperative for the maritime sector to play its part.[5]

ES | Purpose of this report

The Future Fit Shipping workstream, led by The Aotearoa Circle, aims to highlight the importance, associated challenges and potential opportunities of decarbonising New Zealand's maritime supply chains.

Specifically, this report identifies key considerations in establishing green shipping corridors (port-to-port trading routes that use zero-to-low emissions fuels) and outlines actionable recommendations that support the establishment of one or more corridors.

These recommendations draw upon:

- The economic opportunity and imperative to progress the decarbonisation of our key trade lanes.
- Four preliminary alternative fuel roadmaps (biofuels, methanol, ammonia, and liquified natural gas).
- Exploration of fuel production and commercial adoption considerations for international shipping.

To better understand the economic opportunities associated with transitioning New Zealand's shipping lanes, an economic impact assessment has been undertaken to illustrate the potential for avoided costs associated with successful action towards decarbonising shipping lanes.

Two scenarios have been modelled:

- An indicative IMO GHG levy scenario where New Zealand fails to decarbonise its shipping lanes at the same rate as competing trading nations.
- A 5–15% fall in New Zealand's goods exports by 2050. This scenario is intended to incorporate the IMO GHG levy scenario, and also capture incremental risks from an increased focus on Scope 3 emissions, a changing regulatory environment in key trading partner economies, shifting consumer preferences and a loss in reputation or trust in New Zealand's key export brands.

Insights have also been informed by extensive market engagement, with over 50 stakeholders interviewed, as well as desktop research.

The culmination of this work is this report which highlights prerequisites and potential for establishing green shipping corridors to support emissions reduction efforts. Ultimately, it serves as a call to action for stakeholders to actively participate in the establishment of these corridors, advancing New Zealand's maritime decarbonisation agenda, achieving competitive and resilient routes to international markets and facilitating a transition towards lower emission maritime practices.

ES | Key findings – Charting a lower emission course

The key findings highlight the complex challenge of decarbonising New Zealand's international shipping lanes, but also the significant economic, commercial, and reputational opportunity it represents, including how it can act as a catalyst for wider decarbonisation efforts.

1. **Economic impact modelling suggests that acting to decarbonise New Zealand's shipping lanes at the same rate as competing trading nations could result in avoiding losses in gross domestic product (GDP) of between $17.5 billion to $94.1 billion in NPV terms by 2050.** Decarbonising shipping routes also has the potential to maintain and add to New Zealand's market access, competitive positioning, brand reputation and create opportunities for alternative fuel production within New Zealand, enhancing energy security.
2. **Multiple fuel types will feature in vessels of the future, each currently at different maturity levels.** This projected multiple fuel future greatly increases the complexity of transitioning and timing to decarbonise the maritime industry, given interdependences between industry stakeholders, including ship owners and operators, ports, engine manufacturers, and fuel providers. Renewable fuels, in particular biofuels, are likely to be the earliest forms of fossil fuel displacement.
3. **Certain ports will need to expand port capacity. Larger container vessels are expected.** Most existing and on-order alternative fuel vessels are significantly larger than those currently regularly calling at New Zealand ports and exceed current port infrastructure capacity.
4. **Green corridors can be a catalyst for change.** Green corridors can provide scale and volume signals to essential actors needed to establish low-to-zero emissions shipping, including fuel producers, vessel operators, cargo owners, regulatory authorities and ports.
5. **Multiple enabling factors are needed for a green corridor.** These include access to low-to-zero emissions vessels, alternative fuel production, storage, and bunkering capability, a conducive regulatory ecosystem, fit-for-purpose port infrastructure and aggregation of sufficient volume and value of trade. However, not all of these enabling factors need to exist within New Zealand.

ES | Key findings – Charting a lower emission course

6. **Taking a staged approach.** Analysis and planning is required to proactively establish green shipping corridors. A recommended starting point is focusing on routes that provide the greatest scope for maritime emissions reductions. This is the most feasible from an implementation point of view and would require the least number of enabling factors within New Zealand to be established. Key factors required in New Zealand include aggregation of sufficient volume and value of cargo, access to alternative fuel powered vessels and fit for purpose port infrastructure.
7. **Future decarbonisation and domestic freight movements.** Decarbonisation of the maritime industry also presents opportunities for cargo aggregation around key hub ports, mode shift, and the future targeted decarbonisation of New Zealand's domestic freight network (both landside and coastal).
8. **Domestic use cases for low-to-zero emission fuels.** Changes in freight movements and modes, coupled with potential demand for alternative fuels from Australia and the South Pacific region, the aviation sector, and other potential use cases, can provide demand / off-take certainty to incentivise investment in domestic production and storage of targeted alternative fuels (such as biofuels), which may also spur supply side responses for renewable energy and biogenic carbon feedstock supply.
9. **Scalable alternative fuel production infrastructure challenges.** Alternative fuel production at scale, in a multiple fuel future, faces a range of challenges. The earliest forms of fossil fuel displacement are likely to be renewable fuels, for which New Zealand can be a local producer. Biofuels have the advantage of being a 'drop-in' fuel that is largely compatible with existing technology and require relatively little modification to existing infrastructure, supporting decarbonisation of the domestic freight system.
10. **A conducive regulatory system is needed to support alternative fuel production.** This includes a regulatory system that continues to drive New Zealand's energy system to a low carbon one, financial support and incentives to address barriers to alternative fuel production and scaling, and an enabling ecosystem that provides consistent and conducive rules for the safe handling of alternative fuels.
11. **Transition to alternative fuels will have cost implications.** Alternative fuels cost significantly more than traditional fossil-based shipping fuels. However, these impacts will vary, with the container segment reporting potential end consumer price impacts in the order of 1% – 4% of commodity value.

ES | What do we do about it?

The economic impact assessment undertaken for this workstream underscores the substantial avoided costs and benefits associated with decarbonising New Zealand's shipping lanes, creating an immediate imperative for action.

It is recommended that a considered approach to establishing green shipping corridors be taken, concentrating on routes that are most feasible from an implementation point of view and that require the least number of enabling factors within New Zealand. This strategy not only allows New Zealand to take a lead in decarbonising key shipping lanes but also brings economic benefits in a low-cost and low-risk manner. Importantly, proposed collaborative work on a trans-Tasman basis can be advanced concurrently in relation to alternative fuels and other feasible green corridors, such as dedicated trans-Tasman routes, ensuring that New Zealand remains proactive in its maritime decarbonisation agenda and Australia-New Zealand 2+2 Climate and Finance Dialogue Joint Statement commitments.

Our recommendations have been grouped and include establishment of an initial green shipping corridor, leveraging trans-Tasman collaboration and broader actions.

WHAT DO WE DO ABOUT IT?

Establishment of an initial green shipping corridor (1/2)

The following recommendations focus on establishing an initial green shipping corridor, given their potential to accelerate progress in tackling the challenges of decarbonising shipping. By focusing on routes that provide the greatest scope for maritime emissions reductions while balancing feasibility and speed, New Zealand can maximise its decarbonisation efforts.

An overview of the recommendations is presented on the right, with further detail in section 7. A **proposed lead** for each action is identified with a focus on government organisations as enablers and facilitators, reflecting operational mandates and an ability to bring together private and public sector organisations necessary to action the proposed recommendations outlined.

RECOMMENDATIONS	POTENTIAL LEADERS
• **Establish a collaborative working group including public and private organisations to focus on establishing an initial green corridor**. Government should take a lead role in convening and establishing the working group, given its commitment to facilitate industry discussion as part of aviation and shipping decarbonisation and its commitment to convening roundtables with the maritime sector in its second emissions reduction plan.	Facilitated by Ministry of Business, Innovation and Employment (MBIE) and Ministry of Transport (MoT)
• **Evaluate the potential to use book and claim systems as a transitional mechanism to establish first green corridors (as required).**	Ministry for the Environment (MfE)
• **Undertake an assessment of existing trade flows, shipping services / routes and port capacity to identify potential candidates for green corridors.**	MoT
• **Undertake targeted feasibility assessments of prospective corridor(s),** examining any technological, regulatory and commercial requirements to establish the corridor.	Cross governmental – Ministry of Foreign Affairs and Trade (MFAT) and MBIE

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WHAT DO WE DO ABOUT IT?

Establishment of an initial green shipping corridor (2/2)

The following recommendations focus on establishing an initial green shipping corridor, given their potential to accelerate progress in tackling the challenges of decarbonising shipping. By focusing on routes that provide the greatest scope for maritime emissions reductions while balancing feasibility and speed, New Zealand can maximise its decarbonisation efforts.

An overview of the recommendations is presented on the right, with further detail in section 7. A **proposed lead** for each action is identified with a focus on government organisations as enablers and facilitators, reflecting operational mandates and an ability to bring together private and public sector organisations necessary to action the proposed recommendations outlined.

RECOMMENDATIONS	POTENTIAL LEADERS
• **Identify bilateral policy schemes to consider how complimentary policy action could benefit both ends of the identified corridor.** Examples include bilateral support schemes, such as port-side reduction fees serving participating companies based on origin of cargoes.	MFAT
• **Develop a comprehensive roadmap for the identified corridor**, with clear timelines and milestones which should outline specific actions, assign responsibilities, and set measurable outcomes to track progress.	Working group facilitated by MoT

WHAT DO WE DO ABOUT IT?

Leveraging trans-Tasman collaboration (1/3)

Establishing an initial green shipping corridor in the manner proposed will unlock the opportunity to consider other feasible green corridors, such as dedicated trans-Tasman routes (which will likely have specific establishment considerations), and the decarbonisation of New Zealand's wider freight network (landside and coastal). The potential demand for alternative fuels for shipping in Australia and the South Pacific region, the aviation sector and other use cases (e.g., supporting flexible energy generation), will further support the potential for alternative fuel production in New Zealand.

While New Zealand's geographic isolation poses significant challenges to establishing a viable biofuel industry independently, partnering with the Australian Government, leveraging funding programmes like the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC), engaging peak industry bodies such as Bioenergy Australia and the Bioenergy Association of New Zealand (BANZ), and developing a Joint Biofuels Roadmap for low carbon liquid fuels, offer a strategic solution.

The working group established to explore the initial corridor and MfE, due to its role in 2+2 Climate and Finance Dialogue with Australia, can lead / facilitate the actions to the right.

RECOMMENDATIONS	POTENTIAL LEADERS
• **Develop joint research and development (R&D) initiatives.** Collaboration on R&D, aligned with joint roadmaps and supported by peak bodies, can accelerate biofuel technology development.	Supported by MBIE and Department of Climate Change, Energy, the Environment and Water (DCCEEW)
• **Ensure policy alignment and harmonisation.** Harmonising policies and standards for biofuels, informed by joint roadmaps and peak bodies, would create a unified market.	–
• **Establish a co-funded and specialised bilateral fund (Joint Biofuels Fund)**. New Zealand and Australia can leverage existing funding bodies or establish a specialised fund with grants, loans, and production credits, guided by joint roadmaps and peak body insights, to finance biofuel projects. *The government could also crowd in investment from industry, as demonstrated by initiatives such as AgriZero.*	Supported by MBIE and DCCEEW
• **Jointly fund feasibility work from Joint Biofuels Fund**. Targeted funding for feasibility studies can bridge the gap between concept and implementation, enabling industry to progress biofuel projects to pilot and scale.	Supported by MBIE, DCCEEW, ARENA, and CEFC

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WHAT DO WE DO ABOUT IT?

Leveraging trans-Tasman collaboration (2/3)

Establishing an initial green shipping corridor in the manner proposed will unlock the opportunity to consider other feasible green corridors, such as dedicated trans-Tasman routes (which will likely have specific establishment considerations), and the decarbonisation of New Zealand's wider freight network (landside and coastal). The potential demand for alternative fuels for shipping in Australia and the South Pacific region, the aviation sector and other use cases (e.g., supporting flexible energy generation), will further support the potential for alternative fuel production in New Zealand.

While New Zealand's geographic isolation poses significant challenges to establishing a viable biofuel industry independently, partnering with the Australian Government, leveraging funding programmes like the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC), engaging peak industry bodies such as Bioenergy Australia and the Bioenergy Association of New Zealand (BANZ), and developing a Joint Biofuels Roadmap for low carbon liquid fuels, offer a strategic solution.

The working group established to explore the initial corridor and MfE, due to its role in 2+2 Climate and Finance Dialogue with Australia, can lead / facilitate the actions to the right.

RECOMMENDATIONS	POTENTIAL LEADERS
• **Collaborate on projects and infrastructure between New Zealand and Australia.** Joint projects, supported by peak bodies and aligned with the **Joint Biofuels Roadmap**, can address shared challenges like feedstock availability and distribution networks.	Supported by MBIE, DCCEEW, ARENA, and CEFC
• **Establish joint trade frameworks and market development between New Zealand and Australia**. A bilateral trade framework for biofuels, such as a trade agreement with preferential trading terms in relation to biofuels. The trade framework can also work towards identifying and addressing of any non-tariff barriers in relation to biofuels. The framework can be informed by peak bodies and the Joint Biofuels Roadmap, ensuring a stable market.	Supported by MFAT and Department of Foreign Affairs and Trade (DFAT)

WHAT DO WE DO ABOUT IT?

Leveraging trans-Tasman collaboration (3/3)

Establishing an initial green shipping corridor in the manner proposed will unlock the opportunity to consider other feasible green corridors, such as dedicated trans-Tasman routes (which will likely have specific establishment considerations), and the decarbonisation of New Zealand's wider freight network (landside and coastal). The potential demand for alternative fuels for shipping in Australia and the South Pacific region, the aviation sector and other use cases (e.g., supporting flexible energy generation), will further support the potential for alternative fuel production in New Zealand.

While New Zealand's geographic isolation poses significant challenges to establishing a viable biofuel industry independently, partnering with the Australian Government, leveraging funding programmes like the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation (CEFC), engaging peak industry bodies such as Bioenergy Australia and the Bioenergy Association of New Zealand (BANZ), and developing a Joint Biofuels Roadmap for low carbon liquid fuels, offer a strategic solution.

The working group established to explore the initial corridor and MfE, due to its role in 2+2 Climate and Finance Dialogue with Australia, can lead / facilitate the actions to the right.

RECOMMENDATIONS

- **Undertake assessment of additional green corridors (including dedicated trans-Tasman shipping lanes) that are candidates for decarbonisation.** This should focus on routes that have the largest potential for emissions reductions, have clear demand for emissions reductions (i.e., high value and volume of trade), can be serviced by shipping lines that have alternative fuel capable vessels, have access to appropriate domestic port infrastructure and would have access to alternative fuel production, either in New Zealand or Australia. Consideration of whether a book-and-claim system could be utilised in the interim for such a route should also be considered, although how book-and-claim systems interact with IMO measures would need to be determined.

  While this report has undertaken a preliminary assessment of the factors that would be required to establish a dedicated trans-Tasman green shipping corridor, further analysis is required to determine overall viability.

POTENTIAL LEADERS

Supported by MBIE and DCCEEW

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WHAT DO WE DO ABOUT IT?

Broader actions (1/2)

Establishing a green shipping corridor has the potential to drive future decarbonisation opportunities and impact how freight moves domestically. Changes in freight movement and mode, complemented by additional domestic use cases, have the potential to incentivise investment in domestic production and storage of targeted alternative fuels.

The recommendations below focus on the continued importance of a renewable energy transition, as well as other actions that should be taken to more broadly support the decarbonisation of New Zealand's shipping lanes.[6] Sufficient renewable energy must be available to power alternative fuel production; otherwise, the fuels will not be green.

RECOMMENDATIONS	POTENTIAL LEADERS
• **A continued shift of New Zealand's energy system to a renewable one is fundamental.** Sufficient renewable energy must be available to power alternative fuel production; otherwise, the fuels will not be green. A continued transition to a low carbon energy system is therefore needed. To do this, **priority and continued focus should be given to the detailed list of recommendations outlined previously in the** Low Carbon Energy Roadmap**.**	See The Aotearoa Circle Low Carbon Energy Roadmap
• **Undertake an assessment of the future freight task within New Zealand**, including vessel size trends, cargo aggregation and domestic port infrastructure requirements, leveraging the Ministry of Transport's role as the Government's system lead on transport. This could be achieved through **updating the National Freight Demand Study.**	MoT
• **Develop a national strategy for sustainable sourcing feedstock for alternative fuels.** This should also include consideration around sequencing of which sector(s) get priority for feedstock supply.	MfE and MBIE

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WHAT DO WE DO ABOUT IT?

Broader actions (2/2)

Establishing a green shipping corridor has the potential to drive future decarbonisation opportunities and impact how freight moves domestically. Changes in freight movement and mode, complemented by additional domestic use cases, have the potential to incentivise investment in domestic production and storage of targeted alternative fuels.

The recommendations below focus on the continued importance of a renewable energy transition, as well as other actions that should be taken to more broadly support the decarbonisation of New Zealand's shipping lanes.[7] Sufficient renewable energy must be available to power alternative fuel production; otherwise, the fuels will not be green.

RECOMMENDATIONS	POTENTIAL LEADERS
• **Engage proactively in IMO discussions, incorporating insights from actively monitoring and understanding global technology advancements in the area of renewable fuels and maritime applications**.	MoT
• **Facilitate knowledge sharing around experience from establishing green corridors and decarbonising shipping more generally with nations that have progressed to an advanced exploration of green corridors.**	MFAT
• **Maintain a continued focus on opportunities to support / mandate domestic decarbonisation initiatives and ensure alignment with emerging global regulations.**	MfE, supported by MoT and Energy Efficiency and Conservation Authority (EECA)

ES | Conclusion

Given the cross-border nature of international shipping emissions, decarbonisation of the maritime sector requires a global focus to ensure effective outcomes. This will include alignment on technology solutions and adoption of low carbon fuels to support achieving net-zero targets.

Establishing green shipping corridors is, however, a significant opportunity to progress maritime decarbonisation and key for New Zealand to maintain its competitive position in global trade.

While the challenge of decarbonising New Zealand's shipping lanes and establishing green shipping corridors is a complex one, this report proposes that the opportunity exists for New Zealand to leverage existing trade volumes, port infrastructure and shipping line relationships, to work towards the introduction of green shipping corridors. This initiative will provide a range of benefits including maintaining market access, improved brand reputation, increased export competitiveness, supporting identification of domestic fuel production opportunities, enhancing domestic energy security and ensuring access to low-to-zero emissions technologies / vessels.

1

Introduction

1 | Key observations

- The maritime industry is the backbone of international trade, accounting for more than 80% of global freight transported by volume.
- New Zealand relies very heavily on shipping for trade with 99.7% of trade by volume and 81% by value transported by sea, underscoring the importance of access to efficient maritime supply chains.
- The maritime industry is emissions intensive, responsible for roughly 3% of global emissions, with projections that this could rise to 17% by 2050.
- As a global industry, shipping emissions cross national borders and require a multifaceted global approach to decarbonise – including on technology solutions and low carbon fuels.
- Key drivers for transition include the increasing availability and cost reduction of alternative fuels, customer willingness to pay a green premium, and regulatory changes.
- In response to growing concerns over climate change, the IMO has adopted a GHG Reduction Strategy and a net-zero framework. Ship owners failing to meet these targets will face financial penalties.
- Until low-to-zero carbon fuels are more readily available, vessel energy efficiency measures and operational initiatives will be crucial for achieving near term emissions reduction.
- Fully decarbonising the maritime sector by 2050 will require substantial investment, leading to higher maritime logistics costs and posing potential challenges for smaller / more vulnerable nations.
- Establishing green shipping corridors is seen as integral step to demonstrating potential and accelerating emissions reduction in a targeted manner.
- Global regulations and policies of New Zealand's major trading partners have the potential to negatively affect market access and cost competitiveness if we fail to progress decarbonising of international shipping routes in line with these parties.
- The Future Fit Shipping workstream, led by The Aotearoa Circle, highlights the importance, associated challenges and potential opportunities of decarbonising New Zealand's maritime supply chains.

1.1 | Overview of the maritime industry

The maritime industry is the backbone of international trade, accounting for more than 80% of global freight transported by volume.[8]

In 2024, global trade reached $33 trillion,[9] highlighting the important role of maritime transport, particularly container shipping, in sustaining the global economy. Trade dynamics significantly influence the volume, value, composition, patterns, and trends in international shipping. As a small open trading nation situated in the South Pacific and at the end of long supply chains, New Zealand relies heavily on shipping for trade. 99.7% of trade by volume and 81% by value is transported by sea, underscoring the importance of having access to efficient maritime supply chains.[10]

The maritime industry is, however, emissions intensive, with operations relying heavily on fossil fuels, such as heavy fuel oil and diesel. Shipping is responsible for roughly 3% of global emissions,[11] with projections that this could rise to 17% by 2050.[12] If considered a country, the sector would rank as the sixth largest emitter.[13] The maritime sector is a 'hard-to-abate' sector, requiring a multifaceted approach that includes enhancing ship efficiency, optimising logistics, and replacing fossil fuels with lower-emission alternatives.[14]

Decarbonisation will likely involve a variety of fuels, requiring close monitoring of global industry trends for countries like New Zealand, who will likely be technology and fuel 'takers'. The sector is under pressure to decarbonise and is exploring lower emission fuel options and their impacts, but transitioning on a large scale demands new value chains and collaboration among ship owners, operators, ports, fuel suppliers, engine makers, and shipyards. A lack of clear demand signals from policymakers, suppliers, and eco-conscious consumers, coupled with concerns over health, safety, costs, energy density, crew skills, and port availability, complicates these efforts.[15]

1.1 | Overview of the maritime industry

Key drivers for transition include the increasing availability and cost reduction of alternative fuels, customer willingness to pay a green premium, and regulatory changes.[16] Det Norske Veritas (DNV), a leading classification society and recognised advisor to the maritime industry, estimates that adopting operational and technical energy efficiency measures could cut fuel consumption by 4% to 16% by 2030.

Achieving a 16% reduction could save 40 million tonnes of fuel and reduce CO_2 emissions by 120 million tonnes, equivalent to the emissions from operating 55,000 smaller ships or 2,500 large vessels using carbon-neutral fuel. Until low-to-zero carbon fuels are more readily available, energy efficiency measures will be crucial for achieving emissions reductions targets.[17] Optimistically, it appears that there has been widespread adoption of efficiency levers among shipping companies, such as hull form optimisation, wind assisted propulsion systems, and speed reductions, despite not yet adopting new fuels.[18]

Beyond decarbonisation challenges, the shipping industry faces disruptions from increased trade tensions and geopolitical conflicts. Events like the Covid-19 pandemic, the ongoing war in Ukraine, and tensions in the Horn of Africa have disrupted supply chains and increased costs. In addition, the global energy and cost-of-living crises will impact global shipping for years to come.[19]

For New Zealand, reducing maritime emissions presents both risks and opportunities. If we do not take steps to proactively decarbonise key shipping routes, we may face adverse impacts on market access and competitiveness, due to global regulations and decarbonisation policies of major trading partners. Conversely, a strategically timed and proactive approach to decarbonisation can enhance market access, bolster competitive positioning, and strengthen brand reputation. Timing will be a key consideration, however, as pursuing mandated requirements too aggressively relative to key trading partners and international stakeholder initiatives could undermine competitive positions.

81%

of trade by value is transported by sea in New Zealand.

6th

If considered a country, the maritime sector would rank as the sixth largest emitter globally.

120m

Achieving a 16% reduction could save up to 120 million tonnes through technical energy measures.

1.2 | International policy and regulatory landscape[21]

International shipping is excluded from the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC). Instead, its decarbonisation pathway is governed by the IMO.

Established in 1948 as a specialised agency of the United Nations, the IMO is pivotal in regulating maritime transport, focusing on safety, security, and environmental performance. It sets global standards for shipping safety, environmental protection, and efficiency, fostering cooperation among member states.

Key conventions under the IMO umbrella include:

- **International Convention for the Safety of Life at Sea (SOLAS), 1974:** Focuses on ship safety, covering aspects such as construction, equipment, and operation to prevent maritime disasters.
- **International Convention for the Prevention of Pollution from Ships (MARPOL)**: Aims to prevent pollution from ships, with specific regulations addressing oil spills, hazardous cargo, and sewage discharge. Notably, MARPOL Annex VI targets air pollution by imposing limits on sulphur oxides (SOx) and nitrogen oxides (NOx) emissions. The IMO 2020 regulations specifically reduced the maximum allowable sulphur content in marine fuels from 3.5% to 0.5%, significantly decreasing SOx emissions from ships.
- **Standards of Training, Certification, and Watchkeeping for Seafarers (STCW):** Establishes training and certification standards for seafarers, ensuring competency and safety in maritime operations.

In response to growing concerns over climate change, the IMO introduced a GHG Reduction Strategy, targeting at least a 50% GHG reduction by 2050 compared to 2008 levels, with a vision to phase out entirely within this century. Key measures include the Energy Efficiency Design Index (EEDI), which mandates energy efficiency standards for new ships, and the Energy Efficiency Existing Ship Index (EEXI), which applies similar standards to existing vessels.

A Carbon Intensity Indicator (CII) regulates operational efficiency, encouraging practices that enhance fuel efficiency and reduced emissions. This positions the IMO as a leader in establishing resilient maritime practices, balancing economic growth with environmental stewardship.

Recently, IMO member states have discussed new climate policies to support net-zero emissions by or around 2050, considering options such as an emissions levy, a credit-trading system, and 'bridge' proposals between the two. In April 2025, the IMO announced the final net-zero framework and emissions-intensity reduction targets: 4% by 2028, increasing to 30% by 2035, with an upper target rising from 17% to 43% over the same timeframe. Ship owners failing to meet these targets will face financial penalties: $380 USD per tonne of emissions for not meeting lower targets and $100 USD per tonne for not meeting upper targets. Ship owners not meeting the lower targets can also purchase 'remedial units' for $380 USD per tonne of emissions each or buy 'surplus' units from compliant operators.[20]

1.3 | The challenge of transitioning the maritime sector

Fully decarbonising the maritime sector by 2050 will require substantial investment. The global nature of shipping necessitates a unified move towards zero-emission targets, ensuring a fair transition as outlined in the IMO's 2023 GHG reduction strategy.

Challenges have been identified for vulnerable nations, especially Small Island Developing States (SIDS) that are heavily dependent on shipping. United Nations Trade and Development (UNCTAD)[22] notes that developing countries, least developed countries (LDCs), and SIDS may experience increased domestic inflationary pressures due to their limited capacity to absorb the cost pass-through from the energy transition in shipping and the associated rise in logistics expenses.[23] To address these issues, inclusive decision-making and financial mechanisms are vital, such as directing levy revenues into infrastructure and training in developing nations, promoting a fair and inclusive transition.[24]

The transition will also present opportunities for countries and regions due to the growth of the hydrogen economy. For example, South Africa's hydrogen sector is expected to generate 1.9 to 3.7 million jobs and contribute $60 billion to GDP by 2050.[25] Globally, decarbonising the maritime industry could create up to four million jobs by 2050.[26] Achieving these employment benefits will also require retraining and upskilling across renewable energy production. Knowledge and technology transfer will also be needed, particularly with regards to safety protocols.

1.4 | Green shipping's significance to New Zealand and Australia

Green shipping refers to routes where ships are powered by low to zero emission fuels. As of 30 October 2024, 62 green corridor initiatives have been announced, marking three years of steady growth and sustained interest in this concept.[27]

These corridors are pivotal in promoting sustainable solutions, supported by public and private stakeholders.[28] They provide a platform for testing targeted policy initiatives such as regulations, financial incentives, and safety measures, thereby fostering demand for lower emission practices. Decarbonising shipping along these corridors can also boost economic activity by leveraging the supply of low-emission fuels.[29]

The IMO's ambitious GHG reduction targets for the maritime sector necessitate adopting new technologies and collaborative efforts to cut emissions globally. Green shipping corridors are integral to targeted outcomes.

Trans-Tasman shipping represents an important trade link between New Zealand and Australia, with Australia being New Zealand's third-largest sea trade partner.[30] The establishment of a trans-Tasman green shipping corridor aims to reduce emissions along this route and set a benchmark for the Asia-Pacific region.

A central motivation for this workstream

The 2024 Australia-New Zealand 2+2 Climate and Finance Dialogue Joint Statement reflects the commitment to establishing a trans-Transman green shipping corridor, with Ministers from both countries agreeing to explore conditions for green shipping corridors, including direct routes between the two nations.[31] This statement represents part of a broader initiative to transition toward lower emission practices and demonstrates a shared commitment to reducing the carbon footprint of maritime transport between the two countries.

The insights and recommendations in this report will help progress New Zealand's trans-Tasman commitments (2+2 Climate and Finance Dialogue Joint Statement) to reduce shipping emissions and show global leadership on this important issue.

1.5 | The Future Fit Shipping workstream

The potential to decarbonise maritime shipping through initiatives such as green corridors has been explicitly recognised by the New Zealand government in its second emissions reduction plan. The government has noted its role is to facilitate industry discussion through existing forums, consider regulatory barriers and ensure New Zealand's interests are represented on the international stage.[32]

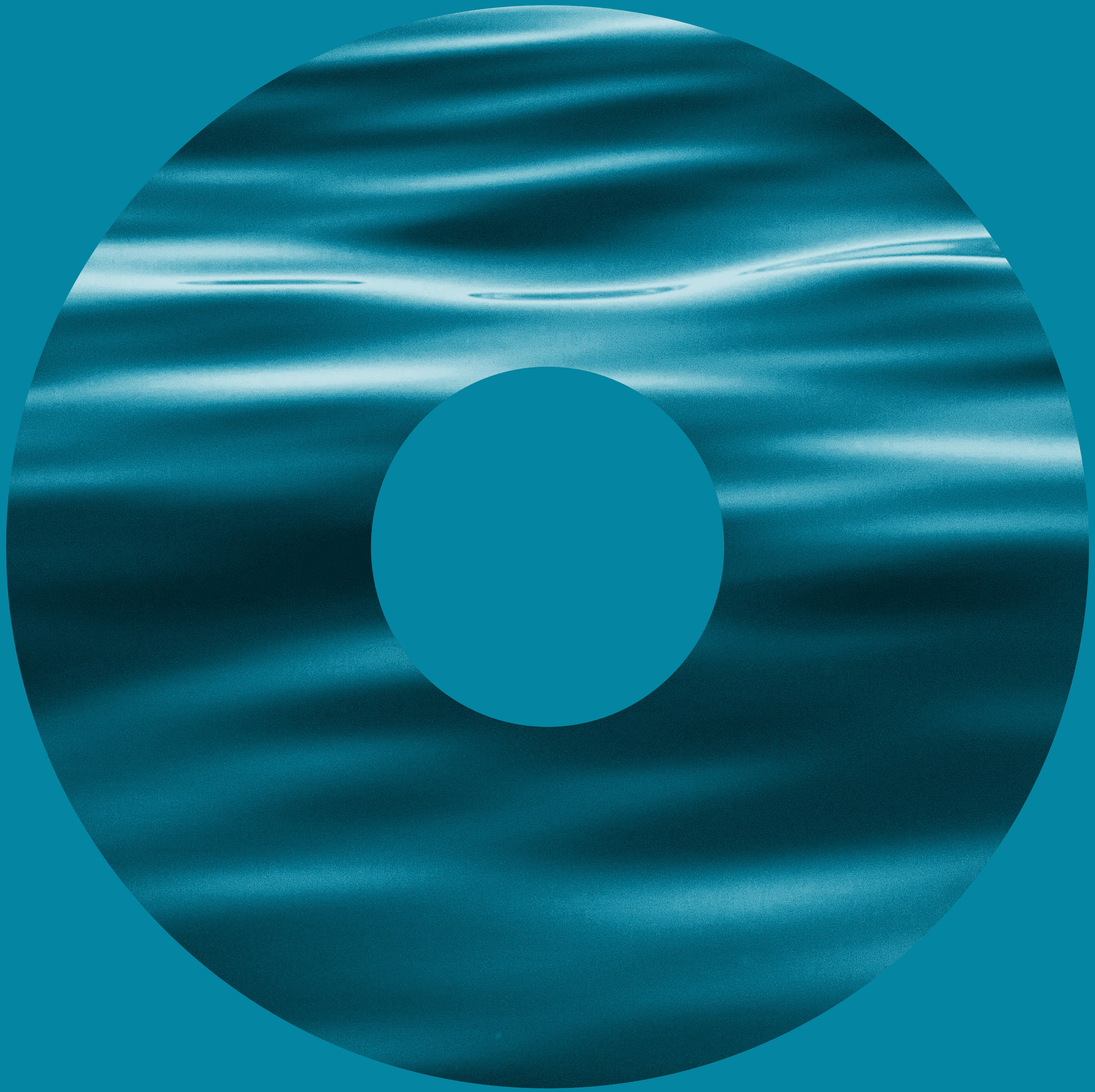
The Future Fit Shipping workstream, led by The Aotearoa Circle and supported by Deloitte, highlights the importance, associated challenges and potential opportunities of decarbonising our maritime supply chains, through the following lenses:

1. **Economic impact assessment**: An analysis of the potential avoided costs to New Zealand's economy if successful action is taken to decarbonise New Zealand's shipping lanes.
2. **Establishing green shipping corridors**: Highlighting considerations, issues and opportunities, for establishing green corridors. This includes specific considerations for establishing a green shipping corridor on dedicated trans-Tasman routes.
3. **Preliminary alternative fuel roadmaps**: Four roadmaps focusing on Biofuels, Liquefied Natural Gas (LNG), Methanol, and Ammonia. These roadmaps provide an overview of production pathways, infrastructure requirements, and initial views on overall feasibility.

   Note: these roadmaps are intended to highlight implementation considerations and are not detailed execution roadmaps.

Extensive stakeholder engagement has been a cornerstone of this workstream, involving over 50 sector representatives across both the public and private sector and both sides of the Tasman. This engagement has enabled understanding of the diverse perspectives and stakeholder needs within the sector, fostering collaboration, and identifying key interrelationships that can drive the implementation of green shipping corridors. A list of stakeholders engaged as part of this workstream is provided in **Appendix F.**

2



Economic Opportunities

2 | Key observations

- In addition to the recently agreed GHG levy on emissions, set to be implemented by the IMO from 2027, a raft of regulatory initiatives are impacting New Zealand's trading activities.
- By taking positive actions to reduce maritime shipping emissions on our international trading lanes, New Zealand has an opportunity to avoid some of the costs and other potential market access considerations that may arise should it lag competing trading partners in decarbonising.
- In addition to avoiding carbon levies, the benefits associated with decarbonising international shipping include maintaining competitive market access, addressing shifting consumer preferences, maintaining New Zealand's brand reputation, and access to low-to-zero emissions technologies (including international vessels).
- Two illustrative scenarios have been assessed to demonstrate potential order of magnitude economic impacts should certain events take place in the future:
  - Scenario 1 – IMO GHG Levy, and
  - Scenario 2 – Fall in Exports of 5% – 15%.
- Scenario 1 – IMO GHG levy – illustrates that NZ$17.5b of negative GDP impact can be avoided by 2050 in NPV terms.
- Scenario 2 – Fall in exports – illustrates a potential impact of NZ$33.7 – NZ$94.1b by 2050 in NPV terms of an assumed reduction in exports of 5% – 15%.
- Wider economic benefits associated with progressing decarbonising of shipping lanes include the potential to improve relative export competitiveness, identify / derisk opportunities for future domestic alternative fuel production, reducing domestic emissions and enhancing energy security.
- The scale of avoidable costs associated with decarbonising New Zealand's shipping lanes and the potential for further economic benefits provide an imperative for action.

2.1 | Rationale behind the economic impact assessment

Spurred by a wave of decarbonisation regulation, the maritime sector is in the midst of unprecedented change. In addition to the recently agreed GHG levy on emissions, set to be implemented by the IMO from 2027, there are a raft of regulatory initiatives that are impacting New Zealand's trading activities.

Examples of such regulations include:

- The inclusion of maritime shipping emissions in the EU ETS. Taking effect from 1 January 2024, shipping companies are required to buy and surrender emission allowances for tank-to-wake carbon dioxide emissions within EU and European Economic Area ports, emissions on voyages between such ports, and 50% of emissions of voyages into or out of them.[33]
- Adopted in July 2023 and in force from 1 January 2025, the FuelEU Maritime Regulation requires that ships above 5,000 GT transporting cargo or passengers for commercial purposes meet annual well-to-wake GHG emissions intensity requirements. The intensity requirements are a 2% improvement compared to 2020 by 2045, 14.5% by 2035 and 80% by 2050.[34]
- Over 70% of New Zealand exports by value are to countries with mandatory climate-related disclosures (proposed or in force) and 40% of New Zealand exports by value are to countries with carbon border adjustment mechanisms.[35]

In addition, in November 2024, New Zealand's Climate Change Commission also recommended the inclusion of international shipping in domestic emissions reduction targets, noting:[36]

- The significant scale of these emissions,
- An opportunity to increase certainty, transparency and accountability in New Zealand's efforts to limit global warming, and
- Better aligning New Zealand with trading partners and international efforts to reduce GHG emissions.

In New Zealand's second emissions reduction plan, published 11 December 2024, the New Zealand Government noted that its role included:[37]

- Facilitating industry discussions through existing forums, consider regulatory barriers and ensure New Zealand's interest are represented on the international stage.
- Creating conditions for green shipping routes by 2035.
- Reviewing domestic use of international carbon intensity requirements.

2.1 | Rationale behind the economic impact assessment

By taking positive actions to reduce maritime shipping emissions on international trade lanes, New Zealand has an opportunity to avoid some of the costs and other potential market access consequences that may arise should it lag trading partners in decarbonising international shipping lanes. The most immediate avoided costs include proposed levies on shipping emissions.

Additional industry related market access considerations of a failure to act include:

- potentially negative impacts on future shipping services availability; and
- cargo de-prioritisation and vessel technology / efficiency, impacting supply chain costs.

Market engagement has confirmed that there would also be wider benefits associated with decarbonising, including:

- Maintaining competitive market access, especially for exports to countries with carbon border adjustment mechanisms.
- Addressing shifting consumer preferences, especially for direct purchasers of New Zealand's exports who must increasingly comply with mandatory climate-related disclosure regulations and are increasingly focusing on Scope 3 emissions.
- Maintaining New Zealand's brand reputation and trust by continuing to act to reduce emissions throughout New Zealand exports' value chain.
- Potentially creating commercial incentives for the development of alternative fuel production and supply in New Zealand.

The economic analysis is based on two 'what if' scenarios, designed to demonstrate the potential order of magnitude impacts should certain events take place in the future. The scenarios and associated results should therefore not be interpreted as forecasts or predictions.

2.2 | Overview of scenarios modelled

We have assessed two scenarios:

IMO GHG Levy

This provides an indicative view of the potential impact of the IMO GHG levy on New Zealand's economy.

Fall in Exports

A scenario illustrating the impacts of an assumed fall in goods exports. This scenario models a 5% reduction by 2050 as the lower bound of the assumed fall in exports, and a 15% reduction by 2050 as the assumed upper bound of the assumed fall in exports.

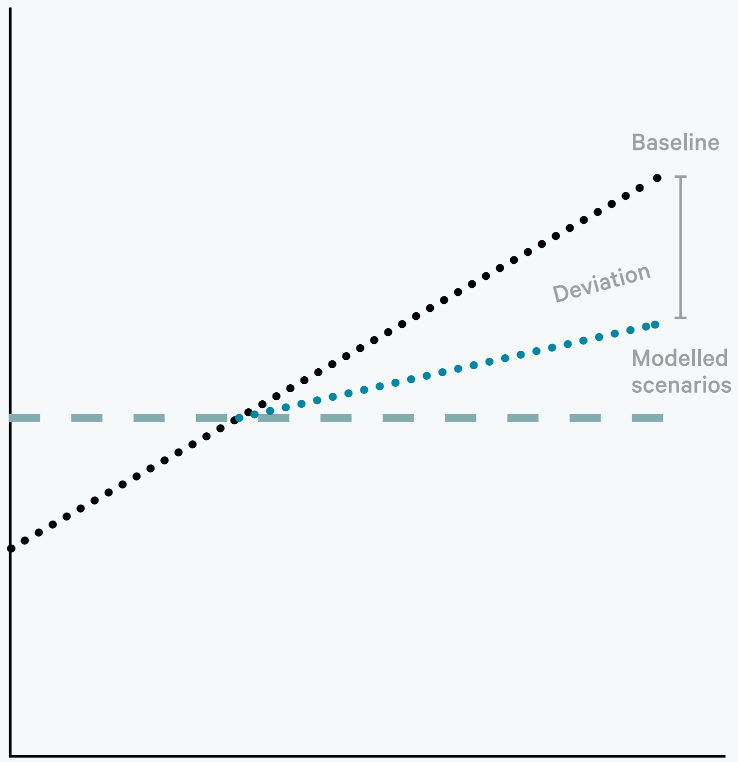
These scenarios are intended to be illustrative and complimentary.

Approach to modelling the scenarios

The modelling of the scenarios described has been undertaken using Deloitte Access Economics' in house computable general equilibrium (CGE) model. Each scenario is assessed against a baseline. The baseline in this case considers a scenario where New Zealand is able to decarbonise its shipping lanes at the same pace as competing trading nations, meaning no relative supply chain cost differences and so a continuation of status quo growth in trade.

The results of this modelling should be interpreted as 'deviations' from the baseline. For example, a GDP deviation of -$200 million means that New Zealand's GDP is $200m lower than in the modelled scenario, when compared to the baseline.

Figure 1: Stylised representation of modelling approach



Source: Deloitte Access Economics

2.2 OVERVIEW OF SCENARIOS MODELLED

Scenario 1 – IMO GHG levy

The first scenario modelled provides an indicative view of the potential impact of an IMO GHG levy on New Zealand's economy. The scenario models the potential cost on New Zealand if it fails to decarbonise its shipping lanes at the same rate as competing trading nations. Failing to decarbonise at the same rate as competing trading nations means New Zealand faces a higher cost associated with transporting goods in and out of New Zealand by sea. By taking action on decarbonising New Zealand's international shipping lanes, New Zealand can avoid these costs.

Overview of the IMO GHG levy and key modelling assumptions

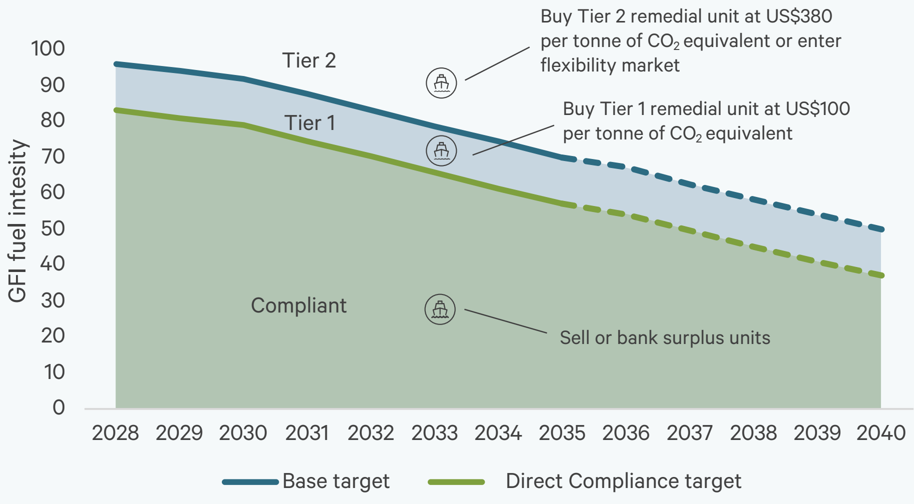
The IMO is proposing a global GHG levy on shipping emissions, set to take effect from 2027. The policy will apply to ships over 5,000 gross tonnes and is designed to incentivise decarbonisation by penalising emissions-intensive vessels. It introduces two emissions intensity targets: a Base Target (a 4% reduction by 2028, increasing to 30% by 2035) and a more ambitious Direct Compliance Target (starting at 17% in 2028 and rising to 43% by 2035).

Ships that achieve emission intensity below the Direct Compliance Target will earn surplus units, which can be banked or sold. Conversely, if a ship has an emissions intensity above the Base Target, it has a negative compliance balance and accrues two tiers of compliance deficits:

- A Tier 1 compliance deficit, priced at USD $100 per tonne of CO_2 equivalent, if its emissions are between the Base and Direct Compliance Targets
- Both a Tier 1 compliance deficit and a Tier 2 compliance deficit if its emissions are above the Base Targets. The Tier 2 compliance deficit is priced at USD $380 per tonne of CO_2 equivalent – or an ability to purchase surplus units from other ships at a price determined through a market-based trading system.

An overview of the IMO GHG levy is provided on the right:

Figure 2: Overview of IMO GHG reduction measures



Source: Deloitte Access Economics

These mechanisms are designed to create financial incentives for early movers but also introduce complexity and variability in the actual price of compliance.

Given this uncertainty, the modelling for this scenario adopts a simplified and conservative approach. Rather than attempting to predict the evolving dynamics of surplus unit supply and demand, a flat levy of USD $100 per tonne of CO_2 equivalent has been applied as an indicative 'what-if' scenario. The $100 USD per tonne of emissions IMO levy modelled under this scenario should therefore be treated as indicative of potential impacts. Further details of the approach to modelling the IMO GHG levy are provided on the next page.

2.2 OVERVIEW OF SCENARIOS MODELLED

Scenario 1 – IMO GHG levy

One channel through which New Zealand's trade flows could be impacted is through the imposition of levies on emissions associated with shipping. The IMO is close to adopting a proposed GHG levy on international shipping.

This scenario considers how New Zealand could avoid negative impacts associated with an indicative $100 USD per tonne CO_2e emissions IMO levy starting in 2027. This levy has been modelled as a tax applied to imports and exports of goods based on expected emissions from marine transportation.

Under this scenario, the levy is initially applied to all economies. As decarbonisation is achieved in shipping routes across countries, the levy incurred by countries declines over time, with the assumed exception of New Zealand. This creates a relative disadvantage for New Zealand exporters and importers, who face relatively higher transport costs.

This scenario also captures the fact that there is likely to be an offsetting cost advantage to New Zealand by continuing to use fossil fuel based marine fuels. The differences in costs between fossil fuel based marine fuels and green fuels draws from Maersk McKinner Moller Centre for Zero Carbon shipping and DNV projections.

It is expected that the revenue raised by this levy will be directed to support decarbonising shipping. The modelling assumes other regions receive support as they decarbonise shipping, but that New Zealand does not receive any revenue from the levy.

In the baseline, New Zealand takes action towards decarbonising its shipping lanes, meaning it avoids the relative disadvantage associated with higher transport costs and maintains status quo export and import growth, while also positioning itself to access the revenue raised by the levy.

IMO implements GHG levies from 2027.

Competing trading partners start establishing "green shipping" corridors.

By 2030, competing trading partners use up to 16% of zero, or near-zero, GHG fuels for shipping.

By 2050, competing trading partners use up to 94% of zero, or near-zero, GHG fuels for shipping.

2.2 OVERVIEW OF SCENARIOS MODELLED

Scenario 2 – Fall in exports

The second scenario contemplates a fall in goods exports of between 5% and 15% by 2050. Specifically, a 5% fall in exports by 2050 acts as the assumed lower bound, while a 15% fall in exports by 2050 acts as the assumed upper bound, of the fall in goods exports scenario. This scenario is intended to incorporate the IMO GHG levy scenario, and also capture incremental risks highlighted during market engagement from a failure to decarbonise shipping lanes, via an assumed negative impact range on exports. These risks include an increased focus on Scope 3 emissions, a changing regulatory environment in key trading partner economies, shifting consumer preferences and a loss in reputation or trust in New Zealand's key export brands. Such risks can be seen as additive to the potential costs modelled under Scenario 1 above, as they exist alongside and potentially compound the impact of the IMO GHG levy. By taking action on decarbonising New Zealand's international shipping lanes, New Zealand can avoid the negative economic impacts of a broader fall in goods exports.

The assumed 5% to 15% fall in exports has been informed by responses to a targeted survey of members of the New Zealand Council of Cargo Owners. We note the inherent uncertainty associated with the broader risks to New Zealand's goods exports from a failure to decarbonise shipping lanes. Hence, this scenario is intended to highlight the order of magnitude impacts across this assumed range. Further details on the scenario and modelling approach are provided under **Appendix A.**

2.2 OVERVIEW OF SCENARIOS MODELLED

Scenario 2 – Fall in exports

By taking action to decarbonise shipping lanes, New Zealand could mitigate a range of potential risks to exports. The key channels of such risks have been highlighted through market engagement and include an increased focus on Scope 3 emissions, a changing regulatory environment in key trading partner economies, shifting consumer preferences and a loss in reputation or trust in New Zealand's key export brands.

To illustrate the potential implications for the New Zealand economy, as well as the inherent uncertainty, we have considered what an avoided 5% and 15% fall in New Zealand's goods exports could mean for the economy by 2050.

Over 70% of New Zealand exports by value go to countries with mandatory climate related disclosures, resulting in increased pressure to reduce scope 3 emissions.

Competing trading partners continue to decarbonise supply chains, including establishing 'green' shipping corridors.

New Zealand fails to establish "green" shipping corridors and decarbonise international shipping lanes.

New Zealand goods exports fall between 5% and 15% by 2050, owing to falling competitiveness and loss of market access.

2.3 Potential avoided costs associated with taking action to decarbonise shipping lanes

Taking action to decarbonise international shipping lanes has the potential to avoid significant costs, as demonstrated by the figures to the right. The GDP, employment, export and import impacts presented capture flow-on economy wide impacts (i.e., they capture how a reduction in exports for a certain sector impacts all other actors in an economy (e.g., businesses, consumers and government).

Based on market engagement, in addition to the IMO levy, acting to decarbonise could reduce risk exposure from:

- Increased focus on Scope 3 emissions
- Changing regulatory conditions in key export markets
- Shifting consumer preferences
- Loss of brand reputation and trust

Annual GDP impact as at 2050

The opportunity demonstrated by the result is the ability for New Zealand to avoid costs by taking action to decarbonise shipping

-$1.8b

Avoided impact of $100 USD/t$CO_2$e IMO levy

This is approximately equal to $300 of GDP per person in 2050

-$4.4b

Avoided 5% fall in goods exports

This is approximately equal to $727 of GDP per person in 2050

-$11.8b

Avoided 15% fall in goods exports

This is approximately equal to $1,969 of GDP per person in 2050

2.3 | Potential avoided costs associated with taking action to decarbonise shipping lanes

Economic impact over time	GDP Deviation NPV terms by 2050 in 2024 NZD	Employment Deviation in FTE terms by 2050	Exports Deviation in NPV terms by 2050 in 2024 NZD	Imports Deviation in NPV terms by 2050 in 2024 NZD
Avoided impacts of IMO levy	-$17.5b	-2,644	-$2.3b	-$9.7b
Avoided 5% fall in goods exports by 2050	-$33.7b	-13,200	-$24.2b	-$38.9b
Avoided 15% fall in goods exports by 2050	-$94.1b	-36,000	-$66.6b	-$106.0b

NPV results are between 2025 and 2050 at a 2% discount rate (as commonly used for cliamte analysis and consistent with Treasury guidelines on the social rate of time preference)

2.3 | Potential avoided costs associated with taking action to decarbonise shipping lanes

The modelled impacts of the IMO scenario, that assumes an effective $100 USD per tonne of emissions price, is smallest in magnitude. This is driven by the fact that New Zealand does not suffer a material cost disadvantage for the shipping of goods in and out of New Zealand initially, as other countries also pay the IMO levy while in the midst of transitioning off conventional fossil fuels. However, the impacts under the IMO levy escalate over time, as competing trading nations are assumed to increasingly decarbonise their shipping lanes and progressively pay less of the IMO levy. Further, as alternative fuels scale up in production and become more efficient, the relative cost advantage that relying on fossil fuels presents dissipates over time.

It should be noted that several factors could increase the value of avoided impacts associated with the IMO levy. This includes a scenario whereby the effective IMO levy exceeds $100 USD per tonne of emissions and / or where the relative cost advantage of relying on fossil fuels dissipates faster over time.

The relative cost advantage of fossil fuels may dissipate faster if, for example, further support is provided around innovation and scaling of the production of alternative fuels. For illustrative purposes, if it was assumed that there was no cost difference between alternative and fossil fuels, the impact of a $100USD IMO levy is estimated to be $47.4 billion by 2050 in net present value terms, which sits within the 5% and 15% avoided fall in goods exports scenarios. While a scenario where no cost differential exists between alternative and fossil fuels is considered unrealistic, this does highlight the sensitivity of modelled impacts to assumed fuel price deviations over time and serves to illustrate how the IMO levy could have more of an impact if certain factors change and no action is taken to decarbonise New Zealand's shipping lanes.

2.4 | Other economic opportunities

The economic assessment outlined above focuses on the avoided costs associated with taking action to decarbonise shipping lanes. The avoided costs capture benefits associated with avoiding IMO GHG levies and maintaining market access and brand reputation.

Broader opportunities associated with decarbonising shipping lanes, also include:

- **Increased export competitiveness**: Taking a leading role in reducing shipping emissions, by decarbonising shipping lanes ahead of competing trading nations, may act to increase New Zealand's export attractiveness, and therefore competitiveness, such as for our meat and dairy exports. The potential increase in exports, and wider economic benefits, would be in addition to the avoided costs estimated in the economic impact assessment.

  Reducing shipping emissions will have cost implications. For example, DNV's *Maritime Forecast to 2050* indicates decarbonisation could double container transport costs by 2050, with these costs ultimately being passed down the value chain.[38] However, the impact on end consumer prices for goods transported by ship are likely to be relatively small, given transport costs make up a small fraction of the final price of goods shipped by sea.[39] Estimates suggest that, even with ambitious upstream emission reduction targets, the impact on prices is low – no more than 1%-4% in the medium term – if zero supply-chain emissions are the goal.[40]

  The opportunity to take a leading role in reducing shipping emissions to increasing export attractiveness and competitiveness is therefore one that shows promise and is relatively less risky.

- **Identifying / de-risking domestic fuel production opportunities**: Decarbonising shipping lanes, such as through green shipping corridors, may help to facilitate near term opportunities for local production of alternative fuels, such as biofuels for domestic land transportation and/or coastal shipping routes that act to aggregate cargo for international shipping. The investment and ongoing production of alternative fuels would spur additional economic activity and benefits for New Zealand.
- **Enhance domestic energy security**: Local production of alternative fuels would enhance energy security via reduced reliance on imported energy.
- **Secure access to zero-emissions technologies**: Ensuring 'technological inclusivity' – a term coined by the IMO. The transfer of technologies is important to ensure New Zealand has access to suitable zero-emission vessels and technologies and can share this knowledge with other sectors.[41]

3

International Shipping Lines Transition Considerations

3 | Key observations

- Shipping lines will play a lead role in determining future fuel choices.
- International shipping cannot be treated as one homogenous segment, and it is important to take a segment specific approach to decarbonisation initiatives and opportunities.
- A range of alternative fuels are actively being introduced into the global fleet, as lines seek to keep their fuel adoption options open.
- A multiple fuel future greatly increases the complexity of transitioning to decarbonise the maritime industry.
- Alternative fuel adoption is anticipated to evolve:
  - After fossil-based fuel oil, biodiesel and fossil-based LNG are forecast to be the most adopted fuels by 2030.
  - By 2050 a fleet comprised of fuel oil/biodiesel, methane, methanol, and ammonia is anticipated.
- New Zealand and other nations will be technology takers in relation to vessel configurations and operational deployments of leading shipping lines.
- Securing ships able to operate on alternative fuels is likely to be a challenge in light of the implementation of the IMO GHG levy from 2027 onwards.
- As shipping lines look to replace the vessel fleet servicing New Zealand, and ongoing supply chain efficiencies are sought, larger vessels will continue to be introduced, impacting associated port infrastructure requirements.
- A trend towards larger vessels is also evident for alternative fuel powered vessels, as lines seek to maximise the decarbonisation impacts from their associated vessel investments – with most alternative fuel vessels on order exceeding New Zealand port capacity.
- Shipping lines face a range of financial considerations regarding fuel transition and green corridor implementation including new build vessel construction costs and existing fleet retrofitting requirements, shipyard availability, supporting port / bunkering infrastructure, profit margins and incremental cost absorption capacity, market willingness to pay and regulatory incentives / requirements.
- As stricter emissions regulations in regions such as Europe impose penalties on older, less environmentally friendly ships, shipping lines are likely to redirect these vessels to routes with less stringent environmental standards. This presents potential risks for New Zealand.

3 | Overview

As the maritime industry navigates the complex transition to low emission vessels, international shipping lines find themselves at a crossroads. Currently reliant on traditional internal-combustion engines, many shipping companies are exploring lower emission fuel alternatives that promise to reduce their carbon footprint. However, this transition is fraught with challenges, including fluctuating demand signals that create uncertainty and apprehension about the viability and reliability of new fuel sources.

It is also important to take a segment specific approach as the deep-sea shipping sector cannot be treated as one homogenous segment. There are different features and considerations across container and bulk that affect the uptake of green fuels. The container segment has seen a greater increase in demand for green shipping solutions compared to the bulk segment. This is due to multiple factors, including its closeness to end customers, branded businesses (cargo), higher profit margins (relative to dry and wet bulk), ability to spread costs over many products and customers, and predictable routes, that make implementation easier.[42] While outside the scope of this report, we note that shorter routes (e.g. short sea or inland shipping) also present alternative decarbonisation considerations and options, such as electrification.

Navigating these considerations is crucial for shipping lines aiming to embrace a resilient future while balancing operational efficiency and economic viability.

Reflecting the global nature of the marine industry, shipping lines will play a lead role in determining future fuel choices, driven by their strategic deployment choices and significant investment required in new vessels designed for specific fuel types. By allocating resources to research and development, these companies not only enhance their operational capabilities but also influence broader market dynamics regarding fuel availability and infrastructure requirements throughout the supply chain. As a nation heavily reliant on maritime trade, New Zealand and other trading nations, will be technology takers and adopt the vessel configurations and operational deployments preferred by leading shipping lines, making it essential for local stakeholders to remain informed and actively engaged in relation to these evolving trends in the global shipping landscape.

3.1 | A multiple fuel future

A survey of 29 shipping companies in late 2022 indicated that a mix of alternative fuel use is expected through 2050. The majority of respondents indicated that after fossil-based fuel oil, biodiesel and fossil-based LNG will be the most commonly adopted fuels by 2030. The most common scenario projected by 2050 is for a fleet of vessels comprised of fuel oil/biodiesel, methane, methanol, and ammonia. Hydrogen and nuclear power lagged in the projections.[43]

This projected multiple fuel future greatly increases the complexity of transitioning to decarbonise the maritime industry, given interdependences between industry stakeholders, including ship owners and operators, ports, engine manufacturers, and fuel providers. Managing this complexity and multiple fuel supply chains over the next several decades will also have an impact on the speed at which the industry decarbonises.[44]

3.2 | Current investments and initiatives by shipping lines

Shipping lines are increasingly investing in green technologies to address environmental concerns and regulatory pressures. Key initiatives include the adoption of low-emission fuels, such as green methanol and LNG, alongside investments in dual-fuel capable vessels, underscoring the plurality of fuels likely to power shipping vessels in the future.

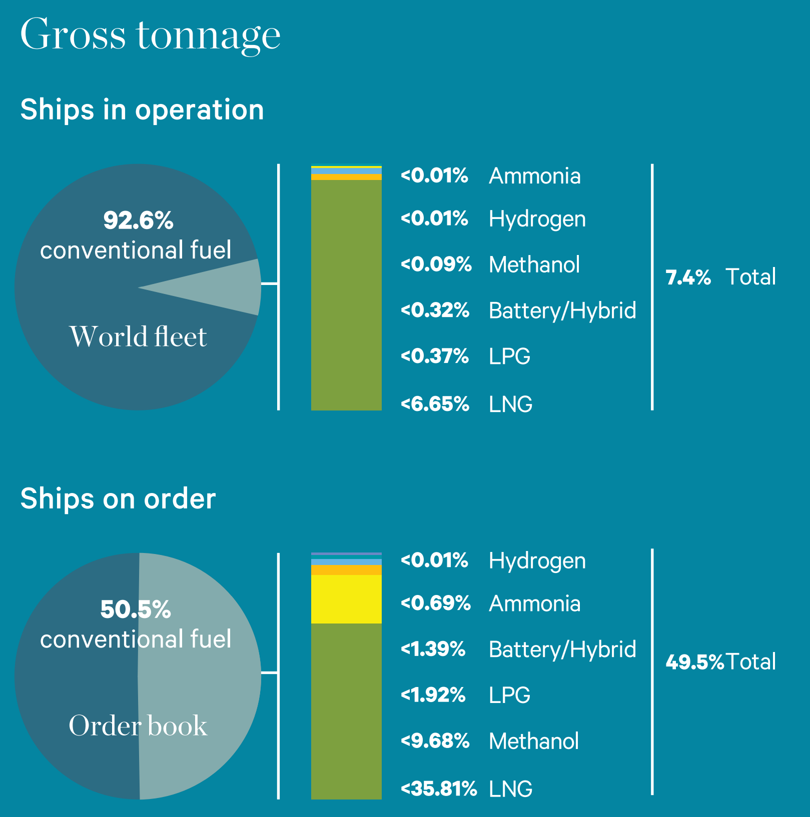
Increasing investment in alternative fuel powered vessels

There is marked shift towards investment in alternative fuel powered vessels by international shipping lines. According to the DNV, as of early 2024 there were 267 confirmed methanol-fuelled ships in operation or on order, with the majority being container ships.[45] The number of LNG-fuelled ships in operation doubled between 2021 and 2024, with 641 in operation by the end of 2024 – a number expected to double by the end of the decade.[46]

Recently, shipping company ANL made its first container ship voyage powered by LNG from Southeast Asia to Australia. This was an 8,000 TEU dual-fuel LNG-powered vessel and ANL are calling it "Oceania's first LNG-powered container vessel".[47]

More broadly, the trend of larger ships being ordered with dual-fuel capabilities is continuing, with the order book comprising a large number of methanol and LPG-fuel ships and the emergence of ammonia as a fuel. As of June 2024, only 7.4% of ships, measured in gross tonnage, in operation can use alternative fuels, but 49.5% of the tonnage of ships on order can operate on alternative fuels.[48]

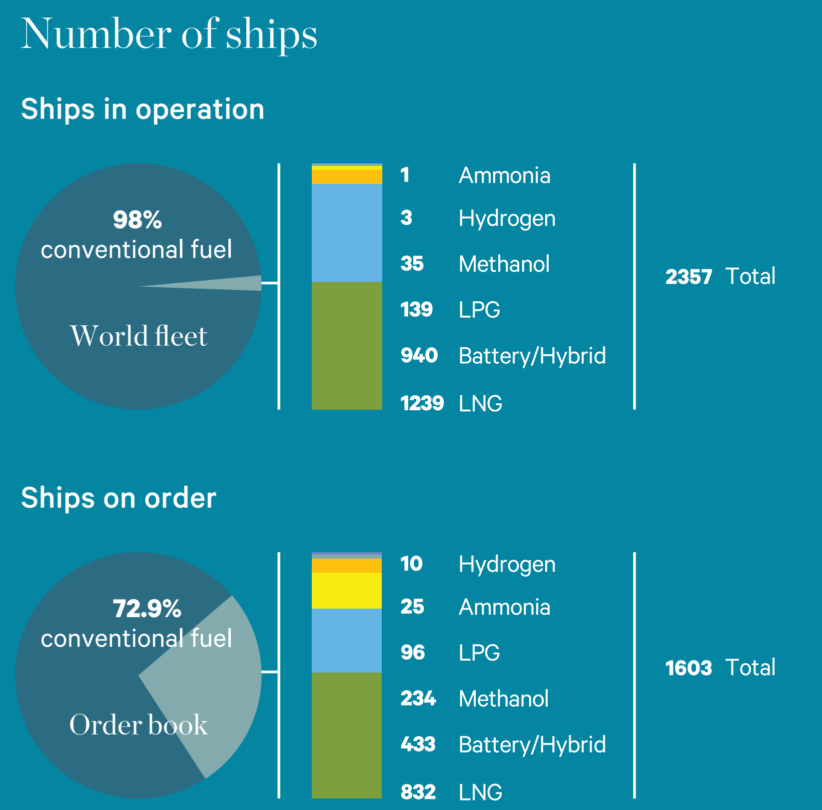
Figure 3: Alternative fuel update in world fleet in number of ships (upper) and gross tonnage (lower), as of June 2024



Source: DNV "Energy Transition Outlook 2024: Maritime Forecast to 2050 – A deep dive into shipping's decarbonization journey"

3.2 | Current investments and initiatives by shipping lines

Figure 4: Alternative fuel update in world fleet in number of ships (upper) and gross tonnage (lower), as of June 2024



Source: DNV "Energy Transition Outlook 2024: Maritime Forecast to 2050 – A deep dive into shipping's decarbonization journey"

There is broad agreement that internal combustion engines (ICEs) will remain the dominant propulsion system for ships until at least 2050. Presently, these engines can run on fuel oil, liquefied methane, and methanol, with ammonia-powered ICEs expected to be introduced soon. In parallel, fuel cell technologies, which use hydrogen or other alternative fuels to produce electricity for ship propulsion, are expected to see significant progress between 2030 and 2050, although their use will probably be restricted to particular niche sectors.[49]

Another consideration for shipping lines is the technology readiness of the various alternative fuels and how this impacts commercial adoption and integration with ships. Technological maturity in terms of fuel production and engine technology does not necessarily translate to fuels being ready for commercial maritime adoption. Technology Readiness Levels (TRL), a scale from the National Aeronautics and Space Administration (NASA), are a type of measurement system used to assess the maturity level of a particular technology. There are nine technology readiness levels and these can be used to compare readiness across fuel production, engine technology, and vessel integration.

On this scale, methanol and LNG are of sufficient maturity for vessel integration, whereas ammonia is not yet.[50] This reflects trends seen in alternative fuel powered ship orders to date.

3.3 | Alternative fuel capable vessel size

There has been an ongoing trend towards the introduction of larger vessels, driven by the drive to increase scale and efficiency.

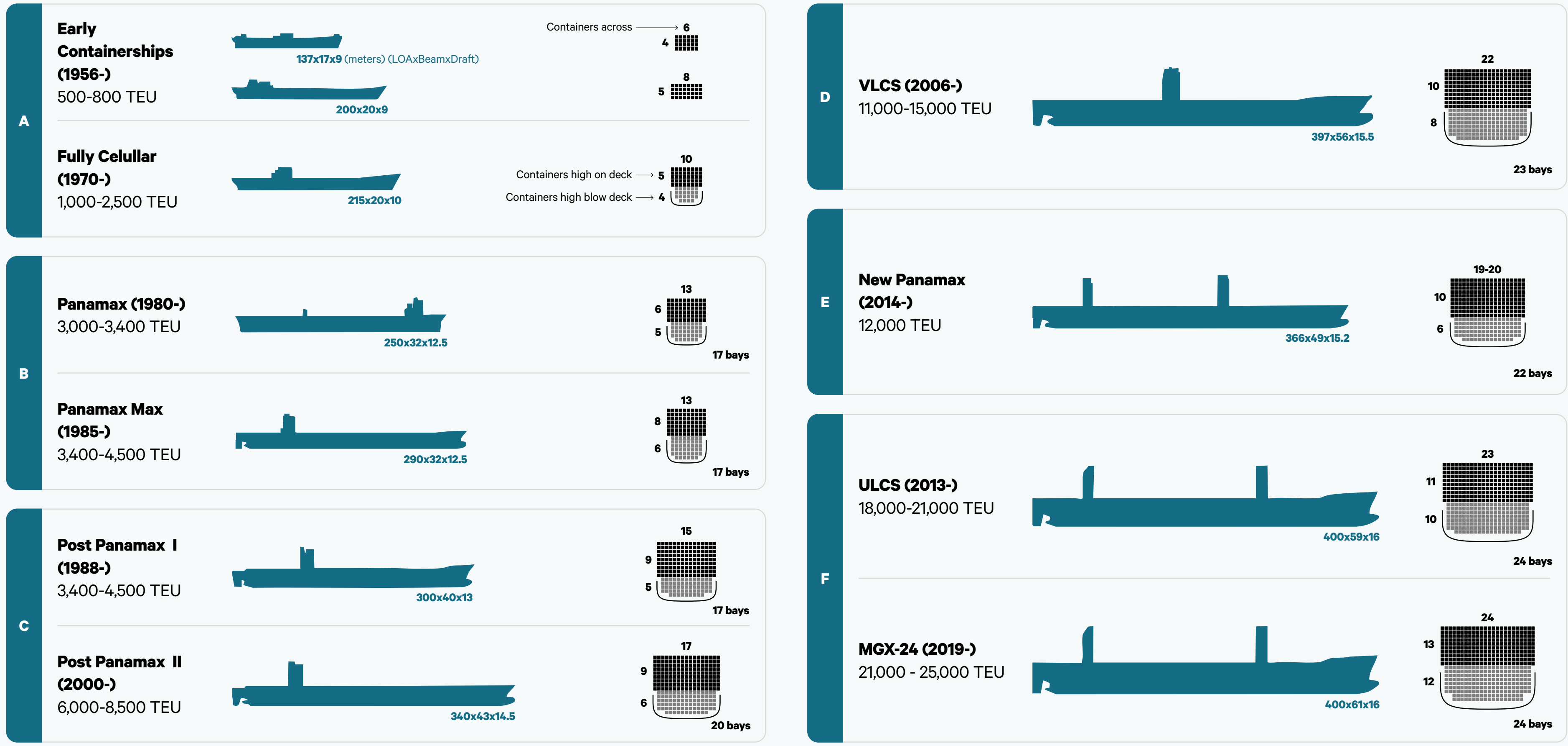
This trend towards larger vessels is also evident for alternative fuel powered vessels as lines seek to maximise the decarbonisation impacts from their associated vessel investments. For example, in the container segment, Maersk is investing in a fleet of dual-fuel vessels capable of running on methanol, aiming to reduce its carbon footprint and achieve net-zero emissions by 2040. The vessels are designed with varying levels of capacity:[51]

- 12 of the vessels on order have a capacity of 16,000 TEU.
- 6 of the vessels on order have a capacity of 17,000 TEU.
- 6 of the vessels on order have a capacity of 9,000 TEU.

Of note, all of these vessels exceed the scale of regularly calling container vessels at New Zealand ports.

Market engagement has indicated that while a limited number of smaller alternative fuel vessels exist, these are currently deployed in countries with strict regulations, highlighting the influence of regulatory frameworks on fleet choice and deployment.

Figure 5: Evolution of containerships



Source: The Geography of Transport Systems

3.4 | Fleet replacement

Aside from purchasing new vessels, shipping lines also have the option of retrofitting existing ships. A Transition Strategy study projected that by 2046, approximately 35,000 vessels will undergo retrofitting, representing nearly half of the global fleet by 2050. This anticipated demand is expected to exert considerable pressure on available shipyard capacity.[52]

Notwithstanding the potential for retrofitting ships, converting ships to operate on new fuels involves several challenges, particularly regarding technical complexity and costs, with estimates suggesting retrofitting a container vessel can exceed USD $30 million.[53] Substantial retrofit expenses can deter investment in older vessels with limited remaining lifetime and lower asset values. Additionally, design implications must be evaluated, as significant modifications to the engine and fuel systems may be required for compatibility with new fuel types. The availability of main engine fuel conversion kits also limits the number of candidates eligible for conversion. When assessing retrofit feasibility, shipping lines consider key factors such as the duration of conversion, off-hire costs during the retrofit, fuel price projections, potential emissions costs related to regulatory compliance, and the overall expenses associated with both engine and ship conversion.[54]

3.5 | Regulatory drivers of fleet/deployment

As stricter emissions regulations in regions such as Europe impose penalties on older, less environmentally friendly ships, shipping lines are likely to redirect these vessels to routes with less stringent environmental standards. This strategic allocation allows companies to avoid costly compliance measures and fines associated with operating in heavily regulated markets, incentivising the deployment of newer, cleaner vessels that can more easily meet regulatory requirements.

Market engagement indicated that redirecting older ships to less regulated areas enables shipping lines to optimise operational costs by utilising aging assets in markets that do not impose the same level of scrutiny or penalties. This, however, raises concerns regarding the environmental and economic impacts of increased emissions in these regions, and has been identified as a key concern in achieving a fair international transition. This strategy could lead to a disproportionate environmental and commercial burden on countries such as New Zealand that do not impose additional emissions regulations on shipping and do not have the same trading volume and values as other jurisdictions. Redirecting older ships to less regulated areas also potentially undermines local decarbonisation efforts, negatively impacts international reputation, and the cost efficiency of international marine supply chains, including via disproportionately attracting the recently agreed IMO GHG levies.

3.6 | Bunkering considerations

Shipping lines need to consider a range of factors regarding fuel type and bunkering locations. This includes relative cost, the volumetric energy density of alternative fuels, and implications for cargo space. The lower energy density of alternative fuels compared to conventional fuel oil necessitates larger fuel tanks to achieve the same operational range. Lower energy density can significantly reduce available cargo space, leading to potential cargo cannibalisation, where valuable cargo capacity is sacrificed for fuel storage.

The following table highlights the relative energy density of alternative fuel types.

Fuel type	Volumetric energy density [GJ/m³]	Storage pressure [bar]	Storage temperature [°C]
Marine gas oil	36.6	1	20
LNG	23.4	1	-162
Methanol	15.8	1	20
Liquid ammonia	12.7	1	-33
Biodiesel	35.6	1	4 – 21
Ethanol	23.5	1	15 – 25

Sources: Marine Methanol Future-Proof Shipping Fuel, Alternative Fuels Data Center - US Department of Energy, Biodiesel Handling Use Guide

Market feedback indicates that while shipping lines continuously review route configurations, bunkering will likely remain concentrated at established major ports, such as Singapore, where 18% New Zealand's exports, and 23% of its imports, went through as of 2023.[55] This reflects their current utilisation of major ports as bunkering locations, their scale of operations, available infrastructure and proposed developments to bunker alternative fuels.

Bunkering in New Zealand for international vessels has historically not been seen as commercially competitive, and more focused on Pacific Island services, dedicated coastal routes or as a backup option. Current market engagement suggests that establishing alternative fuel production or bunkering facilities for international shipping within New Zealand is unlikely, at least in the short term. Shipping lines anticipate being able to complete their journeys without needing to bunker in New Zealand, and alternative fuels are expected to be more cost-competitive elsewhere. Factors such as anticipated production scale, feedstock availability, lower energy costs, and direct financial support mechanisms contribute to this expectation.

4

Implementing a Green Corridor

4 | Key observations

- Green corridors offer the opportunity to target and accelerate progress in tackling decarbonising shipping.
- Green corridors can be a catalyst for change providing:
  - Offtake certainty to fuel providers and generating demand signals to vessel owners, engine manufacturers and shipyards.
  - Allowing policy makers to create an enabling ecosystem with targeted supporting initiatives.
  - Facilitating corridor specific arrangements such as cargo aggregation and other demand facilitation structures.
  - Enabling technology transfer and knowledge sharing via interaction with a range of stakeholders.
- Critically thinking about which routes to pursue is essential. In general, a favourable route should significantly contribute to global shipping's energy transition, while still being comparably feasible from an implementation standpoint within a reasonable timeframe.
- Enabling factors to the introduction of a green shipping corridor include:
  - alternative fuel availability;
  - fuel storage and bunkering;
  - supportive regulation;
  - alternative fuel capable vessels;
  - port infrastructure; and
  - sufficient cargo volumes and / or value.
- New Zealand has historically not been a major bunkering hub for international shipping with other locations offering better cost and fuel availably.
- Establishing an initial international green shipping corridor would require New Zealand focusing on accessing alternative fuel capable vessels, necessary upgrades of port infrastructure and cargo aggregation.
- Domestic policy incentives and regulations are important for creating visibility of national and sectorial strategies, facilitating demand via initiatives such as introduction of blending mandates, and the provision of economic support to help bridge the cost gap between conventional and low-to-zero emission marine fuels, while maintaining consistent safety standards.

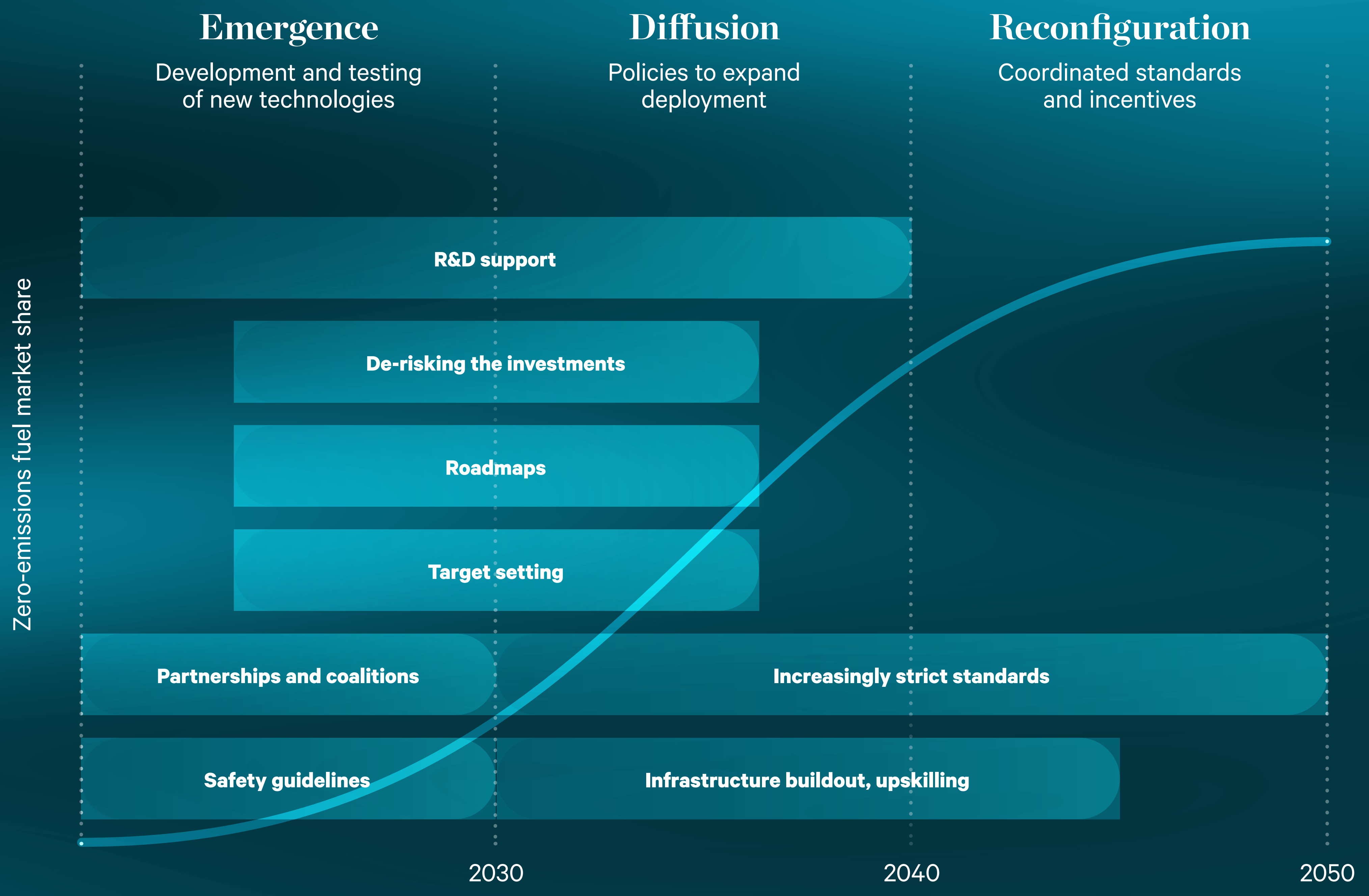
4 | Key observations

- Aside from regulations, such as the IMO GHG levy that directly seeking to address the fuel cost gap, further financial incentives and support may still be required to enable financing of alternative fuel infrastructure.
- The ability to pass on incremental costs associated with the use of low-to-zero emissions fuels has been challenging and may depend on the product being shipped.
- The World Economic Forum suggests that companies willing to invest in measures to reduce emissions are in reality risking little in terms of impact on end-consumer prices, even with ambitious upstream reduction targets, the impact on prices was found to be low – no more than 1-4% in the medium term if zero supply-chain emissions is the goal.
- Due to the international nature of shipping services, not all enabling factors for the introduction of a green shipping corridor need to be present in New Zealand.

4.1 | Green corridors can be a catalyst for change

Green corridors provide an opportunity to accelerate progress in tackling the challenges of decarbonising shipping.

As with other technological transitions, progress can be visualised using an S-curve, illustrating the nonlinear nature of the shift required. Shipping is currently in the 'emergence' stage, with green corridors being used to support policymakers in creating an enabling ecosystem for decarbonising shipping in this phase.[56]



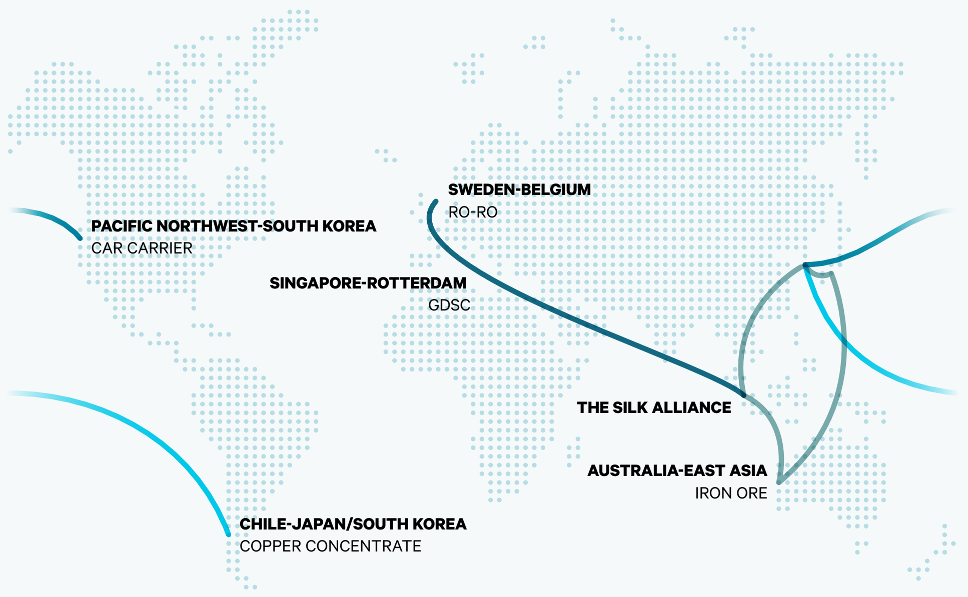
4.1 | Green corridors can be a catalyst for change

Green corridors can be a catalyst for change and can provide enough scale and volume to include all essential actors needed to establish low-to-zero emissions shipping, including fuel producers, vessel operators, cargo operators, regulatory authorities and ports. Some of the key advantages of establishing a green corridor are provided below.[57]

- Green corridors can provide offtake certainty to fuel producers, allowing for additional scaling of low-to-zero fuel production at one location.
- Green corridors can generate strong demand signals to vessel owners, shipyards and engine manufacturers to scale and catalyse investments in zero-emission shipping.
- Like special economic zones, green shipping corridors allow policy makers to create an enabling ecosystem with targeted, fit-for-purpose regulatory system and financial incentives.
- Green corridors may enable corridor-specific arrangements, such as joint ventures, demand aggregation structures, and emissions reduction credits and tracking mechanisms that lower the threshold for action throughout the value chain.
- Enabling technology transfer and knowledge sharing due to interaction with a range of stakeholders across the value chain and the sharing of transition risks.[58]

There is continued interest in green corridors, with a steady growth in green corridor initiatives. At least six initiatives globally have successfully completed an advanced exploration phase and are now at the stage of commercial action needed to realise introduction and operation of green corridors.

Figure 6: Initiatives known to have progressed to the preparation stage (as of October 2024)

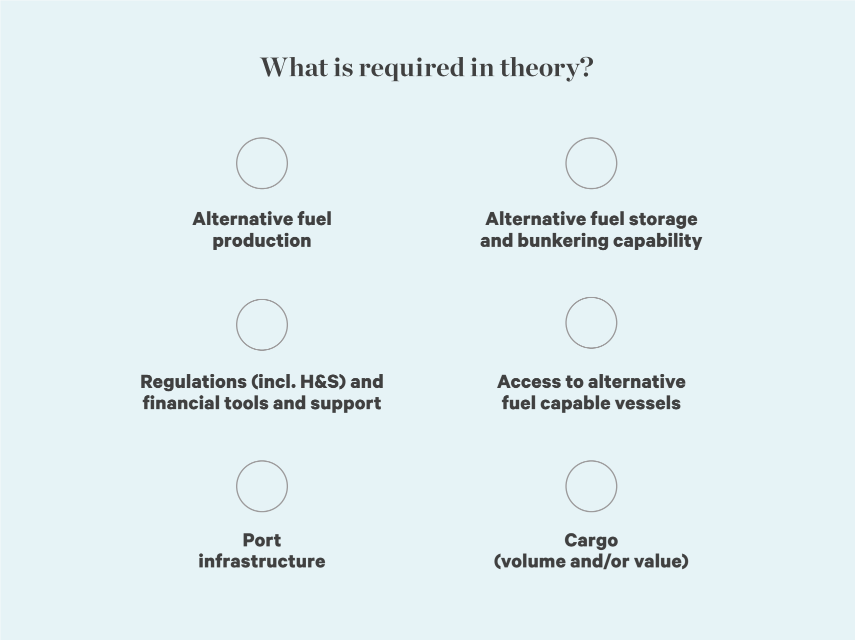


Source: Getting to Zero Coalition - Global Maritime Forum "Annual Progress Report on Green Shipping Corridors" (2024)

4.2 | Building blocks required to establish green corridors

To make a green shipping corridor a reality, there is a need to identify and address a range of enabling factors. These factors, drawn from market research and engagement, are illustrated in Figure 7 below and are discussed in further detail below.

Figure 7: Factors required to establish green corridors



Source: Deloitte

Alternative fuel production

Availability of low-to-zero emissions fuel that is scalable, relatively affordable and secure is a prerequisite to establishing green corridors. In its selection of candidates for green corridors, the availability of zero-emissions fuels was considered an essential factor by the Global Maritime Forum in a pre-feasibility study of 10 shortlisted shipping corridors. Illustrative of this, the Australia-Japan iron ore route was considered a high-potential candidate for a green corridor, in part due to favourable location for alternative fuel production (green hydrogen in Australia).[59]

At present, the production of alternative fuels for maritime shipping in New Zealand is limited:

- The use of biofuels in New Zealand is limited, especially as a transport fuel.[60] Market engagement highlighted instances of regional biofuel production at a smaller scale.
- The only methanol manufacturer is Methanex, based in Taranaki. Currently, they produce methanol from natural gas, a non-renewable source, and export around 95% of their production.[61] Production of green methanol is being explored by Hiringa Energy.[62]
- An ammonia-urea manufacturing plant, which is located at Kapuni in Taranaki, converts atmospheric nitrogen to ammonia and then to urea using natural gas from the region. This production is focused on producing fertiliser.[63] There are several companies and start-ups exploring opportunities to develop low-carbon ammonia.[64]
- While New Zealand has commercially produced natural gas since the 1950s, this is not processed into LNG and the conversion capability does not exist in New Zealand.

Market engagement also confirms that the extent of investment required to produce alternative fuels is significant, with large scale plants estimated to cost in excess of $1 billion USD. This estimated capital outlay excludes costs associated with additional renewable energy and supporting infrastructure.

4.2 | Building blocks required to establish green corridors

To potentially accelerate the early phases of alternative fuel production, it is worth highlighting the book and claim system.[65] It is a certification method in maritime decarbonisation, separating environmental benefits from the physical distribution of fuels. This decoupling allows for early emission reduction actions, even amidst limited low-to-zero emission fuels and vessels, by enabling stakeholders to purchase credits representing cleaner fuel use without direct consumption. This flexibility enables the aggregation of international demand and eases the burden of developing port infrastructure to cater for large vessels and avoids logistical issues of rerouting vessels.

For shippers, shipowners, and fuel providers, the system offers a compelling business case for decarbonisation. It allows them to participate in the green economy, enhancing brand value and competitiveness while expanding market opportunities for alternative fuels. The success of this emerging voluntary market hinges on customer confidence, necessitating verifiability and consistency to ensure transparency and trust in environmental claims.

With the IMO GHG levy set to take effect in 2027, there will be an increased incentive for shippers to reduce emissions. Book and claim systems offer a promising early mechanism to meet IMO GHG levy compliance targets. However, details on how the IMO GHG levy will interact with book and claim systems will need to be determined.

Alternative fuel storage, handling, and bunkering capability

For green corridors to succeed, they must incorporate the necessary storage and bunkering infrastructure for low- to zero-emission fuels. The infrastructure requirements vary based on the type of alternative fuel. Biofuels, for example, require minimal modifications to existing systems, making their integration relatively straightforward. Conversely, fuels like ammonia demand significant infrastructure upgrades due to their toxic and corrosive nature.

Globally, key players in international shipping bunkering include Singapore, the United States, the UAE, the Netherlands, Russia, South Korea, and China. Container shipping alone consumes over 25% of the energy in international shipping, while bulk carriers account for nearly another 25%. The remaining 50% of energy consumption comes from oil, liquefied natural gas, chemical tankers, and other sources.[66]

Historically, New Zealand has not been a significant producer of marine fuels, driven primarily by the scale required to be a cost-effective producer. Bunkering has also not historically occurred at scale in New Zealand for this reason, and due to the distance that New Zealand is from larger markets and trading routes. According to Energy NZ, only about 4.0 PJ/y of fuel oil is used for international shipping in New Zealand, all imported from overseas refineries.[67] This is equivalent to approximately 24,000 tonnes. However, international vessels operating in the Pacific do bunker at the Port of Auckland. Overall, New Zealand lacks the scale of existing bunkering infrastructure that major ports, such as Singapore, currently possess.

4.2 | Building blocks required to establish green corridors

Illustrative of this, the Port of Singapore exceeded 1 million tonnes of alternative fuel sales in 2024. In particular: [68]

- Sale of biofuels grew from 0.52 million tonnes in 2023 to 0.88 million tonnes, with biofuel blends of up to B50 available commercially, with trials of B100 ongoing.
- Sale of LNG increased from 0.11 million tonnes in 2023 to 0.46 million tonnes in 2024.
- Methanol was available on a commercial scale and registered 1,626 tonnes of sales.
- 9.74 tonnes of ammonia was bunkered for the first time globally in trials in the Port of Singapore.

While access to alternative fuels is a key requirement for establishing a green shipping corridor, a range of potential options can exist, as the following case study demonstrates.

4.2 | Building blocks required to establish green corridors

CASE STUDY

Scenarios for the establishment of the Australia-East Asia iron ore green corridor [69]

Following the identification of iron ore shipping routes between Western Australia and East Asia as high-potential candidates for establishing a green shipping corridor powered by zero or near-zero carbon ammonia, a task force of 15 industry representatives from across the value chain was convened under the Getting to Zero Coalition to explore the implementation of the corridor.

A May 2023 feasibility study by four task force members found that the availability of ammonia-powered ships, access to zero or near-zero carbon ammonia, and the availability of bunkering infrastructure could, given a set of conditions, be in place to enable the corridor's kick off by 2028 and achieve 5% uptake of zero or near-zero carbon ammonia on the route by 2030, in line with the IMO's fuel uptake target in its revised GHG strategy.

The wider task force also produced a shared roadmap identifying the actions needed to realise these goals. Meanwhile, many of the individual companies signalled their willingness to act by initiating activities related to the ordering of ammonia-powered vessels and services, production of zero or near-zero carbon ammonia, and development of bunkering infrastructure.

A critical barrier to realising this green corridor, however, was the significant cost gap of running a ship on zero or near-zero carbon ammonia versus conventional marine fuel. The global production cost of zero or near-zero carbon ammonia is forecast to be significantly more expensive than conventional marine fuel through at least 2030, and an independent, third-party assessment has been undertaken to further explore the cost gap ranges for this specific corridor. This cost differential has created a substantial gap in the business case for green shipping corridors and is recognised as the main area where government intervention is likely to be required to progress this initiative.

As part of the proposed development of the Australia-East Asia iron ore green corridor, the Getting to Zero coalition developed a positioning paper, outlining three different scenarios for how the corridor could be implemented and a menu of policy options for consideration by the Australian government. The following highlights the availability of options for associated bunkering requirements.

The scenarios included:

- Delivering the corridor using Australian produced zero or near-zero carbon ammonia. Iron ore carriers from Western Australia to East Asia would bunker Australian-produced zero or near-zero carbon ammonia directly at their ports of origin in the Pilbara bunkered in the Pilbara.
- Delivering the corridor using Australian produced zero or near-zero carbon ammonia bunkered in Singapore. Iron ore carriers from Western Australia to East Asia would sail via the established bunkering hub of Singapore, fuelling with Australian-produced zero or near-zero carbon ammonia.
- Delivering the corridor using internationally sourced zero or near-zero carbon ammonia bunkered in Singapore. Iron ore carriers from Western Australia to East Asia would sail via the established bunkering hub of Singapore for fuelling. Shippers on the corridor would be free to bunker zero or near-zero carbon ammonia from any available source.

4.2 | Building blocks required to establish green corridors

Implementation of appropriate handling regulations and protocols for alternative fuels is also necessary for fuel storage, handling and bunkering, given the potential risks such as volatility, toxicity, and environmental hazards associated with these fuels. Ensuring robust safety measures is paramount to mitigate these risks and protect both works and the environment.

Access to alternative fuel capable vessels

Fundamentally, green shipping corridors require access to alternative fuel capable vessels. While it is clear there is a transition towards alternative fuel capable vessels, the transition to ships operating on alternative fuels, however, will be gradual. Securing ships able to operate on alternative fuels is likely to be a challenge, especially considering the increase in demand for low-to-zero emission vessels that is likely to occur with the implementation IMO GHG levy from 2027 onwards.

While there has been no regular use of alternative fuel powered vessels in New Zealand, there have recently been trials of transporting goods, as the case study below demonstrates.

4.2 | Building blocks required to establish green corridors

CASE STUDY

Zespri's biofuels shipping trial [70]

FCC, one of the international shipping partners of Zespri, recently completed a trial using biofuel in a charter vessel operating between Hong Kong and New Zealand. The purpose of the trial was to test the performance of the ship's engines when burning biofuel. This voyage was the first commercial shipment of Zespri kiwifruit using modern engines burning biofuel for the entire voyage from Tauranga to Shanghai. *Kakariki* was monitored throughout its journey to make sure the biofuel performed well with no unforeseen technical issues.

The vessel *Kakariki* bunkered biofuel in Hong Kong before starting its voyage south, arriving at the Port of Tauranga. The vessel was powered by a blend of biofuel made from used cooking oil. The *Kakariki* bunkered the biofuel in Hong Kong because of a lack of availability in New Zealand.

The biofuel vessel trial was motivated by a desire to reduce Zespri's emissions. International shipping accounts for around 43% of its emissions footprint for fruit sold globally, which makes up a larger part of its emissions profile compared to other primary sector exporters, given the low-emissions nature of its products.

Zespri has noted that while it has limited ability to directly reduce shipping emissions, they are working with key shipping and distribution partners like FCC to increase the efficiency of shipping and logistics and make the transition to low emissions fuels. Zespri also acknowledged that biofuel supply chains are complex and that there is still work to be done to ensure stable supply and that New Zealand's place at the bottom of the South Pacific Ocean means accessing low emissions fuel options is a challenge.

4.2 | Building blocks required to establish green corridors

Port infrastructure

At present, many container vessels visiting New Zealand are Post Panamax sized vessels, which have a capacity of up to 6000 TEUs and require a draught at port of between 13-14.5 metres. Some vessels are nearing the end of their useful life. As shipping lines look to replace the vessel fleet servicing New Zealand, and ongoing supply chain efficiencies are sought, larger vessels will continue to be introduced, impacting associated port infrastructure requirements.

With an observed trend towards the ordering of larger alternative fuelled vessels, establishing green corridors will therefore require compatible port capacity (i.e., draught and container handling infrastructure). The continued introduction of larger capacity vessels will also likely impact domestic supply chains and freight movements, with a limited number of ports able to justify investment and the requirements for aggregation of cargo (via road, rail and / or coastal shipping) to achieve scale economies.

Regulations, financial tools and support

Globally harmonised regulatory and certification frameworks are essential for the global uptake of the inherently international shipping sector.[71] Domestic policy incentives and regulations are also important for creating visibility of national and sectorial strategies, facilitating demand via initiatives such as the introduction of blending mandates, and the provision of economic support to help bridge the cost gap between conventional and low-to-zero emission marine fuels while maintaining consistent safety standards. The maritime industry's global nature means governance primarily falls under international regulations set by the IMO. Accession to IMO conventions is vital for ensuring policy and safety regulation consistency across countries.

Concerns have also been raised in relation to the importance of achieving an equitable fuel transition pathway. Illustrative of this, significant public funding for hydrogen-related investments in Europe and North America may disadvantage projects in emerging markets and developing economies. IRENA highlights a widening disparity in the availability of renewable energy financing between developed and developing countries, making competition increasingly challenging.[72] Additionally, geographical location plays a significant role in a country's ability to become a major fuel supplier; proximity to key markets offers competitive advantages through easier and more cost-effective access as does availability of requisite feedstocks and renewable energy sources.

Local regulations and incentives

Local regulations and incentives also have an important role to play in enabling green corridors. Local regulations and incentives can create an enabling ecosystem for the production and deployment of alternative fuels and associated storage, bunkering and port infrastructure.

- Emission reduction policies locally, such as New Zealand's emissions trading scheme (ETS) act to provide both demand and supply side signals for renewable energy, with cost-effective renewable energy a key requirement for the production of alternative fuels at scale. Strong signals from emission reduction policies can also elicit supply-side responses for necessary biogenic carbon feedstock supply, needed for the production of alternative fuels such as green methanol and biofuels.

4.2 | Building blocks required to establish green corridors

- Market engagement has suggested that New Zealand's ETS policies are currently not stringent enough to provide appropriate demand and supply signals for renewable energy. Feedback noted that a higher emissions price is needed to create further demand for renewable energy, which would elicit supply side responses for the supply of renewable energy and alternative fuels and necessary biogenic carbon feedstock supply.
- As previously indicated, the Climate Change Commission has also recommended the inclusion of international shipping in New Zealand's emissions reduction targets.
- Financial incentives, such as development capital, production tax credits or contract for differences can act to de-risk investment in production of low-to-zero fuels.
- Market engagement noted that the cost gap between low-to-zero and conventional fuels creates financial risk. Uncertainty around feedstock supply, technology maturity and secure offtake, further add to risk considerations. Market feedback suggested that, aside from regulations, such as the IMO GHG levy, financial incentives and support may still be required to address the cost gap and enable financing of alternative fuel infrastructure.

In addition to differences in fuel cost, other financial considerations of transitioning international shipping to low-carbon fuels include new build vessel construction costs and existing fleet retrofitting requirements, provision of supporting port / bunkering infrastructure, profit margins and incremental cost absorption capacity, and market willingness to pay. For example, the Global Maritime Forum estimates approximately $3.2 trillion in investment, supported by effective regulation and subsidy schemes, is needed for the low-carbon transition in the near term.[73]

4.2 | Building blocks required to establish green corridors

CASE STUDY

Use of financial incentives to de-risk investment in production of low-to-zero carbon fuels

The cost gap between low-to-zero carbon and conventional fuels creates uncertainty and risk, which can hinder financing and therefore investment in and deployment of alternative fuels. Countries have deployed differing financial incentives and support mechanisms to overcome these barriers:

Revenue support – Hydrogen Headstart Program (Australia) [74, 75]

Australia's Hydrogen Headstart program is a revenue support program for large-scale renewable hydrogen projects. The program has $4 billion AUD of funding, with a further $2 billion AUD announced for an additional funding round in the 2024-25 Federal Budget of May 2024. A range of Australian projects with a focus on producing hydrogen or derivative products such as ammonia or methanol using renewable energy will be selected for funding over the lifetime of the program. Prospective recipients must apply for the funding, with the government selecting successful applicants from this pool.

The funding is provided as a production credit which is intended to cover some of the commercial gap between the cost of producing renewable hydrogen and its incumbent market price. Importantly, this means that funding is only provided once the project is fully constructed and operational, rather than a subsidy of constructing the infrastructure itself. Funding is only released to the recipient once commercial operation of the project commences.

As an example in March 2025, Copenhagen Infrastructure Partners' (CIP) 1,500MW Murchison Green Hydrogen Project in Western Australia received $814 million AUD of funding. This funding is intended to support the plant to produce renewable hydrogen and ammonia using on-site wind and solar energy through electrolysis.

Development Capital and Contract for Differences – Hydrogen Society Promotion Act (Japan)

The Hydrogen Society Promotion Act is a 2024 Japanese law regulating businesses whose operations involve hydrogen and its derivatives. The Act aims to increase the use of green hydrogen and its derivative products.[76] It does so using two levers of support for businesses:[77]

1. Contract for differences (CfD): A subsidy equal to the differential of the base price for clean hydrogen or ammonia and the 12-month average price of grey hydrogen or ammonia respectively. In order to be eligible for CfD funding, the recipient must supply at least 1,000 tons of hydrogen per year.
2. Development Costs (DEVEX): A subsidy for the DEVEX of infrastructure required for the transportation and storage of green hydrogen. The facility must be used by at least two green hydrogen users, and the supply volume must be at least 10,000 tons per year to meet the eligibility criteria for funding.

4.2 | Building blocks required to establish green corridors

CASE STUDY

Use of financial incentives to de-risk investment in production of low-to-zero carbon fuels

Applicants for CfD and DEVEX subsidies must apply as a consortium which includes both a supplier of the hydrogen product and an end user of that product. This provision is intended to ensure there is a fully integrated value chain of clean hydrogen and ammonia in Japan. The program is worth ¥3 trillion JPY, or approximately $35 billion NZD. It is targeted towards sectors that have high abatement costs such as steel, chemicals and transportation. The policy does not stipulate that green hydrogen must be produced in Japan to be eligible for subsidisation, only that it is used in Japan.

Production tax credits – Inflation Reduction Act (United States of America)[78]

The United States' Inflation Reduction Act (IRA) was signed by then President Joe Biden in 2022. A key aim of the IRA was to boost America's supply of clean energy, which has implications for the production of green shipping fuels. These fuels include e-ammonia, e-methanol and e-methane – all of which are derivatives of hydrogen. Clean hydrogen is eligible for a Clean Hydrogen Credit called the 45V credit under the IRA, valued at up to $3 USD per kilogram. The credit will be scaled between 20% and 100% of this maximum value depending on the CO_2e per kilogram of hydrogen produced at a qualifying green hydrogen facility. This credit will lower production costs and incentivise greater supply of green hydrogen in the United States, and green shipping fuels by extension.

In addition to this direct subsidy, other incentives such as renewable electricity credits and R&D funding also provisioned under the IRA can further reduce barriers to investment in and production of green hydrogen.

4.2 | Building blocks required to establish green corridors

Sufficient volume and / or value of trade

Identification of shipping lanes with high traffic volume and emissions, demand for low-to-zero emission shipping, and a limited number of key actors for collaboration, will support the aggregation of sufficient trade cargo volume and / or value, as a key requirement for the establishment of a feasible green corridor.

The presence of high volume and/or value of trade was an explicit criterion in the Global Maritime Forum's pre-feasibility study of shortlisted shipping corridors.[79]

The Australia-Japan iron ore route and Asia to Europe containerships route were identified as high-potential green corridor candidates due to high share of global trade volumes.

In contrast was the selection of the Asia-US automotive shipping corridor. While volumes were low on this route, the value of the traded goods was high, with strong stakeholder willingness to engage in decarbonisation, coupled with strong end-consumer alignment, given the shift towards electric vehicles.

The focus on the value of traded goods directly relates to the economic impact of adopting low-to-zero emissions alternative fuels for shipping. A barrier to the adoption of low-to-zero emissions fuels is the current cost gap between such fuels and conventional fossil fuels. While regulations, such as the IMO GHG levy, aim to close the gap between low-to-zero emissions and fossil fuels, there is a question of what end consumers will be willing to pay for the increased cost associated with transportation using low-to-zero emissions fuels. Market engagement suggests an unwillingness or inability to pass-on the increased costs associated with alternative fuels in the value chain.

However, the ability to pass on incremental costs associated with the use of low-to-zero emissions fuels may depend on the product and maritime segment in question. Analysis by the World Economic Forum suggests that companies willing to invest in measures to reduce emissions are in reality risking little in terms of impact on end-consumer prices.[80] Even with ambitious upstream reduction targets, the impact on prices was found to be low – no more than 1-4% in the medium term if zero supply-chain emissions are the goal.

Figure 8: Estimated cost on end consumer prices for zero upstream emissions in the medium term

€500
Automotive
<2% avg. cost increase on a €30k car

€1
Fashion
<2% avg. cost increase on a €40 pair of jeans

€1
Food
<4% avg. cost increase on a €20 shopping basket

€5k
Construction
<3% avg. cost increase on a €150k home

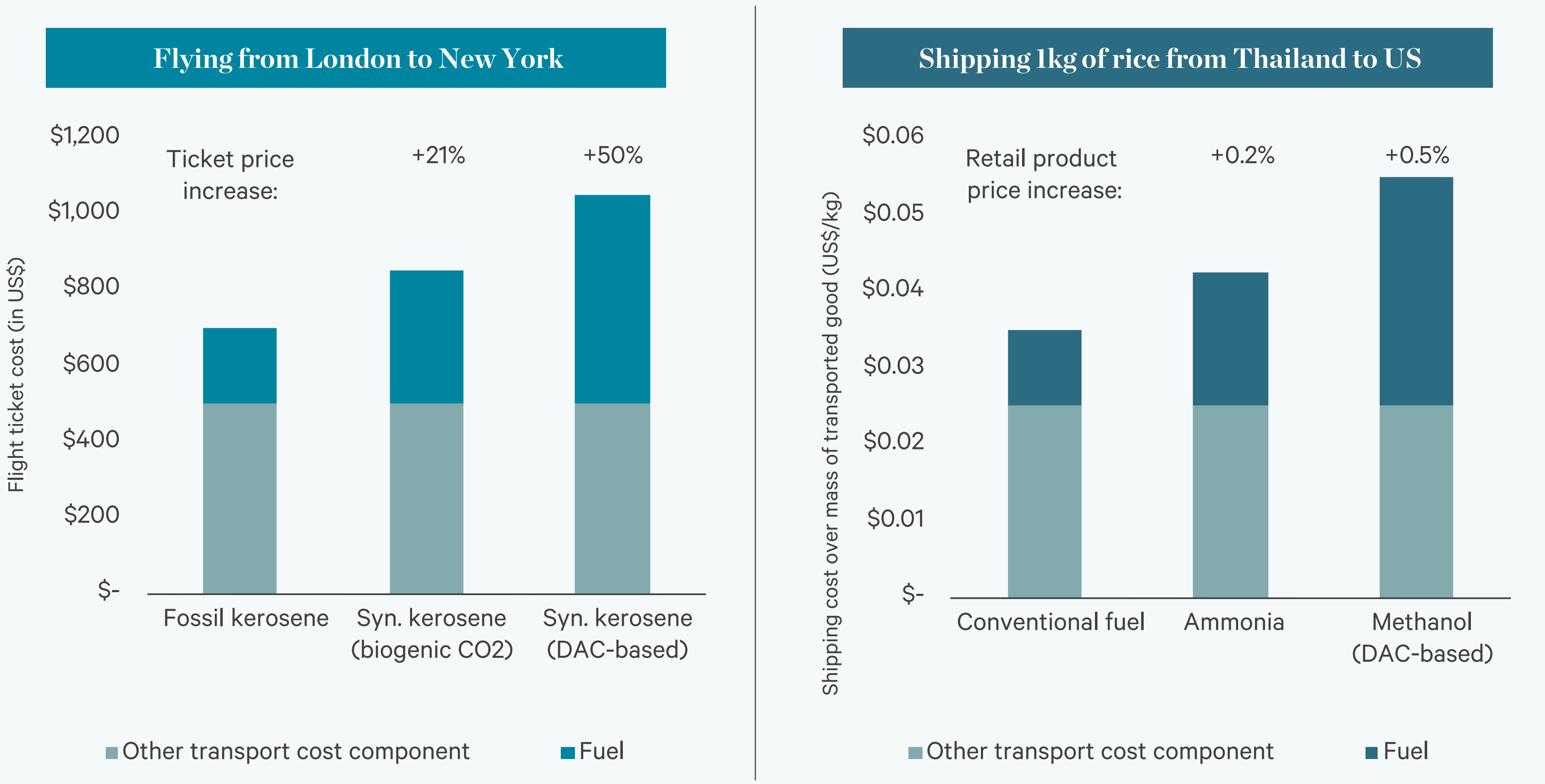
€3
Electronics
<1% avg. cost increase on a €400 personal device

Source: World Economic Forum

4.2 | Building blocks required to establish green corridors

The increase in cost from adopting low-to-zero emission fuels for the maritime sector is also likely to be less than sectors such as aviation, where fuel costs represent an important part of air travel fares, accounting for about 25-30% of airplane ticket prices. In contrast, since transport costs make up a small fraction of the final price of goods shipped by sea, end consumers are far less impacted by fuel price fluctuations in the maritime sector.[81]

Figure 9: Cost implications of switching to synthetic fuels in aviation and shipping on transportation costs and final products[82]

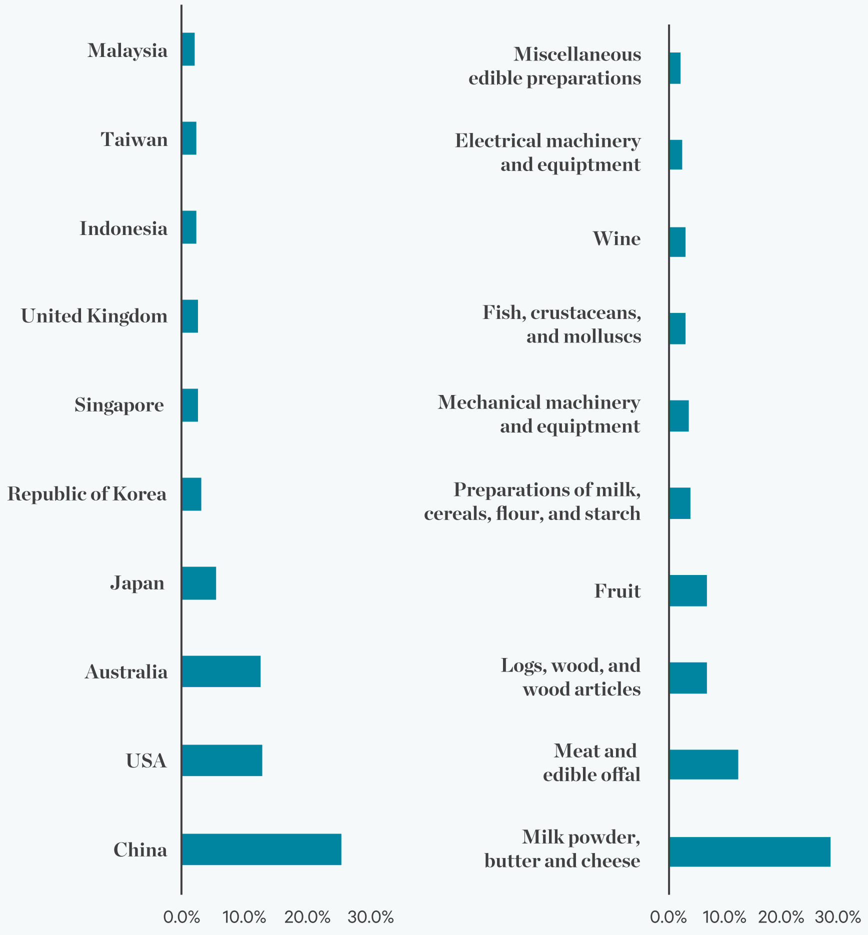


Source: Deloitte Low-carbon fuels: The last mile to net zero – The role of synthetic fuels in decarbonizing the skies and the seas" (November 2024)

4.2 | Building blocks required to establish green corridors

New Zealand's exports are relatively concentrated, with 54% of all exports by value being concentrated in milk powder, butter and cheese (35.6%), meat and edible offal (13.8%), logging products (6.7%) and fruit (6.7%) as of year ended December 2024. New Zealand's exports also go to relatively few destinations, with 50.3% of all exports by value going to China (25.1%), the United States (12.7%) and Australia (12.5%).[83] In addition, significant international cargo volume logistics are actively managed by key parties. For example, Kotahi manages approximately 30% of New Zealand container volumes.[84] These factors support the potential for cargo aggregation opportunities.

Figure 10: Top 10 merchandise and destinations for exports by value, year ended December 2024

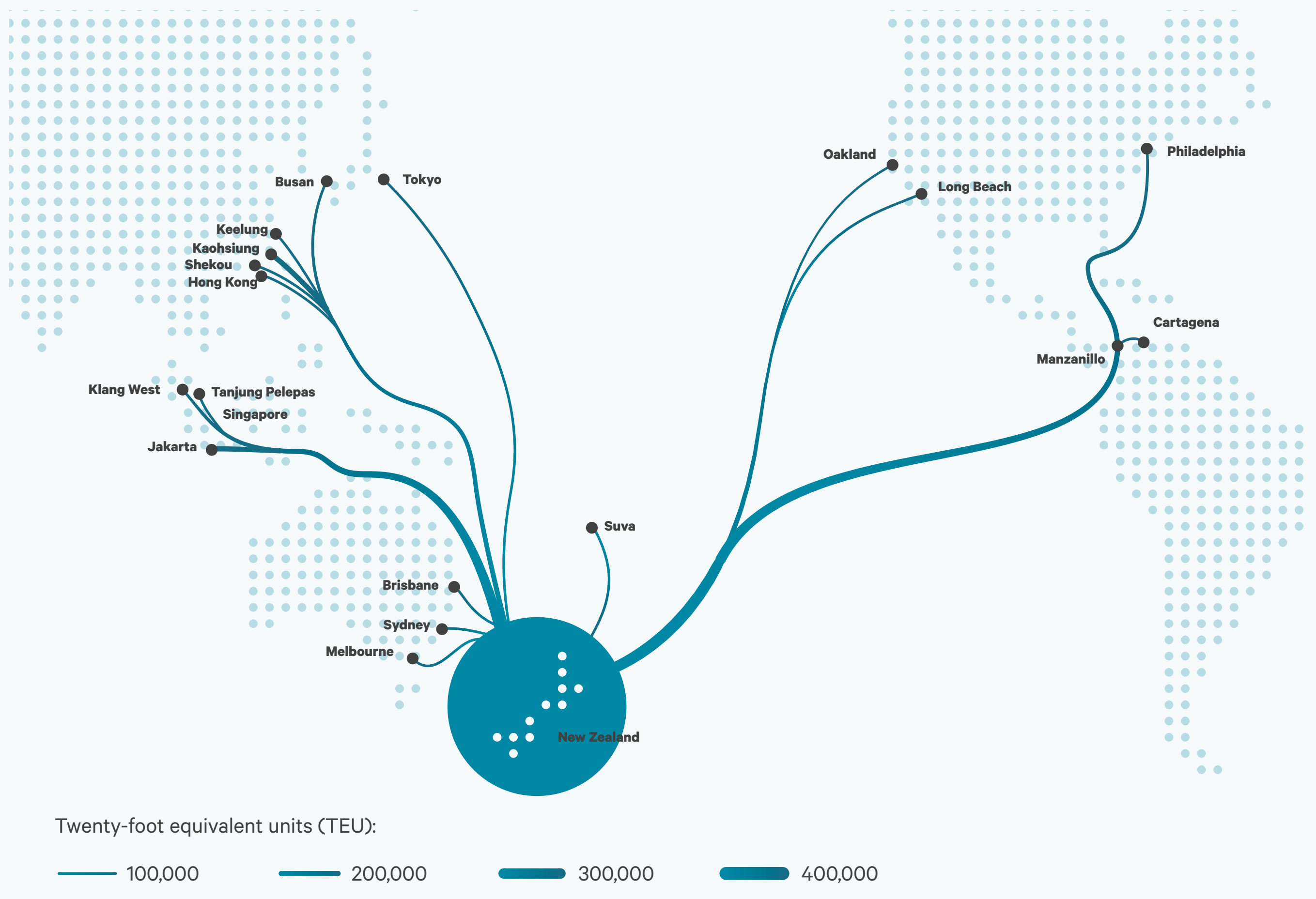


Source: StatsNZ

The potential for cargo aggregation may be further supported by the nature of New Zealand's shipping flows. Analysis undertaken by the Ministry of Transport as part of its Freight and Supply Chain Strategy Issues Paper in 2022 noted that containerised trade flows were somewhat centred through or to South East Asia, with 40% of containerised exports and 34% of containerised imports shipped through or to South East Asia, as demonstrated by the figures below. New Zealand's containerised export and import flow is valuable, accounting for 75% of the value of all sea trade in 2024.[85]

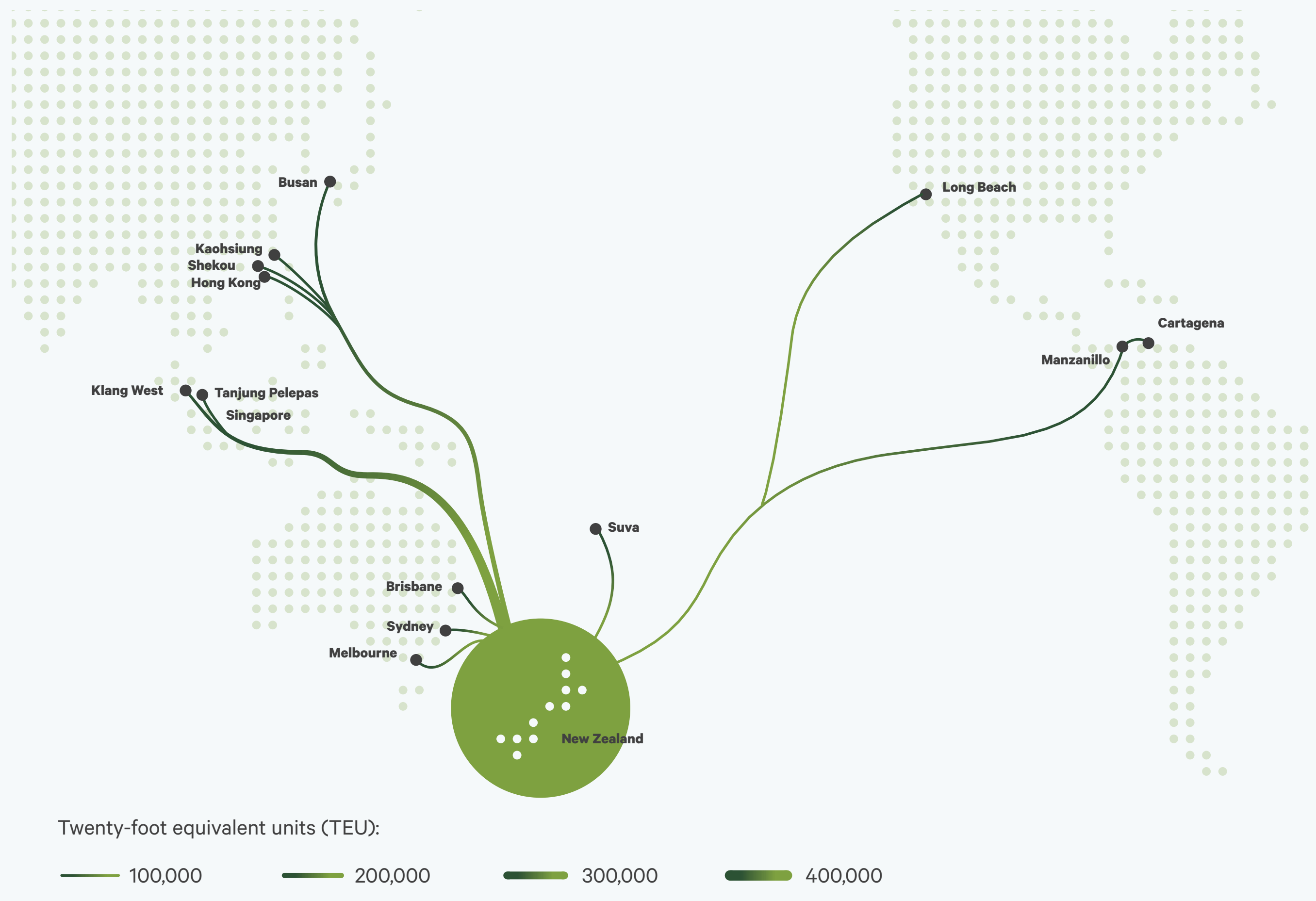
4.2 | Building blocks required to establish green corridors

Figure 11: New Zealand export flow to the next international port



Source: Te rautaki ueā me te rautaki whakawhiwhinga o Aotearoa I New Zealand freight & supply chain issues paper" (April 2022)

Figure 12: New Zealand import flow from the last international port



Source: Te rautaki ueā me te rautaki whakawhiwhinga o Aotearoa I New Zealand freight & supply chain issues paper" (April 2022)

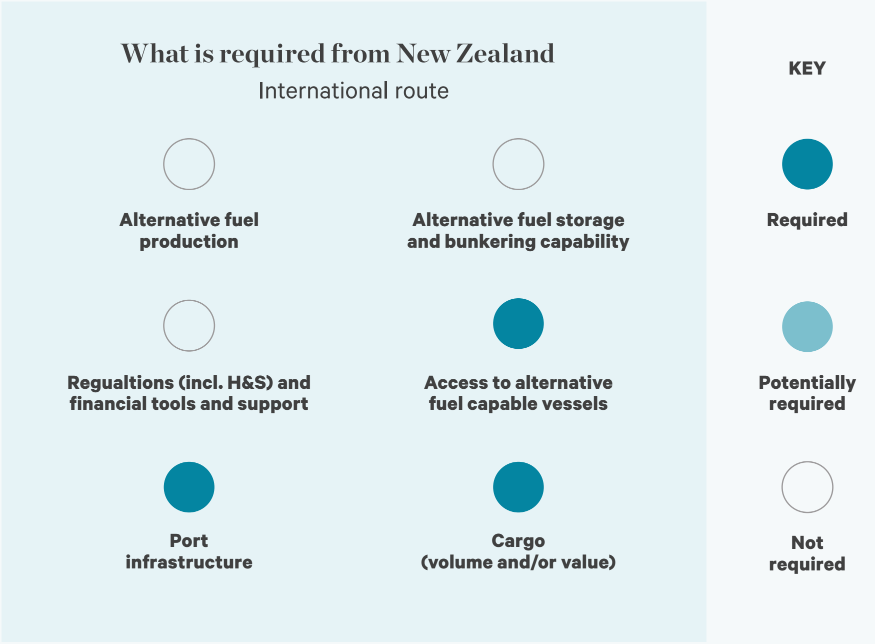
4.3 | The opportunity to establish an international green corridor

While the factors discussed on the previous pages are important for establishing green shipping corridors, the international nature of many shipping services means that they do not all need to be present in New Zealand to progress the establishment of a green shipping corridor.

New Zealand could seek to accelerate the establishment of an international green shipping corridor by focusing on selected critical success factors. These include:

- **Cargo aggregation:** Identifying and aggregating sufficient volume and value of traded goods. Doing so could provide the scale of cargo that would enable larger, alternative fuel powered vessels to economically visit New Zealand, whilst also improving the likelihood that end consumers are willing to pay for the extra cost associated with alternative fuels.
- **Port infrastructure:** Ensuring port infrastructure is able to cater for alternative fuel powered vessels. If bunkering of fuel is provided elsewhere in an international service, alternative fuel storage and bunkering are not a local prerequisite, and port infrastructure requirements would therefore be limited to ensuring channel depth and berth space is available to accommodate these vessels. In addition, associated bunkering related health and safety / training considerations would be avoided.
- **Access to vessels:** Working with shipping lines to access alternative fuel capable vessels.

Figure 13: Factors required within New Zealand to establish an international green shipping corridor



Source: Deloitte

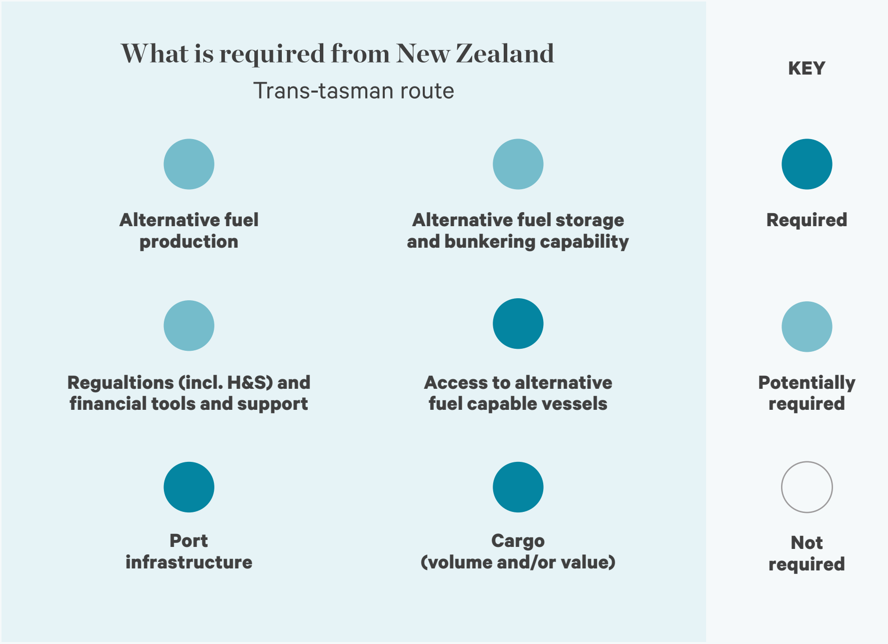
4.4 Establishing a dedicated trans-Tasman green shipping corridor

The factors needed to establish a dedicated trans-Tasman green shipping corridor also include aggregating sufficient volume and value of traded goods, ensuring port infrastructure capacity and accessing alternative fuel capable vessels.

There are, however, additional considerations to enabling a dedicated trans-Tasman green shipping service (i.e. outside of a larger international service) including:

- A dedicated trans-Tasman service would need to consider the **production / sourcing, storage and bunkering of alternative fuels**, noting trans-Tasman schedules as part of a longer international voyage will have alternative international bunkering options.
- If production, storage and bunkering of alternative fuels is required, **a conducive regulatory ecosystem**, covering health and safety regulations around the handling of alternative fuels and regulatory incentives and support to incentivise investment in alternative fuel production, storage and bunkering infrastructure, would also be needed.
- **Access to alternative fuel vessels of appropriate scale** in relation to dedicated trans-Tasman services requirements. Current dedicated container services vessels range from ~1,000 to 2,700 TEUs.[86]

Figure 14: Factors required to establish a dedicated trans-Tasman green shipping corridor



Source: Deloitte

5

Introduction to Alternative Fuels

5 | Key observations

- There is no single solution – a multi fuel strategy will be adopted through 2050 by shipping companies.
- A multiple fuel future increases the complexity and timing of decarbonising the maritime industry, given interdependences between industry stakeholders and multiple fuel supply chains.

Biofuels

- Emerging as a key transitional fuel for the shipping industry, however, limited production capacity and competing demands mean that they will not be the answer in isolation.
- Production in New Zealand is currently limited; however, some scale production opportunities are currently being investigated.

Ammonia

- Domestically focussed on fertiliser production with green ammonia production relying on green hydrogen and renewable energy availability (as is the case for other hydrogen-based fuel derivatives).
- Ammonia production processes are proven efficient and scaled, offering cost advantages relative to other fuels.
- Near term market demand for low-carbon ammonia in maritime applications remains uncertain, especially with competition from other alternative fuels, reflecting relative bunkering, safety and vessel design requirements.

5 | Key observations

Renewable methanol:

- Is increasingly recognised as a viable alternative fuel in the transition towards resilient maritime transport, driven by significant reductions in emissions of nitrogen oxides, sulphur oxides, and particulates.
- Similar to conventional marine fuel in terms of handling and hazards, though it has about half the volumetric energy density, meaning about twice the amount of onboard storage is required.
- In New Zealand, the only methanol manufacturer is Methanex, based in Taranaki. Currently, they produce methanol from natural gas, a non-renewable source, and export around 95% of their production.
- While the technological capability to produce green methanol in New Zealand exists, significant economic and infrastructural challenges impact its feasibility at a large scale.

LNG

- Is increasingly recognised as a viable alternative marine fuel, particularly in the context of global shipping's near-term transition towards decarbonisation.
- Is already used as a marine vessel fuel, though mostly for LNG tankers.
- When considering the combustion of LNG alone, there may be up to a 20% emissions reduction compared to fuel oil, although when considering 'well-to wake' emissions the savings could be negated.
- Potential LNG production faces significant challenges with natural gas supplies declining, gas is not currently converted into LNG domestically, and liquefaction facilities are most economic when built for the bulk export of LNG.
- Importing LNG is being investigated in light of reducing domestic gas supplies. However, the economic viability of this is also under scrutiny.

5.1 | Overview

This section of the report provides a high-level overview of four prospective alternative deep sea marine fuels: methanol, biofuels, ammonia, and liquefied natural gas. Further detail is provided in the Appendix, providing insights into production pathways, infrastructure needs, and feasibility factors for each fuel.

Battery electric was not considered as a deep sea fuel option primarily due to the much lower energy density of batteries, making them more suitable for short-range maritime applications, where space and weight constraints are less critical.

5.2 | Biofuels

Biofuels are emerging as a key transitional fuel for the shipping industry, playing a significant role in the sector's decarbonisation efforts.

Their lower GHG, nitrogen oxides, and sulphur oxides footprint, as compared to conventional marine fuels, plays a significant role in its uptake. Another key advantage of biofuels is their "drop-in" characteristics and compatibility with existing infrastructure, reducing relative cost when compared to alternatives.

As the demand for cleaner fuels grows, biofuels are expected to see a substantial increase in consumption, with projections indicating a rise from 16.5 million metric tons in 2023 to 58 million metric tons by 2030 globally. This growth is driven primarily by the aviation and maritime sectors, which are anticipated to account for over 75% of new biofuel demand.[87]

Biofuel production is also projected to grow, reflecting a broader shift towards renewable energy sources in transportation. The share of biofuels in total liquid transport fuel demand is expected to increase from 5.6% to 6.4%, equivalent to approximately 215 billion litres.[88] This transition not only supports the shipping industry's decarbonisation goals but also promotes a circular economy through the use of sustainable feedstocks, such as waste oils and non-food biomass.

However, the shipping industry faces significant challenges concerning the adoption of biofuels, due to escalating competition for biomass and biofuels from sectors like aviation, which are also seeking cleaner energy sources to meet decarbonisation goals and may be willing to pay a higher price for the fuel. This competition intensifies the difficulty for shipping to secure its fuel needs, potentially leading to increased prices as demand outpaces supply. The availability and scalability of feedstock further complicate matters, as limited resources must be efficiently allocated, often prioritised by policy and market drivers towards sectors deemed more critical or impactful.

Such prioritisation could restrict shipping's access to necessary biofuels, and benefit sectors like aviation that currently have limited viable alternative fuel options. Additionally, the economic viability of producing biogenic fuels imposes a ceiling on production, where costs can limit extensive scaling. As these biofuel resources approach exhaustion, alternative pathways like methanol production may emerge, offering the industry new avenues to explore for sustainable operation.

5.2 | Biofuels

Biofuels in New Zealand

Currently, the use and production of biofuels in New Zealand is limited.[89]

New Zealand's use of biofuels comprises less than 0.1% of its total fuel use. New Zealand's production of biofuels between 2007 and 2022 is bimodal, featuring significant peaks in 2012 and 2020 as a result of policy developments at the time. Fonterra at one point produced 15 million litres of bio-ethanol per year, however, this production has since been substituted. Southern Biofuels Limited, a small South Island based company founded in 2013, produces approximately half a million litres of biodiesel from used cooking oil. This demonstrates the limited scale of biofuel production in New Zealand at present.[90]

There is also no supply of SAF in New Zealand, and a global shortage, with less than 1% of aviation fuel supplied globally being SAF.[91] Air New Zealand led a recent study which indicated that there is a pathway for the domestic SAF industry to meet 50% of New Zealand's aviation fuel demand by 2050.[92]

Other analysis conducted in the past also suggests that credible large-scale production may be feasibile in New Zealand, utilising non-food feedstocks, notably forestry grown on non-arable land.[93] Scion in particular have conducted extensive studies into the potential for increasing domestic use of bioenergy and biofuels and have developed a model that can be used to optimise the site and size of a bioenergy plant based on New Zealand forests and residues.[94] An estimated 10-12 million cubic metres of woody biomass are produced domestically each year.[95] While these recent studies suggest that domestic production is feasible, there is likely to be competiton for feedstocks, particularly from the aviation sector.

In New Zealand, significant infrastructure investment would be required to establish liquid biofuel production facilities and support the feedstock supply chain, especially to achieve production at a larger scale. The NZ Wood Fibre Futures Stage 2 Report estimated that the investment required for a large-scale liquid biofuels plant is expected to exceed $1b NZD.[96] This level of investment is also broadly consistent with recent market engagement, which suggested that a large-scale biofuels plant could cost in excess of $1b USD.

There are ongoing investigations around a proposed biorefinery project at Marsden Point. In October 2024. Channel Infrastructure NZ Limited annouced that it had entered into a conditional project development agreement with Seadra Energy Inc, who is partnering with consortium members Qantas, Renova Inc, Kent Plc, and ANZ (the "Seadra Consortium"), to develop a biorefinery at Channel's Marsden Point site. Should the project development agreement become unconditional, the proposed biorefinery project at Marsden Point would utilise some of Channel's decommissioned refinery assets (which would be refurbished and reconfigured), existing tankage, jetties and certain other infrastructure, as well as approximately 18-20 hectares of land on the site.

5.2 | Biofuels

Conclusion

Biofuels offer a promising avenue for sustainable energy, leveraging diverse feedstocks to reduce carbon emissions across a range of sectors. In New Zealand, the feasibility of biofuel production is largely influenced by the ability to secure a reliable and affordable feedstock supply, which according to previous analysis, shows some promise. However, a significant level of infrastructure investment is required for large scale production plants.

Market demand is also growing as industries seek environmentally friendly alternatives, and success hinges on achieving competitive pricing and the ability to establish reliable supply chains. While the regulatory environment could be seen as supportive, at least compared to other alternative fuels, further regulation and policy measures are necessary to reduce the cost of and increase uptake of biofuels in New Zealand.

While opportunities exists for domestic decarbonisation, including marine applications, where biofuels are a drop in fuel for existing diesel technology, market engagement highlighted competing sector demands for biofuels, and domestic producers' desires to retain flexibility to tailor production to maximise commercial outcomes (including the targeting of export markets).

Internationally, near term limited global production capacity and competition for supply means that biofuels are unlikely to meet international shipping decarbonisation requirements in isolation.

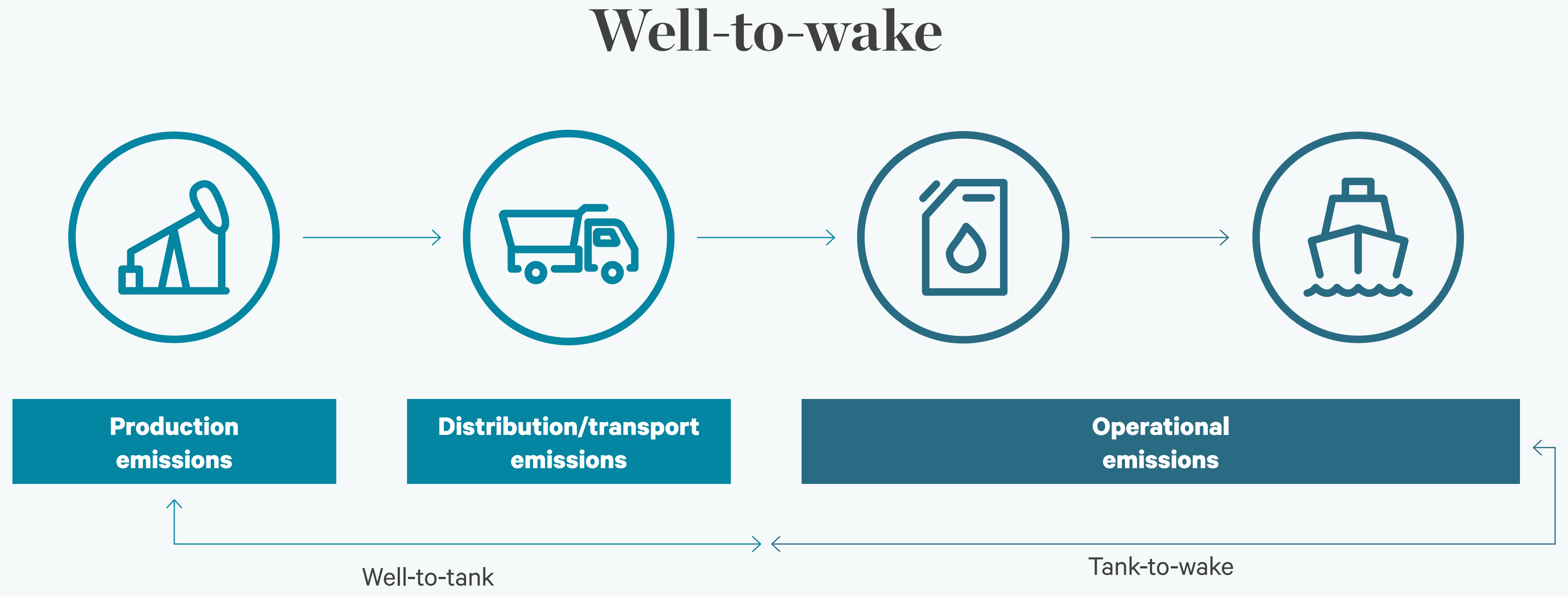
5.3 | Ammonia

Ammonia is primarily understood through the lens of global agricultural systems, considering its significant contribution to it.

Currently ~70% of ammonia globally is used for fertilisers, with the remaining 30% distributed across industrial applications. A large share of ammonia production currently is via fossil-fuels. More than 70% of ammonia is produced using natural-gas based steam reforming, with the second-most common process being coal gasification.[97]

A key part of making ammonia green is the sourcing of hydrogen. To be called green, the hydrogen is produced through the electrolysis of water. Another essential component, nitrogen, is obtained directly from air using air separation units (this accounts for 2-3% of energy use). Subsequently, Ammonia is produced using the Haber-Bosch process powered by renewable electricity (a fully scaled and efficient process providing cost advantages relative to other fuels). As there is no carbon in an ammonia molecule, combustion does not emit CO_2.

Figure 15: Illustration of well-to-wake emissions



Source: Safety4Sea "Be prepared for the next wave: FuelEU Maritime explained" (May 2024)

Green ammonia produced via electrolysis achieves the lowest well-to-wake emissions (see diagram above), reducing GHG emissions by around 61%-77% (assuming 100% renewable electricity), compared to conventional fuels.[98]

Blue ammonia is formed by using blue hydrogen from the steam methane reforming process (along with the use of carbon capture and storage).

Blue ammonia derived from steam methane reforming with carbon capture and storage achieves a reduction of 20 – 31% reduction in emissions on a well-to-wake basis.[99] Though, some suggest that carbon-based e-fuels are not the best long-term solution, with underground carbon storage offering better emissions reductions benefits and the high costs of clean electricity.[100]

5.3 | Ammonia

By 2030, ammonia is expected to play a significant role as a low-carbon shipping fuel, with announced capacity projections ranging from 17 to 114 million tonnes per annum (MTPA). Estimates suggest that 17 MTPA is explicitly allocated for fuel, with 98 MTPA still in an uncertain zone regarding its use for fuel. Compared to conventional marine fuels, ammonia has about one third of the volumetric energy density, so would require about three times the onboard storage space.[101]

Ammonia in New Zealand

New Zealand's only ammonia-urea manufacturing plant produces approximately 220,000 – 250,000 tonnes of agricultural urea annually, all of which is used domestically.[102] The hydrogen used for ammonia production is currently produced using natural gas.[103] While companies are exploring ammonia production from renewable sources, these are early stage currently. Further work would be needed in New Zealand to better understand the costs and feasibility.

Conclusion

In New Zealand, the transition to low-carbon ammonia production presents both opportunities and challenges. The country's ammonia-urea manufacturing plant currently relies on natural gas for hydrogen production, but the potential for low-carbon ammonia is significant. However, renewable electricity availability and cost remains a major barrier, as current generation capacity does not meet the demands of large-scale green ammonia production. Existing ammonia storage and transportation facilities require upgrades to safely handle low-carbon alternatives, and economic considerations highlight the high production costs compared to fossil fuels. Near term market demand for low-carbon ammonia in maritime applications also remains uncertain, especially with competition from other alternative fuels, reflecting relative bunkering, safety and vessel design requirements.

5.4 | Methanol

Renewable methanol is increasingly recognised as a viable alternative fuel in the transition towards sustainable maritime transport, driven by significant reductions in emissions of nitrogen oxides, sulphur oxides, and particulates.

Methanol is similar to conventional marine fuel in terms of handling and hazards, though it has about half the volumetric energy density, meaning about twice the amount of onboard storage is required.[104] The on board requirements for methanol as a fuel are less complex than some of the other alternative marine fuel options, due to being non-cryogenic, liquid at ambient temperatures, and not requiring costly materials for tanks and pipes. In addition, methanol already meets operational safety and engine compatibility requirements.

Currently, global methanol production stands at 98 million tonnes (Mt) annually, with projections to reach 500 Mt by 2050.[105] While approximately 99% of this production uses fossil fuels, primarily natural gas and coal due to their lower costs compared to renewable alternatives, there is a significant and growing push towards renewable methanol to address climate change and reduce carbon emissions.

Several alternative methods have emerged to produce methanol from renewable sources, with lower carbon intensity. These methods include bio-methanol, derived from biomass, and green methanol, produced by capturing CO_2 from renewable sources through technologies like Bioenergy with Carbon Capture and Storage (BECCS) or Direct Air Capture (DAC). To classify methanol as a truly renewable resource, both the feedstock and the energy used in its production must come from sustainable sources, such as biomass, solar, wind, or geothermal energy.

5.4 | Methanol

According to the Methanol Institute, the global renewable methanol production pipeline (including low-carbon methanol) is projected to reach 45 Mt by 2030. This pipeline includes approximately 210 renewable methanol projects, with an anticipated capacity of 35 Mt by 2030 (54% via green e-methanol and 46% via bio-methanol). However, estimates suggest actual renewable methanol capacity will be between 7 and 14 Mt by 2030.[106]

Methanol in New Zealand

In New Zealand, the only methanol manufacturer is Methanex, based in Taranaki. Currently, they produce methanol from natural gas, a non-renewable source, and export around 95% of their production.[107] Methanex expect 500,000 – 700,000 tonnes of production in 2025 (less than half of their annual plant capacity), though this is dependent on gas availability and any on selling of gas to the electricity market that may occur to support domestic energy needs.[108]

Methanex and others such as Hiringa Energy are exploring the feasibility of producing green methanol in New Zealand.

Hiringa Energy's Harakeke Renewable Energy Project in New Zealand[109]

The proposed project is to construct and operate a staged wind and solar farm, hydrogen and methanol plant near Whanganui and to convert to green hydrogen and green methanol for commercial supply. The project aims to produce 90,000 tonnes of green methanol annually.

Conclusion

While the technological capability to produce green methanol in New Zealand exists, significant economic and infrastructural challenges impact its feasibility at a large scale. Significant capital investment associated with a large-scale plant, high production costs driven by the cost of renewable electricity, and a limited willingness to pay, need to be addressed to make green methanol competitive with traditional and other alternative fuels. Additionally, expanding biogenic carbon sources and investing in infrastructure to support these feedstocks are critical for enabling production of renewable methanol, especially at scale.

5.5 | Liquefied Natural Gas (LNG)

LNG is increasingly recognised as a viable alternative marine fuel, particularly in the context of global shipping's near-term transition towards decarbonisation.

It is already used as a marine vessel fuel, though mostly for LNG tankers. LNG offers environmental benefits as a marine fuel, including a reduction of 20-25% in CO_2 emissions compared to traditional marine fuels. It also virtually eliminates sulphur oxides (SO_x) emissions and significantly reduces nitrogen oxides (NO_x).[110] However, market engagement suggested that LNG as a marine fuel will not achieve sufficient emission reductions to meet the new IMO reductions targets as early as 2028/29. In terms of volumetric energy density, LNG has a higher energy density than methanol and ammonia.[111]

Current global LNG production levels are approximately 474 million tonnes per annum (MTPA), with projections indicating an increase to around 667 MTPA by 2028, representing a growth of about 40%.[112]

This expansion is driven by significant supply additions from major producers like the United States and Qatar, which are expected to reshape market dynamics.[113]

The global LNG market is poised for substantial growth, with estimates suggesting that the number of LNG-fuelled ships is expected to double by 2028. This growth is largely supported by demand from Asia, which is projected to account for nearly 45% of incremental gas demand.[114]

LNG in New Zealand

Natural gas has been produced commercially in New Zealand since 1959. There are 6 main natural gas fields (3 onshore and 3 offshore) and a further 12 smaller onshore fields. Currently, all-natural gas produced in New Zealand comes from the Taranaki region.[115] However, this gas is not converted into LNG domestically and Energy NZ suggests that liquefaction facilities are most economic when built for the bulk export of LNG, not solely for marine bunkering.[116]

New Zealand's potential for LNG production faces significant challenges, particularly due to declining natural gas supply and insufficient infrastructure.

While the country has a history of natural gas production, the current landscape indicates that exploring LNG imports may be a more feasible solution. The recent indicated intention to remove regulatory barriers for LNG import facility construction supports the shift, however this was focused on enabling New Zealand to address options for immediate energy security concerns arising from constrained domestic supplies. Though the high costs of importing LNG may present a challenge.[117]

Conclusion

Importing LNG is actively being investigated in light of reducing domestic gas supplies, though the focus to date has been on energy security. However, the economic viability of using imported LNG is raising questions given the very high costs associated with developing the necessary receival and regasification infrastructure. These costs highlight the necessity for scale, which New Zealand lacks. Moreover, as a transitional fuel, LNG provides limited emissions reductions when derived from natural gas. Consequently, importing LNG for shipping appears impractical, given the proximity of other hubs near large-scale production.

5.6 | Comparative analysis of alternative fuels for shipping

FUEL	ADVANTAGES	CHALLENGES	IEA ETP CLEAN ENERGY TECHNOLOGY GUIDE	OPPORTUNITY ASSESSMENT
Biofuels (biodiesel, renewable diesel, biomethanol, bio-LNG	• Minimal modifications needed for existing infrastructure and engines. • Relative technological maturity due to existing use.	• Resource competition for bio-based CO_2 feedstock. • Varying life-cycle emissions across potential feedstocks. • Land use alteration. • Development of commercially viable feedstocks and corresponding feedstock supply chain.	• 8 – 9 (demonstration to early adoption phase)	• Biofuels may be least risky, given the drop-in nature of fuels and the relatively lower infrastructure requirements. • Biofuels are suited to the existing technology being used by vessels locally.
Ammonia (e-ammonia, blue ammonia)	• Low carbon emissions potential when produced from renewable energy sources. • Green hydrogen for ammonia production can be produced from natural solar and wind resources.	• Cost of green/blue hydrogen for ammonia production. • Safety concerns due to toxic and corrosive nature. • Lack of regulations for use as a marine fuel.	• 9 (early adoption phase)	• Unlikely to be a candidate for near term production within New Zealand at scale.

5.6 | Comparative analysis of alternative fuels for shipping

FUEL	ADVANTAGES	CHALLENGES	IEA ETP CLEAN ENERGY TECHNOLOGY GUIDE	OPPORTUNITY ASSESSMENT
Methanol (e-methanol)	• Easy to handle and meets operational safety and engine compatibility requirements. • Compatible with existing storage infrastructure. • Methanol-ready engines are commercially viable. • Scalable, direct air capture (DAC) pathway has no feedstock constraints.	• Cost of green hydrogen for methanol production. • Competition for and supply of bio-based CO_2 feedstock. • Industry competition, other sectors may have a greater willingness to pay. • High cost of DAC feedstock.	• 9 (early adoption phase)	• Appears to be the next least risky alternative fuel, but significant challenges remain for this to be produced at scale.
LNG	• Established safety regulations and handling procedures. • Lower cost and scalable alternative in comparison to other green fuel alternatives with potential to act as a transition fuel. • Relative speed of implementation compared to other alternative fuels. • International availability – bunkering infrastructure is expanding globally.	• Resource competition for natural gas feedstock. • Lower emission reduction. • Cost of storage infrastructure.	• 11 (mature technology)	• Unlikely to be a candidate for near term production within New Zealand at scale.

6

Stakeholder Insights

6 | Key observations

- A diverse fuel mix is expected in the future fleet.
- New Zealand is very unlikely to be cost competitive in the production of alternative fuels for international shipping.
- International vessels are unlikely to need to bunker in New Zealand.
- The opportunity exists to examine future production of alternative fuels for domestic use or export; however, this is not a prerequisite for green shipping, and producing the necessary quantities will be very expensive and difficult.
- New Zealand has a good supply of woody biomass, but there are many competing demands for it.
- Challenges exist for banks and investors to back alternative fuel production at scale, including cost effective available feedstocks, technology maturity, significant scale of investment, and securing offtake noting support is needed to achieve cost parity for alternative fuels.
- Green Corridors can act as a demonstration, clarifying the various factors that need to be true and a catalyst longer-term change.
- New Zealand does not need onshore production of alternative fuels to establish some green corridors. Existing supply chains could be adapted for this purpose. Aggregating demand within the New Zealand export market will be a key factor.
- The impact of fuel costs on goods is relatively small, estimated at 1-4%.
- Larger vessel sizes are anticipated for alternative fuel ships, many of which exceed New Zealand's current port handling capacity; however, shipping lines have indicated the potential to provide alternative fuel capable vessels here.
- While there are smaller alternative fuel vessels, they currently operate in countries with stricter regulations.
- Shipping lines are incentivised to send older, less environmentally friendly ships to jurisdictions that do not enforce strict emissions regulations.
- It is still very early days in terms of establishing a cohesive perspective and regulations for New Zealand Inc.; there are numerous tasks to coordinate, and currently, there is no cohesive plan to mandate alternative fuels.
- Sequencing and priority of feedstock and alternative fuel use will be considerations if produced in New Zealand.
- Ports consider themselves as facilitators of change, reliant on market and consumer forces to drive the change needed in this sector.
- Only certain exporters are currently focussed on shipping-based emissions, particularly those for whom shipping emissions constitute a larger proportion of their overall emissions.

6 | Overview

The following presents a summary of key themes and conclusions from market engagement conducted with over 50 organisations. This engagement also incorporated insights from a government roundtable discussion featuring representatives from agencies across Australia and New Zealand. For the participant list, refer to **Appendix F.**

Stakeholder engagement reflected a range of views, including highlighting a number of challenges to overcome to further support the decarbonisation of the maritime sector from a New Zealand perspective. However, participants also noted opportunities and requirements around decarbonising shipping lanes, alternative fuel production, and expressed a willingness to support the transition. As reflected in the recommendations section in this report, bringing stakeholders together is important to support the realisation of opportunities for New Zealand.

6.1 | Market engagement

Shipping lines

- **Fleet modernisation:** The transition to lower emission fuels necessitates fleet modernisation, which is capital-intensive and complex.
- **Fuel dynamics:** Fuel constitutes a significant portion (25%-30%) of total shipping costs, influencing decisions on fuel type and operational efficiency. A diverse range of zero-low emissions fuels will likely be adopted over time, requiring strategic planning and investment. Other technologies, such as nuclear are also emerging over the longer term although not as yet deemed viable.
- **Investment in technology:** Need investment in new technologies to support the transition to low-emission fuels, but financial risks remain a concern.
- **Global supply chain considerations:** Shipping lines must navigate a complex global supply chain landscape, balancing cost, availability, and regulatory compliance for various fuel types. Ultimately, alternative fuels will be sourced where it is most economic, with other jurisdictions seen as likely to be more price competitive.
- **Bunkering:** Despite the lower energy density of alternative fuels, alternative fuel vessels may not need to bunker in New Zealand.
- **Market adaptation:** Shipping lines must adapt to changing market conditions and customer preferences, particularly in regions with stringent emissions regulations.
- **Demand for green solutions:** Some customers are increasingly demanding alternative fuels, but this trend is not yet widespread across all sectors. Cost increases for goods were cited as being ~1-4% the cost of the good. As consumers become more environmentally conscious, shipping lines may face pressure to demonstrate their commitment to decarbonisation.
- **Regulatory compliance:** Shipping lines are looking for regulatory frameworks that facilitate compliance while also driving demand for lower emission fuels.
- **Collaboration with ports:** Effective partnerships with ports are essential for ensuring that the necessary infrastructure for alternative fuels is in place. Although, the extent of infrastructure investment is lower absent a need for bunkering.
- **Green corridors as a demonstration:** Focusing on a port-to-port green shipping route can act to iron out practical elements that need to be true for sustainable shipping more generally.

6.1 | Market engagement

Supply chain actors (e.g., prospective alternative fuel suppliers and renewable energy providers)

- **Technological advancements:** Technological innovations in alternative fuels such as biofuels, LNG, and methanol provide opportunities for more sustainable shipping, although each has its own set of challenges and requirements.
- **Decentralised energy solutions:** Developing local solutions for low-emission fuel production and bunkering can reduce dependency on international supply chains and leverage renewable electricity investments.
- **New Zealand has certain advantages:** Supply of woody biomass and a high proportion of renewable electricity are advantages.
- **Consumer demand for decarbonisation:** Increasing consumer interest in sustainable practices, particularly in key markets like Europe, presents an opportunity for supply chain players to differentiate themselves by adopting lower emission operations.
- **Financing potential:** As alternative fuel technologies advance and long-term offtake agreements are secured, financing for infrastructure investment will likely become easier to obtain.
- **Strategic partnerships:** Collaborating with major shipping lines, who can provide green vessels, may help supply chain participants to better understand investments required to handle alternative fuels and meet decarbonisation targets.
- **Potential of Green Corridors:** The establishment of green corridors, while not a complete solution, offers a pathway for some companies to lead in maritime decarbonisation, provided infrastructure needs are addressed.

6.1 | Market engagement

Banks and investors

- **Long-term viability concerns:** The commercial viability of new low-emission fuels remains uncertain, posing challenges for banks and investors in assessing potential returns.
- **Asset stranding risks:** There is a potential risk of asset stranding as the market shifts towards lower emission technologies, necessitating careful consideration of investment strategies.
- **Risk aversion:** Reflecting the scale of investment for major alternative fuels projects, banks are closely focusing on risk areas such as feedstock availability and pricing, technology maturity and contracted offtake.
- **Focus on established technologies:** Investors are more inclined to support established technologies rather than emerging alternatives, which may slow the transition to lower emission solutions. There is more experience and appetite in banks for funding renewable electricity projects than alternative fuel projects.
- **Market adaptation requirements:** Both banks and investors must be prepared to adapt to international market decisions and regulatory changes that impact the maritime sector.
- **Need for government support:** There is a perceived need for government intervention to de-risk investments in new technologies, such as through offtake agreements or fixed-price contracts. Potential domestic mandates for alternative fuel usage were raised however market participants also expressed concerns regarding any regulations or mandates on international players that could result in deterring them from coming to New Zealand.
- **Incentive structures:** Introducing incentives, similar to the tax credits offered in other jurisdictions, could significantly enhance banks' and investors' ability to justify funding green initiatives, paving the way for increased support in this sector.
- **Global market dynamics:** Investors must consider global market dynamics and regulatory environments when making decisions about funding maritime decarbonisation efforts.
- **Collaboration opportunities:** There is potential for collaboration between banks, investors, and industry players to create innovative financing solutions that support the transition to sustainable practices.

6.1 | Market engagement

Ports

- **Larger vessels:** New Zealand ports will likely need to invest in infrastructure to accommodate larger dual fuel capable vessels being built and ordered by international shipping lines.
- **Infrastructure for alternative fuels:** Ports will need to provide infrastructure to accommodate bunkering of alternative fuels, which may require significant investment and regulatory changes.
- **Bunkering capabilities:** The ability to bunker green fuels for international lines is not critical for New Zealand and current infrastructure may not support this efficiently, leading to higher costs and logistical challenges.
- **Cost implications:** The high costs associated with alternative fuel infrastructure and decarbonisation initiatives such as shore power will deter investment unless there are clear economic incentives.
- **Capital access challenges:** Many ports face difficulties in accessing the capital needed for large-scale infrastructure projects, particularly when owned by local councils.
- **Market-driven transition:** Ports view themselves as facilitators rather than leaders in the transition to greener practices, relying on market forces and customer demand to drive change.
- **Regulatory environment:** A lack of unified regulations can hinder the transition to greener shipping practices, necessitating government intervention to create a conducive environment for low-emission fuels.
- **Safety and environmental concerns:** Certain fuels cannot be stored in specific port areas due to safety regulations, complicating the logistics of transitioning to alternative fuels (e.g. ammonia).
- **Decarbonisation opportunities:** There is potential to decarbonise coastal feeder services, which could enhance regional port operations.
- **Collaboration with shipping lines:** Effective collaboration between ports and shipping lines is essential to ensure that the necessary infrastructure aligns with the needs of shipping companies.
- **Electrification:** Port decarbonisation efforts were focused primarily on full or hybrid electrification of existing operations as opposed to alternative marine fuel usage.

6.1 | Market engagement

Importers and exporters

- **Supply chain vulnerabilities:** Exporters are vulnerable to disruptions in the supply chain, particularly as they navigate the complexities of new fuel types and regulatory requirements.
- **Infrastructure limitations:** Existing port infrastructure may not support the transition to larger, more efficient alternative fuel ships, limiting exporters' ability to adapt and opportunity for importers to save.
- **Investment in green technologies:** There is a need for investment in green technologies and fuels, but uncertainty around their viability and cost-effectiveness remains a barrier.
- **Regulatory compliance risks:** Importers and exporters face significant risks due to evolving international regulations, particularly from the EU, which mandates emission reduction targets. Non-compliance could jeopardise market access and brand reputation.
- **Market demand for decarbonisation:** There is increasing consumer demand for sustainable practices, particularly in compliance-driven markets such as in Europe. Exporters like Zespri are proactively adapting to these trends to maintain competitiveness.
- **Consumer price sensitivity:** While consumers express a desire for environmentally friendly products, they are often unwilling to voluntarily pay higher prices, complicating the financial feasibility of sustainable practices.
- **Exporter priorities:** Some of the larger exporters are not focusing on reducing shipping emissions, due to these only contributing to a smaller percentage of their overall emissions.
- **Decarbonisation Costs:** The high costs associated with decarbonising shipping operations pose a challenge for exporters, especially given New Zealand's geographical position and reliance on shipping.
- **Need for regulatory certainty:** Emphasised the need for clear and consistent regulations to encourage investment in alternative fuel production and port infrastructure. This includes recommendations for regulatory frameworks that align with international standards to maintain competitiveness.
- **Long-term strategic planning:** Exporters must engage in long-term strategic planning to align with global decarbonisation trends and regulatory frameworks, ensuring they remain competitive.
- **Coordination challenges:** Effective decarbonisation requires collaboration among exporters, shipping companies, ports and fuel providers. An "NZ Inc" approach is essential to aggregate demand for low-emission fuels.

6.1 | Market engagement

Common themes around government intervention

In addition to the insights above, stakeholders also noted the need for government and policy action to address decarbonisation of New Zealand's maritime sector. A summary of themes in this area across stakeholders is presented below.

- **Investment in renewable energy:** Government investment in renewable electricity sources is crucial to support the development of low-emission fuels.
- **Public-Private Partnerships:** A public-private partnership (PPP) model may be beneficial in addressing infrastructure needs and reducing risks associated with new technologies.
- **Consumer pressure:** Increasing consumer demand for decarbonisation, particularly from international markets, is pushing exporters to seek government support for emissions reductions.
- **Economic incentives:** Government reluctance to provide economic incentives for low-emission fuel production hampers progress in the maritime sector. Clear and reliable price and investment signals are required to create demand for alternative fuels, which will stimulate supply across supply chains.
- **Regulatory support:** Regulatory frameworks must evolve to support the commercialisation of low-emission fuels and ensure that New Zealand remains competitive in global markets.
- **International compliance:** New Zealand must align its regulations with international standards to avoid being sidelined in global trade.
- **Risk management:** The government should help mitigate risks associated with new technologies and fuel sources through supportive policies.
- **Long-term vision:** A long-term vision for the maritime industry is essential to guide investments and regulatory changes towards sustainable practices.
- **Lack of national strategy:** There is no cohesive national plan to address maritime emissions, leaving the sector to navigate compliance with international regulations independently.
- **Coordination needed:** An "NZ Inc" approach is necessary for effective coordination among exporters, shipping companies, ports and fuel providers to facilitate decarbonisation.
- **Establishment of collaborative frameworks:** Suggested forming working groups and government-industry forums to foster coordinated efforts between stakeholders.

7

Recommendations

7 | Recommendations

The economic impact assessment undertaken for this workstream underscores the substantial avoided costs and benefits associated with decarbonising New Zealand's shipping lanes, creating an immediate imperative for action.

It is recommended that a considered approach to establishing green shipping corridors be taken, concentrating on routes that are most feasible from an implementation point of view and that require the least number of enabling factors within New Zealand. This strategy not only allows New Zealand to take a lead in decarbonising key shipping lanes but also brings economic benefits in a low-cost and low-risk manner. Importantly, proposed collaborative work on a trans-Tasman basis can be advanced concurrently in relation to alternative fuels and other feasible green corridors, such as dedicated trans-Tasman routes, ensuring that New Zealand remains proactive in its maritime decarbonisation agenda and Australia-New Zealand 2+2 Climate and Finance Dialogue Joint Statement commitments.

Our recommendations have been grouped and include establishment of an initial green shipping corridor, leveraging trans-Tasman collaboration and broader actions.

7.1 | Establishment of an initial green shipping corridor

The following recommendations focus on establishing an initial green shipping corridor, given their potential to accelerate progress in tackling the challenges of decarbonising shipping.

By focusing on routes that provide the greatest scope for maritime emissions reductions while balancing feasibility and speed, New Zealand can maximise its decarbonisation efforts.

New Zealand has an opportunity to leverage key export cargoes, existing port infrastructure and shipping line relationships to seek to establish targeted green shipping corridors. Focusing on the most feasible routes for establishing a green shipping corridor also has the potential to drive future decarbonisation opportunities and change in how New Zealand moves freight domestically.

This includes opportunities for cargo aggregation, both landside and via domestic port-to-port routes, and the targeted decarbonisation of New Zealand's freight network:

- Currently, over 90% of freight in terms of tonnage is transported over road.[118] Accommodating larger alternative fuel powered vessels is likely to impact freight movements within New Zealand, reflecting a need to efficiently aggregate cargo to ports with sufficient infrastructure capacity and operational capability. This may further catalyse consideration of 'hub and spoke' models and opportunities for mode shift, via transportation of freight on less emission's intensive modes, such as rail and coastal shipping.[119]
- Increased aggregation of cargoes on key ports, and associated modal shifts may facilitate the establishment other feasible green corridors, for example, for trans-Tasman dedicated routes.
- Changes in freight movement and mode also may be complemented by additional domestic use cases for low-to-zero emission fuels. Such shifts may provide enough demand / off-take certainty to incentivise investment in production and storage of alternative fuels locally, which may also spur supply side responses for renewable energy and biogenic carbon feedstock supply. As the Introduction to Alternative Fuels section above notes, biofuels have been noted as a leading candidate for local production, given the drop-in nature of fuels and its wide suitability for use with existing transport fuels technology domestically.

7.1 | Establishment of an initial green shipping corridor

As noted by the International Maritime Organisation, critically thinking about which shipping routes to pursue is essential. In general, a favourable route should significantly contribute to global shipping's energy transition, while still being comparably feasible from an implementation standpoint within a reasonable timeframe.[120] Taking steps to operationalise the first green corridors offers a concrete proof point that can be scaled for inter-regional impact.[121]

A **proposed lead** for each action is identified with a focus on government organisations as enablers and facilitators, reflecting operational mandates and an ability to bring together private and public sector organisations necessary to action the proposed recommendations outlined.

The recommendations below focus on the near-term identification of the most feasible route for establishing a green shipping corridor, leveraging existing and anticipated trade flows, port capacity and shipping services, while not being dependent on local fuel production, storage and bunkering capability.

7.1 | Establishment of an initial green shipping corridor

RECOMMENDATIONS	POTENTIAL LEADERS
1. Establish a collaborative working group including public and private organisations to focus on establishing an initial green corridor. Collaboration across the supply chain allows for the identification of a system solution with a high chance of success and scalability,[122] is considered best practice,[123] and has been noted as fundamental by the Silk alliance, an initiative of 12 leading cross-supply chain stakeholders to develop a fleet fuel transition strategy that can enable the establishment of a highly scalable green corridor cluster around Singapore.[124] The working group should agree on foundational governance, align on a shared vision and devise a work plan for collaboration.[125] Government should take a lead role in convening and establishing the working group, given its commitment to facilitate industry discussion as part of aviation and shipping decarbonisation and its commitment to convening roundtables with the maritime sector in its second emissions reduction plan.[126]	Facilitated by MBIE and MoT
2. Evaluate the potential to use book and claim systems as a transitional mechanism to establish first green corridors (as required). Book and claim systems are a certification method in maritime decarbonisation, separating environmental benefits from the physical distribution of fuels. The flexibility of a book and claim system enables the aggregation of international demand and eases the burden of developing port infrastructure to cater for large vessels and avoids logistical issues of rerouting vessels. How book-and-claim systems interact with IMO measures would need to be evaluated and determined.	MfE

7.1 | Establishment of an initial green shipping corridor

RECOMMENDATIONS	POTENTIAL LEADERS
3. Undertake an assessment of existing trade flows, shipping services / routes and port capacity to identify potential candidates for green corridors. Establish criterion for selection of potential green corridors. Reflecting market feedback in this workstream, criteria that should be included are routes that: • Provide the largest potential for emissions reductions (i.e., shipping routes with significant volume and / or value, and distance travelled). • Focus on shipping segments with clear demand for emissions reductions and / or shipping segments that focus on high value products. This assessment should be dynamic and not be limited to current freight flows within and outside of New Zealand and should involve consideration of alternative arrangements. Aggregation of this demand could be implemented by considering joint-purchasing coalitions and grouping of long-term contracts across cargo owners, providing shipping operators and fuel suppliers enough 'demand' to build a business case around meeting this demand.[127] • Are serviced by shipping lines that currently have or will have access to suitable low emissions vessel technology. • Have access to alternative fuels. The opportunity exists to initially leverage offshore alternative fuel production, storage and bunkering capability as part of an international service or through book-and-claim system, given the diverse and emergent nature of alternative marine fuels and current infrastructure limitations within New Zealand to effectively undertake production at scale. • Have access to appropriate domestic port infrastructure. Are serviced by ports that have existing infrastructure to accommodate alternative fuel powered ships currently (i.e., draught and berth length assuming no bunkering requirements) or have development plans to do so.	MoT

7.1 | Establishment of an initial green shipping corridor

RECOMMENDATIONS	POTENTIAL LEADERS
4. Undertake targeted feasibility assessments of prospective corridor(s), examining any technological, regulatory and commercial requirements to establish the corridor.	Cross governmental – MFAT and MBIE
5. Identify bilateral policy schemes to consider how complimentary policy action could benefit both ends of the identified corridor. Examples include bilateral support schemes, such as port-side reduction fees serving participating companies based on origin of cargoes.	MFAT
6. Develop a comprehensive roadmap for the identified corridor, with clear timelines and milestones which should outline specific actions, assign responsibilities, and set measurable outcomes to track progress.	Working group facilitated by MoT

7.2 | Leveraging trans-Tasman collaboration

Establishing an initial green shipping corridor in the manner proposed will unlock the opportunity to consider other feasible green corridors, such as dedicated trans-Tasman routes (which will likely have specific establishment considerations), and the decarbonisation of New Zealand's wider freight network (landside and coastal).

The potential demand for alternative fuels for shipping in Australia and the South Pacific region, the aviation sector and other use cases (e.g., supporting flexible energy generation), will further support the potential for alternative fuel production in New Zealand and Australia.

The recommendations below therefore focus on actions needed to establish a dedicated trans-Tasman shipping corridor and regulatory settings and incentives that may support the production of alternative fuels in both countries, with a focus on biofuels, given the drop-in nature of fuels and its wide suitability for use with existing transport fuels technology domestically.

While New Zealand's geographic isolation poses significant challenges to establishing a viable biofuel industry independently, partnering with the Australian Government, leveraging funding programs like ARENA and CEFC, engaging peak industry bodies such as Bioenergy Australia and the Bioenergy Association of New Zealand (BANZ), and developing a **Joint Biofuels Roadmap** for low carbon liquid fuels offer a strategic solution that can benefit both nations. Additionally, Australia can benefit from New Zealand's inherent advantages around the supply of woody biomass, and the scaling of volume that arises from aggregating demand for alternative fuels across the two nations.

In particular:

- By partnering with Australia, engaging peak bodies like Bioenergy Australia and BANZ and developing Australia and New Zealand Joint Biofuels Roadmaps, New Zealand can overcome its geographical isolation and build a viable biofuel industry focused on biodiesel, SAF, and methanol.
- Leveraging EECA alongside CEFC and ARENA provides a foundation, a **Joint Biofuels Fund** with grants, loans, production credits, and feasibility funding, guided by roadmap priorities and peak body expertise, ensures tailored support would be preferable.
- Joint R&D, feasibility work, policy alignment, collaborative projects, trade agreements, and digital tools would further strengthen this partnership.
- These efforts will advance New Zealand's and Australia's decarbonisation goals and position them as leaders in supplying biofuels to the Asia-Pacific region.

It should be noted that the steps below could occur in parallel to the actions outlined under 7.1 above.

The working group established to explore the initial corridor and MfE, due to its role in 2+2 Climate and Finance Dialogue with Australia, can lead / facilitate the actions in the table below.

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS

1. **Develop joint research and development (R&D) initiatives.** Collaboration on R&D, aligned with joint roadmaps and supported by peak bodies, can accelerate biofuel technology development.
   - **How it works:** New Zealand and Australia could establish a bilateral R&D program focused on biofuels, including shared funding for pilot projects, joint research facilities, or knowledge-sharing agreements. For example, they could develop advanced biodiesel from agricultural waste, SAF from forestry residues, or methanol from biomass—resources abundant in both countries.
   - **Role of Joint Roadmaps:** The Australia and New Zealand **Joint Biofuels Roadmap**, agreed at the highest levels of government (e.g., through bilateral ministerial meetings), would identify priority R&D areas, such as feedstock optimisation or SAF production efficiency. This ensures government funding and support target roadmap-aligned projects, maximising impact.
   - **Role of Peak Bodies:** Bioenergy Australia could connect researchers and businesses, while BANZ ensures local industry expertise informs R&D priorities. Both could co-host innovation challenges to address roadmap goals.
   - **Role of EECA and ARENA:** The EECA could coordinate R&D efforts alongside ARENA. EECA's Technology Demonstration Fund aligns with ARENA's innovation focus, but a specialised fund with targeted grants may be needed for roadmap-driven biofuel R&D.
   - **Benefits:** Roadmap alignment ensures strategic focus, while peak body involvement drives industry-relevant outcomes. Pooling resources reduces costs and mitigates New Zealand's isolation.

POTENTIAL LEADERS

Supported by MBIE and DCCEEW

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS	POTENTIAL LEADERS
2. Ensure policy alignment and harmonisation. Harmonising policies and standards for biofuels, informed by joint roadmaps and peak bodies, would create a unified market. • **How it works:** New Zealand and Australia could develop common standards for biodiesel, SAF, and methanol production, handling, certification, and emissions accounting, aligned with the Joint Biofuels Roadmap. Australia's Guarantee of Origin scheme could be adapted to include New Zealand, ensuring regional consistency. • **Role of Joint Roadmaps:** The roadmap would outline policy priorities, such as harmonised decarbonisation criteria or SAF blending mandates, ensuring government support is directed to roadmap-aligned regulations. This could be formalised through a bilateral agreement, New Zealand's MBIE Australia's DCCEEW. • **Role of Peak Bodies:** Bioenergy Australia and BANZ could provide technical expertise to shape standards, ensuring they reflect industry capabilities and roadmap objectives, such as sustainable feedstock sourcing. • **Role of Government Agencies:** Policy alignment could be driven by MBIE and DCCEEW, with input from EECA and ARENA. • **Benefits:** Roadmap-driven policies, informed by industry expertise, attract investment and enhance market viability for New Zealand's isolated market.	—

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS

3. Establish a co-funded and specialised bilateral fund (Joint Biofuels Fund). New Zealand and Australia can leverage existing funding bodies or establish a specialised fund with grants, loans, and production credits, guided by joint roadmaps and peak body insights, to finance biofuel projects. *The government could also crowd in investment from industry, as demonstrated by initiatives such as AgriZero.*

- **Existing Funding Bodies**
  - **Australia:** ARENA provides grants for renewable energy innovation, such as bioenergy projects, while CEFC offers financing for clean energy, with over $30 billion invested.
  - **New Zealand:** EECA funds renewable energy adoption, akin to ARENA's role.
  - **Collaboration:** New Zealand could co-fund projects with ARENA and CEFC, such as SAF production facilities or biodiesel refineries, ensuring alignment with the **Joint Biofuels Roadmap**. New Zealand could partner with CEFC to finance a regional SAF supply chain, while EECA could align with ARENA on biodiesel pilot projects. The government could also crowd in investment from industry, as demonstrated by initiatives such as AgriZero.
  - **Limitations:** EECA may not be ideally suited for large-scale, biofuel-specific joint programs due to their broader mandates or limited funding capacity. EECA's scope includes energy efficiency, potentially diluting focus on biofuels.

POTENTIAL LEADERS

Supported by MBIE and DCCEEW

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS

- **Proposed Specialised Fund:** To address these limitations, New Zealand and Australia could establish a **Joint Biofuels Fund** with grants, loans, and production credits, aligned with the Joint Biofuels Roadmap and informed by peak body expertise.
  - **Objective:** A dedicated bilateral fund would accelerate the development and deployment of biofuels (biodiesel, SAF, and methanol) in New Zealand and Australia, supporting decarbonisation in both economies and the Asia-Pacific region, with priorities guided by the Australia and New Zealand **Joint Biofuels Roadmap**. The fund's objective would be to provide targeted financial support for biofuel projects, addressing New Zealand's isolation and Australia's need for scalable solutions to meet regional demand for low-carbon fuels, in line with roadmap priorities.
  - **Structure:** The fund would be a bilateral initiative, with equal contributions from the New Zealand and Australian Governments.
    - It would be managed by a joint committee comprising representatives from MBIE, DCCEEW, EECA, CEFC, and ARENA, with advisory input from Bioenergy Australia and BANZ to ensure alignment with roadmap goals and industry needs.
    - The fund would prioritise projects that advance roadmap objectives, such as:
      - Developing or demonstrating innovative biofuel technologies (e.g., next-generation biodiesel, SAF from waste feedstocks, or biomass-derived methanol).
      - Scaling up biofuel production to achieve economies of scale.
      - Establishing shared infrastructure for biofuel production, storage, and distribution (e.g., regional SAF refineries or biodiesel processing plants).
      - Conducting R&D to improve biofuel efficiency and cost-competitiveness.

POTENTIAL LEADERS

Supported by MBIE and DCCEEW

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS

- **Funding mechanisms**
  - **Grants:**
    - Non-repayable funding for high-risk, high-reward projects aligned with roadmap priorities, such as early-stage R&D or pilot plants for SAF or methanol production.
    - Targeted at universities, research institutions, or small-to-medium enterprises, with Bioenergy Australia and BANZ identifying priority areas (e.g., feedstock processing innovations).
    - Example: A grant for a New Zealand-Australia consortium to develop SAF from forestry residues, addressing roadmap goals for aviation decarbonisation.
  - **Concessional Loans:**
    - Low-interest loans for capital-intensive projects, such as biorefineries or fuel terminals, to reduce financial barriers for private investors, prioritising roadmap-aligned infrastructure.
    - Repayment terms could include flexible schedules tied to project milestones, with Bioenergy Australia advising on viable project scales.
    - Example: A loan to finance a joint biodiesel refinery, leveraging New Zealand's agricultural waste and Australia's processing expertise, supporting roadmap targets for transport fuels.

POTENTIAL LEADERS

Supported by MBIE and DCCEEW

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS

- **Production Credits:**
    - Financial incentives paid per unit of biofuel produced (e.g., dollars per litre of SAF or biodiesel), reducing the cost gap with fossil fuels and supporting roadmap goals for market scale-up.
    - Credits could be time-limited (e.g., 5–10 years) to support market entry, with eligibility tied to emissions reduction thresholds verified by BANZ and Bioenergy Australia.
    - Example: A production credit for methanol produced from biomass, incentivising adoption in shipping, aligned with roadmap priorities for industrial decarbonisation.
- Projects would be selected through a competitive process, with criteria including emissions reduction potential, commercial scalability, roadmap alignment, and regional economic benefits. Bioenergy Australia and BANZ could play a role in reviewing applications to ensure industry relevance, alongside government officials.
- The fund would incentivise private sector investment through matching contributions or risk-sharing arrangements.

- **Role of existing agencies:**
    - CEFC: Could administer loans and co-invest in projects, leveraging their green financing expertise.
    - EECA and ARENA: Could oversee grant allocation for R&D and pilot projects, ensuring alignment with national energy strategies and roadmap priorities.
    - A new fund would avoid overburdening these agencies, allowing them to maintain their existing mandates while focusing resources on biofuels.

POTENTIAL LEADERS

Supported by MBIE and DCCEEW

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS

- **Role of peak bodies**
    - Bioenergy Australia: Could provide market insights, connect stakeholders, and advise on project feasibility, drawing on its Bioenergy Roadmap and industry networks, ensuring projects align with the Joint Biofuels Roadmap.
    - BANZ: Could ensure New Zealand's agricultural and forestry feedstocks are sustainably utilised, offering technical guidance on local supply chains to meet roadmap decarbonisation goals.
- **Benefits**
    - Grants de-risk early-stage innovation, loans enable infrastructure development, and production credits ensure market competitiveness, all aligned with roadmap priorities.
    - Peak body involvement and roadmap alignment ensure industry-driven, strategically focused outcomes.
    - Overcomes New Zealand's limited domestic capital and isolation by pooling resources with Australia.
    - Positions New Zealand and Australia as leaders in biodiesel, SAF, and methanol production, enhancing competitiveness in the Asia-Pacific market.
    - Supports decarbonisation of transport, aviation, and industry in both countries and the region.

POTENTIAL LEADERS

Supported by
MBIE and DCCEEW

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS	POTENTIAL LEADERS
• **Joint Funding for Feasibility Work.** Targeted funding for feasibility studies can bridge the gap between concept and implementation, enabling industry to progress biofuel projects to pilot and scale. New Zealand and Australia could establish a joint funding program within the Joint Biofuels Fund to support feasibility work, including technical assessments, economic viability studies, feedstock supply chain analyses, and environmental impact evaluations. This would de-risk projects before significant capital investment, facilitating progression to pilot plants and large-scale production. ◦ **Role of Joint Roadmaps:** The Joint Biofuels Roadmap would prioritise feasibility work for high-impact projects, such as SAF production from forestry residues or biodiesel from agricultural waste, ensuring alignment with strategic goals like aviation decarbonisation or regional fuel security. ◦ **Role of Peak Bodies**: Bioenergy Australia and BANZ could guide feasibility studies by providing industry data on feedstock availability, processing technologies, and market demand. For example, BANZ could advise on New Zealand's biomass supply chains, while Bioenergy Australia could assess Australian market readiness for methanol. ◦ **Role of Agencies:** EECA and ARENA could administer feasibility grants, leveraging their experience in funding early-stage projects. CEFC could provide complementary loans for projects transitioning from feasibility to pilot, ensuring roadmap alignment.	Supported by MBIE and DCCEEW

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS	POTENTIAL LEADERS
4. Jointly fund feasibility work from Joint Biofuels Fund. Targeted funding for feasibility studies can bridge the gap between concept and implementation, enabling industry to progress biofuel projects to pilot and scale. • **How it works:** New Zealand and Australia could establish a joint funding program within the **Joint Biofuels Fund** to support feasibility work, including technical assessments, economic viability studies, feedstock supply chain analyses, and environmental impact evaluations. This would de-risk projects before significant capital investment, facilitating progression to pilot plants and large-scale production. • **Role of Joint Roadmaps:** The Joint Biofuels Roadmap would prioritise feasibility work for high-impact projects, such as SAF production from forestry residues or biodiesel from agricultural waste, ensuring alignment with strategic goals like aviation decarbonisation or regional fuel security. • **Role of Peak Bodies:** Bioenergy Australia and BANZ could guide feasibility studies by providing industry data on feedstock availability, processing technologies, and market demand. For example, BANZ could advise on New Zealand's biomass supply chains, while Bioenergy Australia could assess Australian market readiness for methanol.	Supported by MBIE, DCCEEW, ARENA, and CEFC

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS

- **Role of Agencies:** EECA and ARENA could administer feasibility grants, leveraging their experience in funding early-stage projects. CEFC could provide complementary loans for projects transitioning from feasibility to pilot, ensuring roadmap alignment.
- **Funding Mechanisms:**
  - Feasibility Grants: Non-repayable funding for studies assessing technical, economic, and environmental feasibility of biofuel projects. Grants could cover up to 75% of study costs to encourage industry participation.
  - Seed Loans: Low-interest loans for projects moving from feasibility to pilot, reducing financial barriers for small-to-medium enterprises.
  - Example: A feasibility grant to assess the viability of a joint SAF refinery using New Zealand forestry residues and Australian processing expertise, followed by a seed loan to establish a pilot plant, aligned with roadmap priorities.
- **Benefits:** Feasibility funding reduces project risks, accelerates progression to pilot and scale, and ensures industry-led projects align with roadmap goals, addressing New Zealand's isolation by fostering cross-border collaboration.

POTENTIAL LEADERS

Supported by MBIE, DCCEEW, ARENA, and CEFC

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS	POTENTIAL LEADERS
5. Collaborate on projects and infrastructure between New Zealand and Australia. Joint projects, supported by peak bodies and aligned with the **Joint Biofuels Roadmap**, can address shared challenges like feedstock availability and distribution networks. • **How it works:** New Zealand and Australia could collaborate on producing biodiesel and SAF from agricultural and forestry waste, leveraging Australia's bioenergy experience (e.g., CEFC's investment in the East Rockingham Waste to Energy facility) and New Zealand's agricultural and forestry strengths. Shared biorefineries or methanol production facilities could serve both markets, funded through the Joint Biofuels Fund's grants, loans, or production credits. • **Role of Joint Roadmaps:** The roadmap would prioritise infrastructure projects, such as regional SAF refineries, ensuring government funding targets high-impact initiatives. • **Role of Peak Bodies:** Bioenergy Australia could facilitate partnerships between Australian processors and New Zealand feedstock suppliers, while BANZ could ensure sustainable sourcing of local biomass, aligning with roadmap decarbonisation criteria. • **Role of Agencies:** CEFC could finance infrastructure via loans, while EECA and ARENA support technical development through grants. The specialised fund would ensure sufficient capital. • **Benefits:** Joint infrastructure reduces costs and creates economies of scale, linking New Zealand to Australia's larger networks.	Supported by MBIE, DCCEEW, ARENA, and CEFC

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS

6. **Establish joint trade frameworks and market development between New Zealand and Australia.** A bilateral trade framework for biofuels, such as a trade agreement with preferential trading terms in relation to biofuels. The trade framework can also work towards identifying and addressing of any non-tariff barriers in relation to biofuels. The framework can be informed by peak bodies and the Joint Biofuels Roadmap, ensuring a stable market.

- **How it works:** New Zealand and Australia could negotiate a trade agreement with preferential trading terms for biodiesel, SAF, and methanol, mirroring the Australia-Singapore Green Economy Agreement. They could jointly market biofuels to the Asia-Pacific region, targeting aviation and shipping, as outlined in the roadmap.
- **Role of Joint Roadmaps:** The roadmap would identify key export markets and trade priorities, ensuring government support aligns with regional demand for biofuels.
- **Role of Peak Bodies:** Bioenergy Australia and BANZ could identify market opportunities and advocate for trade policies that support biofuel exports, leveraging their industry networks.
- **Benefits:** A guaranteed market offsets New Zealand's geographical disadvantage, leveraging Australia's trade networks.

POTENTIAL LEADERS

Supported by MBIE, DCCEEW, ARENA, and CEFC

7.2 | Leveraging trans-Tasman collaboration

RECOMMENDATIONS	POTENTIAL LEADERS
7. Undertake assessment of additional green corridors (including dedicated trans-Tasman shipping lanes) that are candidates for decarbonisation. This should focus on routes that have the largest potential for emissions reductions, have clear demand for emissions reductions (i.e., high value and volume of trade), can be serviced by shipping lines that have alternative fuel capable vessels, have access to appropriate domestic port infrastructure and would have access to alternative fuel production, either in New Zealand or Australia. Consideration of whether a book-and-claim system could be utilised in the interim for such a route should also be considered, although how book-and-claim systems interact with IMO measures would need to be determined. While this report has undertaken a preliminary assessment of the factors that would be required to establish a dedicated trans-Tasman green shipping corridor, further analysis is required to determine overall viability.	—

7.3 | Broader actions

Establishing a green shipping corridor has the potential to drive future decarbonisation opportunities and impact how freight moves domestically.

Changes in freight movement and mode, complemented by additional domestic use cases, have the potential to incentivise investment in domestic production and storage of targeted alternative fuels. Sufficient renewable energy must also be available to power alternative fuel production; otherwise, the fuels will not be green.

The recommendations below focus on the continued importance of a renewable energy transition, as well as other actions that should be taken to more broadly support the decarbonisation of New Zealand's shipping lanes. Sufficient renewable energy must be available to power alternative fuel production; otherwise, the fuels will not be green.

7.3 | Broader actions

RECOMMENDATIONS	POTENTIAL LEADERS
1. **A continued shift of New Zealand's energy system to a renewable one is fundamental.** Sufficient renewable energy must be available to power alternative fuel production; otherwise, the fuels will not be green. A continued transition to a low carbon energy system is therefore needed. To do this, priority and continued focus should be given to the detailed list of recommendations in the Low Carbon Energy Roadmap.	See The Aotearoa Circle Low Carbon Energy Roadmap.
2. **Undertake an assessment of the future freight task within New Zealand,** including vessel size trends, cargo aggregation and domestic port infrastructure requirements, leveraging the Ministry of Transport's role as the Government's system lead on transport. This could be achieved through updating the National Freight Demand Study and including vessel size trends, cargo aggregation and domestic port infrastructure requirements. An up to date understanding of the freight task today is critical to better understanding likely future freight flows and associated infrastructure requirements to help identify broader domestic decarbonisation opportunities. The national Freight Demand Study should also include scenario-based assessments of future freight flows, including aggregation of freight to support the visits of larger alternative fuel powered vessels. Examples of considerations for the study include: • Whether a coordinated 'hub and spoke' model of inland and coastal freight movements can provide further scope for freight aggregation, movement efficiency and decarbonisation. • Domestic port infrastructure capacity (existing and planned) ability to meet anticipated freight and vessel requirements – including alternative fuel vessels and a coordinated 'hub and spoke' model.	MoT

7.3 | Broader actions

RECOMMENDATIONS	POTENTIAL LEADERS
3. Develop a national strategy for sustainable sourcing feedstock for alternative fuels. Securing a steady supply of biogenic carbon is critical. A national strategy should ensure sustainable biomass availability, focusing on quantity, quality, and environmental impacts, while leveraging New Zealand's forestry resources. This should also include consideration around sequencing of which sector(s) get priority for feedstock supply.	MfE and MBIE
4. Engage proactively in IMO discussions, incorporating insights from actively monitoring and understanding global technology advancements in the area of renewable fuels and maritime applications. Approve and adopt IMO regulations as they relate to safety and handling around alternative fuel production, storage and bunkering, to ensure internationally consistent standards.	MoT
5. Facilitate knowledge sharing around experience from establishing green corridors and decarbonising shipping more generally with nations that have progressed to an advanced exploration of green corridors.	MFAT
6. Maintain a continued focus on opportunities to support / mandate domestic decarbonisation initiatives and ensure alignment with emerging global regulations.	MfE, supported by MoT and EECA

A | Technical Appendix

This section provides further detail of the economic impact analysis undertaken by Deloitte Access Economics.

This appendix is organised as follows:

- Scenario, interpretation, descriptions and assumptions
- Overview of Deloitte Access Economics Computable General Equilibrium (CGE) model, DAE-RGEM

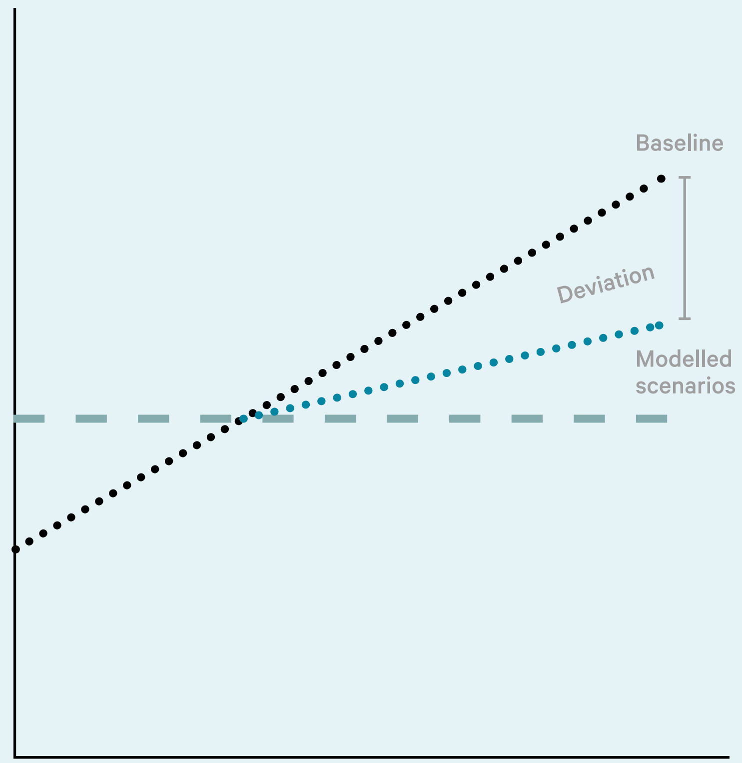
Scenario descriptions and assumptions

Interpretation

The results of the economic impact modelling should be interpreted as 'deviations' from a baseline. For example, a GDP deviation of -$200 million means that New Zealand's GDP is $200m smaller in the modelled scenario, when compared to the baseline. This is not to say that there is negative growth in the modelled scenario. Rather, a -$200 million GDP impact suggests that GDP growth in the modelled scenario is lower when compared to the baseline.

The employment impacts, on the other hand measure the difference in job creation in the economy at any one point in time and is measured in full-time-equivalent employee terms. For example, a -1,000 FTE in 2050 impact suggests that the economy creates less 1,000 FTE jobs in the modelled scenario, compared to the baseline.

Figure 16: Stylised representation of modelling approach



Source: Deloitte Access Economics

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Scenario descriptions and assumptions

The baseline

The baseline in this case considers a scenario where New Zealand is able to decarbonise its shipping lanes at the same pace as competing trading nations, meaning no relative supply chain cost differences and so a continuation of status quo growth in trade. Exports and imports therefore grow in line with overall GDP growth.

For New Zealand, the short-term baseline GDP growth rate is based on in house Deloitte Access Economics projections. Over the longer-term, the baseline assumes that New Zealand's GDP grows at 2% per annum. For other regions within DAE-RGEM, the short-term baseline GDP growth rates are sourced from the International Monetary Fund.[128] Over the longer-term, other countries / regions baseline GDP growth is also assumed to be 2% per annum.

IMO GHG levy scenario

The IMO Marine Protection Committee (MEPC) 83 took place between 7 – 11 April 2025 at the IMO in London. During MEPC 83, regulatory text was finalised and 'approved' for the amendments to be circulated to the MARPOL Annex VI parties ahead of their anticipated adoption at the 2nd Extraordinary Session of MEPC (MEPC/ES 2) in Autumn this year (October 2025).

The draft regulations signal the approval of mid-term GHG reduction measures to be in force from 1 March 2027, for all ships above 5,000 gross tonnes and above. However, the following exceptions have been included:

- For ships solely engaged in voyages within waters subject to the sovereignty or jurisdiction of the State the flag of which the ship is entitled to sail i.e. ships operating exclusively in the waters of their flag State.
- Ships not propelled by mechanical means, and platforms including Floating Production, Storage, and Offloading vessels and Floating Storage Unit vessels and drilling rigs regardless of their propulsion.
- Semi-submersible vessels until further review of the application of the new chapter to MARPOL Annex VI implementing the new requirements.

The mid-term GHG reduction measures

The mid-term GHG reduction measures set out two GHG Fuel Intensity Standards that ships subject to the regulations must comply with:

- A Base target: This requires reductions in GHG fuel intensity (measured against a 2008 GHG Fuel Intensity reference point) starting at a 4% reduction in 2028 and increasing to 30% by 2035.
- A Direct Compliance target: This requires reductions in GHG fuel intensity (measured against a 2008 GHG Fuel Intensity reference point) starting at 17% reduction in 2028 and increasing to 43% by 2035.

A | Technical Appendix

Scenario descriptions and assumptions

If a ship has a GFI lower than the Direct Compliance target, it will receive Surplus Units (SUs). Conversely, if a ship has a GFI above the Direct Compliance target, it has a negative compliance balance and accrues two tiers of compliance deficits:

- For a GFI between the Base and the Direct Compliance targets, a ship generates a Tier 1 compliance deficit.
- For a GFI above the Base target, a ship generates both a Tier 1 compliance deficit (for the emissions between the Base and the Direct Compliance targets) and a Tier 2 compliance deficit (for the emissions above the Base target).

To handle deficits and surpluses, the requirements include several compliance approaches.

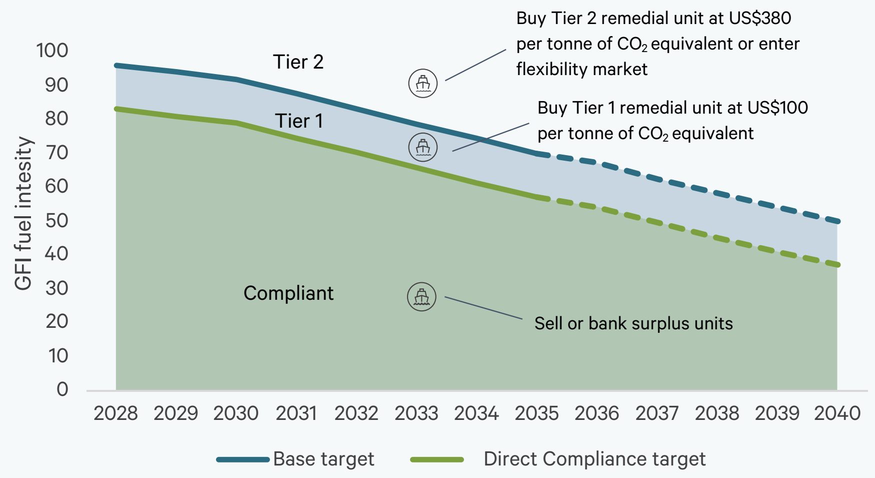
- A ship with a compliance surplus can transfer SUs to ships with a compliance deficit, or it can bank the units for later use within the two subsequent calendar years.
- A ship can balance its Tier 2 compliance deficit with SUs from other ships, or it can buy Remedial Units from the IMO Net-Zero Fund. The Tier 1 compliance deficit can only be compensated by Tier 1 Remedial Units.

The initial prices for Remedial Units are set out below:

- **Tier 1 Remedial Unit: $100USD per tonne of CO_2 equivalent**
- **Tier 2 Remedial Unit: $380USD per tonne of CO_2 equivalent**

A graph summarising the Base and Direct Compliance Targets, Tiers and implications is presented to the right:

Figure 17: Overview of IMO GHG reduction measures



Source: Deloitte Access Economics

A | Technical Appendix

Scenario descriptions and assumptions

Modelling approach for the IMO GHG levy scenario
Determining the effective IMO levy that ship owners will be subject to is complex. The levy payable by shipping lines will depend on the extent to which either the Base Target or the Direct Compliance Target is met, which, in turn depends on the alternative fuel and other efficiency measures used.

Further complexity is added by the ability of shipowners who fail to meet the Base Target to purchase SUs from other ships in a flexibility market.

The demand for SUs will depend on the emission intensity reductions required in any particular year, as well as the extent which shipping lines can reduce emissions across their fleet relative to targets. The supply of surplus units will depend on the extent to which shipping lines are able to exceed targets, which in turn will depend on the pace of decarbonisation across fleets, itself a function of the price of alternative fuels and investment in alternative fuel powered vessels. Predicting the effect IMO levy per tonne of CO_2eq over time is therefore complex.

As a pragmatic way forward, Deloitte Access Economics has undertaken a simplified approach to assessing the impacts of the IMO levy, focusing on what an indicative $100USD per tonne of CO_2eq levy might mean for New Zealand in a scenario where it fails to decarbonise its shipping lanes, while competing trading nations do.

Key elements of the modelling approach for the IMO GHG levy scenario are detailed below:

- The levy of $100 USD is per tonne CO_2eq is implemented by the IMO and takes effect in 2027. It is assumed that this levy is passed on in full by shipping lines to importers and exports. There is a possibility that pass through of the IMO levy differs across shipping lanes.
- The amount of GHG emitted as a result of the shipment of goods between countries is determined using UNCTAD data[129] on trade between countries by commodity, weight and distance and the well-to-tank emission conversion factors provided by the United Kingdom government for 3000-7999 twenty-foot equivalent container ships.[130]
- The IMO levy is proposed to cover well-to-wake emissions, which also covers the last leg of emissions associated with fuel combustion and conversion in a ship, and so the use of well-to-tank emission conversion factors is likely to be conservative. However, the modelling also does not explicitly take into account the 2008 GHG fuel intensity reference point proposed by the IMO.
- The assumed $100 USD per tonne CO_2eq levy amount is applied to the calculated tonnes of emissions associated with the shipment of goods between countries determines using the UNCTAD data. This levy amount is modelled as a tax applied to imports and exports of goods within DAE-RGEM, on the assumption the IMO levy will be passed on to cargo owners by shipping lines.
- In specifying which variables within DAE-RGEM to ‘shock’ to mimic the IMO levy, care was taken to consider the potential impacts of revenue raised by the levy. Countries within DAE-RGEM are able to impose taxes on both inward and outward-bound trade.

A | Technical Appendix

Scenario descriptions and assumptions

When goods flow from one region to another, it can be taxed by both the origin and destination region. In order to mimic the impacts of the IMO levy, when goods flow between two countries that are not New Zealand, we assumed that half the levy is imposed as a tax on exports by the origin region, and the other half as a tax on imports by the destination region. This means these countries share the levy revenue. In line with the IMO's indication that revenue would be recycled to support decarbonising economies. It was assumed that New Zealand does not receive revenue from the levy given the scenario contemplates a scenario where New Zealand does not act to decarbonise its shipping lanes. Instead competing trading nations that act to decarbonise shipping lanes do.

- In the IMO levy scenario, competing trading nations are assumed to steadily decarbonise their shipping lanes. This reduces the amount of emissions associated with transporting goods to and from competing nations, and so the amount the IMO levy they are required to pay, over time.

The extent to which competing nations decarbonise is based on Lloyd's Register shipping fuel mix projections.[131] In particular, it is assumed that competing trading nations utilise 16% zero-to-low emission fuels for shipping goods by 2030, increasing to 55% by 2040 and 94% by 2050 respectively.

- Under the IMO scenario, New Zealand does not act to decarbonise its shipping lanes. While this means it is subject to the IMO levy for longer than competing trading nations, it also means that New Zealand continues to use fossil fuels, which are projected to remain cheaper than zero-to-low emission fuels for the foreseeable future. This cost differential offsets the impact of the IMO levy on New Zealand.
- The cost differentials between fossil fuels and zero-to-low emissions fuels have been informed by projections from the Maersk McKinner Moller Centre for Zero Carbon Shipping[132] and DNV[133], particularly on the difference between Low Sulphur Fuel Oil and other alternative fuels.

The plurality of fuel options, each with different production pathways, and thus costs and potential routes to market, make it inherently difficult to determine the exact cost difference between fossil fuels and zero-to-low emission fuels over time, and is reflected in the wide range of projected cost differences across a range of sources.

- As a pragmatic way forward, it is assumed that zero-to-low emissions fuels are approximately 2 times the cost of fossil fuels in 2027 and that this difference falls to 1.6 times by 2050.
- Within DAE-RGEM, the difference in costs between zero-to-low emission and fossil fuels has been modelled as a reducing the cost of transporting goods to and from New Zealand.

A | Technical Appendix

Scenario descriptions and assumptions

Fall in exports

This second scenario contemplates a fall in goods exports of between 5% and 15%. This scenario is intended to supplement the IMO GHG levy scenario, capturing incremental risks associated with an increased focus on Scope 3 emissions, a changing regulatory environment in key trading partner economies, shifting consumer preferences and a loss in reputation or trust in New Zealand's key export brands.

Such risks can be seen as additive to the potential costs modelled under Scenario 1 above, as they exist alongside and potentially compound the impact of the IMO GHG levy. By taking action on decarbonising New Zealand's international shipping lanes, New Zealand can avoid the negative economic impacts of a broader fall in goods exports.

The assumed 5% to 15% range has been responses to a targeted survey of members of the New Zealand Council of Cargo Owners. Within DAE-RGEM, the 5% to 15% fall in exports has been modelled as a year-on-year reduction in goods exports that results in a 5% to 15% reduction across all goods exports by 2050 respectively.

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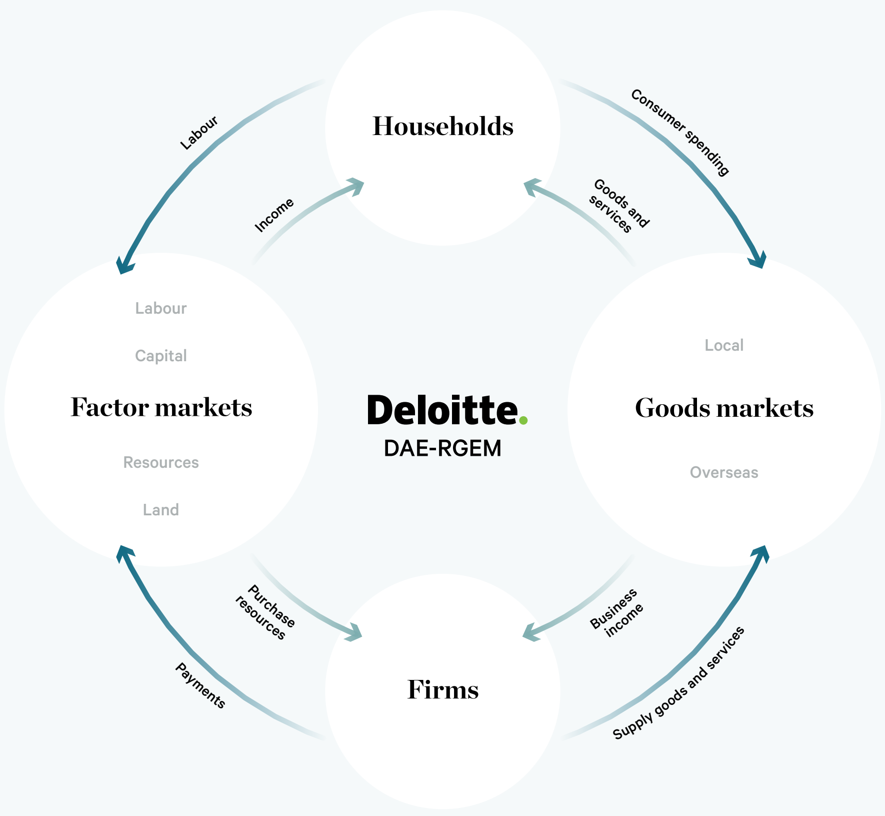
Overview of DAE-RGEM

The Deloitte Access Economics – Regional General Equilibrium Model (DAE-RGEM) is a large scale, dynamic, multi-region, multi-commodity computable general equilibrium model of the world economy. The model allows policy analysis in a single, robust, integrated economic framework. This model projects changes in macroeconomic aggregates such as GDP, employment, export volumes, investment and private consumption. At the sectoral level, detailed results such as output, exports, imports and employment can also be produced. A stylised diagram of DAE-RGEM is provided to the right.

Figure 18: Stylised representations of DAE-RGEM



Source: Deloitte Access Economics

The core economic data underpinning DAE-RGEM – the social account matrix (SAM) – is sourced from the Global Trade Analysis Project (GTAP) database.[134]

Model configuration

For the purposes the analysis for this workstream, DAE-RGEM has been configured in the following ways:

The model has been configured to dynamically consider the impact of the scenarios through to 2050 at annual time intervals.

The model has been configured to consider the impacts across the following regions: New Zealand, Australia, USA, China, India, UK, Asia Pacific, Europe and Rest of World.

The following sectors have been included in DAE-RGEM.

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Overview of DAE-RGEM

Sector	GTAP sector
Plants	Paddy rice
	Wheat
	Cereal grains
	Vegetables, fruit, nuts
	Oil seeds
	Sugar cane, sugar beet
	Plant-based fibres
	Other crops
Dairy cattle	Raw milk
Fishing	Fishing
Other animals	Bovine cattle, sheep and goats, horses
	Wool, silk-worm cocoons
	Other animal products
Forestry	Forestry
Meat manufacturing	Bovine meat products
	Other meat products
Dairy processing	Dairy products
Other food manufacturing	Vegetable oils, fats
	Processed rice
	Sugar
	Food products
	Beverages, tobacco products
Light manufacturing	Textiles
	Wearing apparel
	Leather products
	Wood products
	Paper products, publishing
Coal	Coal
Oil	Oil
Gas	Gas
Other mining	Other mining
Hydrogen	Petroleum, coal products*
Petroleum, coal products	Petroleum, coal products
Heavy manufacturing	Chemical products
	Basic pharmaceutical products
	Rubber and plastic products
	Mineral products
	Ferrous metals
	Metals
	Metal products
	Computer, electronic, and optical products
	Electrical equipment
	Machinery, equipment
	Motor vehicles and parts
	Transport equipment
	Other manufactured goods
Electricity transmission and distribution	Electricity transmission and distribution

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Overview of DAE-RGEM

Sector	GTAP sector
Conventional electricity	Coal base load
	Gas base load
	Oil base load
	Other base load
	Gas peak load
	Oil peak load
Emissions free electricity	Nuclear base load (in regions outside of New Zealand)
	Wind base load
	Hydro base load
	Hydro peak load
	Solar peak load
Gas manufacture and distribution	Gas manufacture, distribution
Water	Water
Construction	Construction
Trade	Trade

Sector	GTAP sector
Accommodation, food and service activities	Accommodation, food and service activities
Road Transport	Road Transport and Warehousing and support activities
Water Transport	Water Transport
Air Transport	Air Transport
Financial Services	Financial Services
Insurance	Insurance
Real Estate Activities	Real Estate Activities
Dwellings	Dwellings
Other services	Communication
	Business services
	Recreational and other services
Government services	Public administration and defense
	Education
	Human health and social work activities

B | Biofuels

Overview and summary

Biofuels are emerging as a crucial transitional fuel in the shipping industry, playing a significant role in the sector's decarbonisation efforts. As the demand for cleaner fuels grows, biofuels are expected to see a substantial increase in consumption, with projections indicating a rise from 16.5 million metric tons in 2023 to 58 million metric tons by 2030. This growth is driven primarily by the aviation and maritime sectors, which are anticipated to account for over 75% of new biofuel demand.[136]

Biofuel production is also projected to grow, reflecting a broader shift towards renewable energy sources in transportation. The share of biofuels in total liquid transport fuel demand is expected to increase from 5.6% to 6.4%, equivalent to approximately 215 billion litres.[137] This transition not only supports the shipping industry's decarbonisation goals but also promotes a circular economy through the use of sustainable feedstocks, such as waste oils and non-food biomass.

This roadmap touches on several types of biofuels, outlining the production pathways, infrastructure developments, and market activities required for integrating biofuels into the maritime industry. The roadmap concludes with a high-level view on the overall feasibility of production of biofuels in New Zealand, informed by market engagement and research.

Currently, the use and production of biofuels in New Zealand is limited, especially as a transport fuel.[138] The majority of domestic biomass use is in the industrial sector for process heat and some electricity generation.[139]

B | Biofuels

Biofuels as an alternative marine fuel

Rationale for Biofuels in Shipping[140]

Biofuels are expected to play a vital role in the decarbonisation of the shipping industry. Their lower green house gas (GHG), NOx, SOx footprint as compared to conventional marine fuels plays a significant role in its uptake. Another key advantage of biofuels is their compatibility with existing infrastructure, reducing relative cost when compared to other alternatives. As a transitional fuel, biofuels address multiple commercial benefits such as:

- **Ability of commercial marine technologies to work on liquid biofuels:** This already existing capability is an advantage for biofuels, as they can be easily blended with existing marine fuels (e.g. 20% FAME blends). Such blends are already commercially available.
- **Limited changes to bunkering and storage infrastructure:** Limited to negligible changes required to integrate biofuels into the existing storage and bunkering infrastructure make them a suitable option as a transition fuel in the short-term.
- **Lower lifecycle emissions:** Fuels such as bioLNG (produced from agriculture and animal waste) are expected to reduce carbon emissions by 30% as compared to fossil fuel LNG, indicating lower lifecycle emissions.

Despite the commercial benefits, biofuels do face certain challenges of their own:

- **Fuel-specific issues:** Diesel-based biofuels such as SVO and FAME face issues including engine carbon build-up and water contamination, respectively. However, HVO with its low oxygen content, offers higher fuel efficiency and longer lifespan, addressing many of these challenges.
- **High cost of certain biofuels:** Certain alcohol and gas-based biofuels such as bioethanol, bio-methanol, and bioLNG are cost-intensive to use due to the need for engine adaptations and specialised storage and bunkering infrastructure. Additionally, high feedstock costs for biofuels also intensify the issue.
- **Biofuel availability:** Current biofuel production levels are insufficient to meet global demand if biofuels were to replace marine fuels entirely. Significant production scale-up is necessary to meet future demand.
- **Sustainability:** Scaling up biofuel production must be managed to mitigate social and environmental impacts. Ensuring secure, long-term supplies of low-cost, sustainably-sourced feedstock is crucial for the economic viability of biofuels.

B | Biofuels

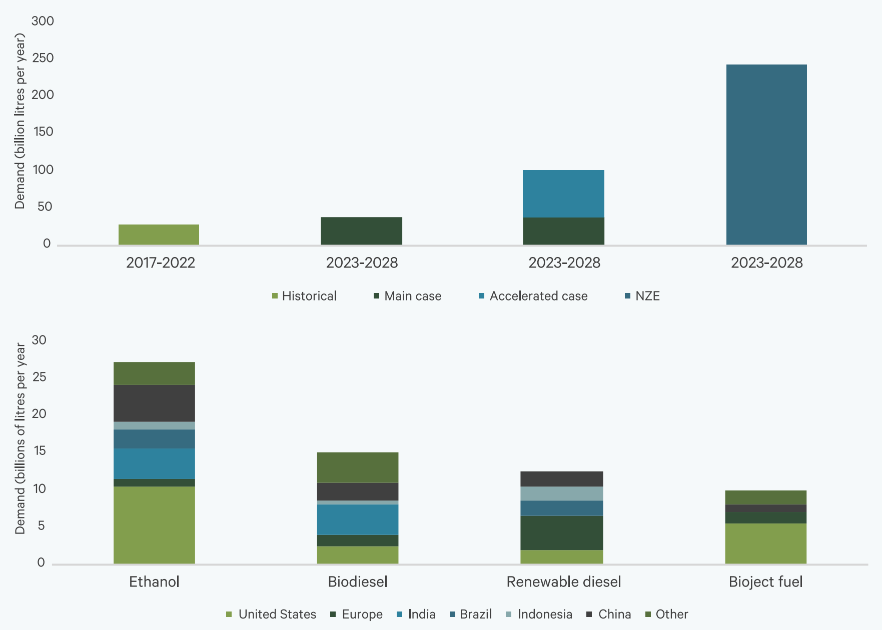
Background

Role of Biofuels as a Transition Fuel

Biofuel demand is expected to increase by 38 billion litres over 2023-28, a 30% increase over 2017-22, with renewable diesel and ethanol accounting for ~66% of this growth, followed by biodiesel and biojet fuel. In the International Energy Agency's (IEA) Net Zero by 2050 accelerated scenario (net-zero achieved by 2050 with rapid reductions as compared to base case), biofuels are projected to play a significant role in decarbonising the shipping sector. Accordingly, estimates suggest that biofuels production could grow at a compound annual growth rate (CAGR) of 8%, albeit catering to only 40% of net-zero emissions. [141]

Multiple pathways are available to address this gap, including stronger policies, technology advancements, entering new markets, increasing the use of bio jet fuel, reducing GHG emissions intensity and expanded feedstock supply are needed. [142]

Figure 19: Forecast vs Net Zero Scenario demand growth, 2017-2030 (yop) and additional demand growth in the accelerated case, 2023-2028 (bottom)



Maritime shipping continues to be a vital form of freight transportation, offering an energy-efficient and cost-effective mode of transportation, resulting in growing fuel demand.

Favourable demand dynamics along with new regulatory requirements create a strong market potential for transition from conventional marine fuels to biofuels (including biofuel blends), due to their low GHG emissions. The environmental benefits, regulatory policies, and government support create a strong business case for the transition to biofuels.[143]

A biofuels transition offers several opportunities for the marine shipping industry in the form of:

- **Low sulphur content:** In addition to reduced GHG emissions, biofuels are also low in sulphur content, which is one of the key gases gaining the attention of the IMO.
- **Net-reduction of carbon costs:** Second-generation biofuels, derived from sustainable feedstocks offer the cost advantages.
- **New-alternate fuels:** Continuous introduction of new alternate fuels in the marine fuel mix would eventually reduce fossil-fuel dependency, with drop-in marine biofuels exhibiting strong potential.
- **New engine technologies** with potential to open new markets for biofuels.[144]

B | Biofuels

Background

Figure 20: SWOT analysis of marine fuels from biomass

Type of Biofuels

Biofuels can be found in different states such as solid, liquid, or gaseous. Currently they can be categorised into the following:

- **Straight Vegetable Oil (SVO):** An unprocessed or lightly refined vegetable oil derived from crops like rapeseed, soybean, and palm oil. It is used as fuel in modified diesel engines, but due to its high viscosity, it often requires engine modifications to function effectively.[145]
- **Biodiesel**: A renewable, biodegradable fuel made from vegetable oils, animal fats, or recycled restaurant grease through a chemical process called transesterification, which converts oils and fats into fatty acid methyl esters (FAME). It can be used in diesel engines without major modifications, either as a pure fuel (B100) or blended with petroleum diesel (e.g., B20, B5), offering reduced GHG emissions.[146]
- **Renewable Diesel or Hydrotreated Vegetable Oil (HVO):** A fuel chemically identical to petroleum diesel, produced from fats and oils such as soybean oil or canola oil through processes like hydrotreating, gasification, and pyrolysis. Known previously as green diesel, it can replace or blend with petroleum diesel and is primarily used in California due to the economic benefits provided by the Low Carbon Fuel Standard.[147]
- **Bioethanol**: A renewable fuel derived from biological materials, such as crops (e.g., sugarcane, corn) or waste. It serves as a petrol substitute or additive, reducing reliance on petroleum and emissions. Feedstocks include sugars, starches, and lignocellulosic biomass, with corn being the dominant source globally.[148]
- **Biomethanol**: A renewable form of methanol produced from forestry and agricultural waste, waste-derived biogas from landfills and sewage. It offers significant carbon emission reductions compared to conventional methanol, although its high production cost is a limiting factor to its uptake.[149]
- **BioLNG (Liquefied Biomethane or LBM):** Derived from the liquefaction of biomethane, enabling its use in sectors such as heavy-duty road transport and maritime shipping. It can be transported via pipelines or directly liquefied and shipped for onboard usage, offering high energy density and lower emissions.[150]

B | Biofuels

Background

Key Biofuel Producers[151]

- **Sunshine Biofuels (USA):** Offers liquid biofuels derived from biomass as substitutes for diesel and heavy fuel oil. Their biodiesel, branded as Sunshine Renewable Diesel, is produced from recycled cooking oil, offering low sulphur emissions and a higher flash point than conventional biodiesel.
- **Avril Group (France):** Offers biodiesel based on oilseed and protein products. The company is Europe's leading biodiesel producer, manufacturing biodiesel from rapeseed oil under the brand Diester.
- **Archer Daniels Midland (USA):** Offers a biofuel portfolio including first-generation bioethanol from corn and biodiesel from canola (rapeseed) and soy, produced via transesterification.
- **Solazyme (USA):** Offers transportation fuels produced from microalgae. The company developed a proprietary biotechnology platform using heterotrophic algae, which relies on sugar as feedstock.
- **Neste Corporation (Finland):** Offers petroleum products and renewable fuels, with four HVO production plants in Finland, the Netherlands, and Singapore.
- **Emerald Biofuels (USA):** Offers drop-in renewable diesel, produced from non-edible waste oils.
- **UPM (Finland):** Offers a wood-based renewable diesel produced from non-food forest residues (under the BioVerno brand), specifically tall oil, a by-product of pulp production.
- **SunPine (Sweden):** Offers green diesel, a drop-in fuel blendable with conventional diesel, by primarily extracting tall oil (CTO) from the pulp and paper as a raw material.
- **Galp (Portugal):** Offers biofuels as a component of its petroleum products, by primarily using palm oil from Brazil for biofuel production.
- **Eni (Italy):** Offers biofuels from vegetable oil and biomass, including green diesel, naphtha, and LPG.
- **Evoleum, formerly known as QFI Biodiesel (Canada):** Offers advanced biofuels for the maritime, trucking, and energy utility industries, with expertise in biodiesel and biobunker fuels, which are derived from industrial and domestic waste, including recycled vegetable oil.
- **Renewable Energy Group (USA):** Offers drop-in renewable diesel and heating oil for transportation and power generation, with 12 active biorefineries across the USA.

B | Biofuels

Background

Current Demand for Biofuels

As per IEA, the global biofuel demand is expected to shift toward aviation and maritime sectors by 2030, with rising competition for feedstock waste oils driving up prices.

The biofuel market is projected to grow annually by 20%, reaching 58 million metric tons by 2030, up from 16.5 million metric tons in 2023, reflecting a significant increase in production volume. According to the IEA, the share of biofuels in total liquid transport fuel demand is expcted to increase from 5.6% to 6.4%, (equivalent to 215 billion liters by 2030).[152]

Surge driven by aviation and maritime sector

According to the IEA, the aviation and shipping sectors will account for over 75% of new biofuel demand by 2030. Marine biodiesel consumption is expected to increase by 1.8 billion liters by 2030, primarily driven by the ReFuelEU Maritime legislation, which mandates reductions in greenhouse gas intensity. Despite competition from LNG and shore power, the demand for biodiesel in shipping is projected to grow significantly, particularly in Europe. Biofuels, particularly drop-in options like biodiesel and bio-methanol, are increasingly adopted by companies like Maersk and CMA CGM, with Maersk aiming for net-zero emissions by 2040 using a mix of fuels, including biofuels.

B | Biofuels

CASE STUDY 1

Renewable Diesel: GoodFuels Marine – Driving Sustainability in the Marine Fuel Industry [153]

Introduction of GoodFuels Marine

Based in Amsterdam, Netherlands, GoodFuels Marine is a fuel trader and service provider specialising in high-quality hydrotreated drop-in fuels tailored for the Marine Gas Oil (MGO) market. It offers an integrated, end-to-end solution for the marine industry's sustainable biofuel needs. While the company does not own production facilities, it plays a crucial role as a supply chain orchestrator, connecting vessel operators with fuel producers. GoodFuels focuses exclusively on second-generation biofuels and is actively broadening its portfolio to further enhance sustainable marine fuel options.

The company also engages in feedstock development and trading to support its marine biofuel operations, though production and refining are outsourced to third-party entities. The company collaborates with logistics and fuel distribution partners to grow its biofuel fleet and is preparing to enter the fuel commodities market in Western Europe and Scandinavia, demonstrating its commitment to expanding sustainable energy solutions globally.

Partnership with Boskalis and Wartsila

In a two year pilot program intiaited in 2015, GoodFuels partnered with Boskalis (a provider of dredging and marine solutions) and Wartsila (a marine engine supplier), to develop sustainable, scalable, and cost-effective drop-in biofuels for commercial shipping. The project focused on creating renewable diesel from eco-friendly feedstocks like waste frying oil, industrial waste residues, and lignocellulosic biomass.

The initiative involved three critical steps: fuel testing and development, sustainable production, and scaling up to commercial levels. This partnership underscored their commitment to advancing sustainable maritime fuels.

Achievements

In July 2015, GoodFuels reached a significant milestone by earning the highest certification standard from the Roundtable of Sustainable Biomaterials (RSB).

Since then, they have been collaborating with various partners to source sustainable feedstocks, including energy crops, waste oils, and pulp and paper residues, carefully tailored to geography and production scale. Presently, GoodFuels provides marine biofuels compatible with MGO (Grade 1) and HFO (Grade 3), which can either be blended with conventional fuels or utilised as heating fuels.

CASE STUDY 2

Biomethanol: Enerkem – Transforming Waste into Clean Fuels

Introduction of Enerkem

A private Canadian cleantech company, with technology to convert waste biomass and municipal solid waste into clean transportation fuels and chemicals. With its proprietary gasification and catalytic conversion technology, it produces syngas, methanol, and ethanol fuels. The company operates one pilot plant, one demonstration plant, and one commercial facility, all based in Canada.

Partnership and Commercial Facility

In 2014, Enerkem partnered with the City of Edmonton and Alberta Innovates to establish and operate a commercial-scale plant. This collaboration aimed to divert municipal solid waste from landfills and convert it into syngas and methanol. The facility has a production capacity of 38 million liters of methanol and ethanol annually.

Technology and Impact

Enerkem's advanced technology not only addresses waste management challenges but also contributes to the production of sustainable fuels. By leveraging waste biomass and municipal solid waste, the company reduces landfill dependency and promotes the circular economy. The commercial facility serves as a model for integrating waste-to-fuel solutions into urban waste management systems.

Achievements and Future Potential

Enerkem's Edmonton facility exemplifies the strategic application of cleantech innovation to effectively address critical environmental challenges while contributing to sustainable development. The company's ability to scale its technology and produce substantial volumes of clean fuels solidifies its position as a frontrunner in the renewable energy industry.

B | Biofuels

CASE STUDY 3

FAME: Avril Group – Advancing Biodiesel Innovation

Introduction of Avril Group

Founded in 1983, Avril Group is a global agro-industrial organisation based in France, specialising in the development of oilseed and protein products derived from crops. The company is renowned for producing biodiesel from rapeseed oil under its flagship brand, Diester, and holds the position of Europe's largest biodiesel producer. Avril integrates biofuels into diesel blends ranging from 5% to 30% for its company vehicles, while French diesel vehicles utilise an 8% blend.

Innovation in Biodiesel Development

The company is actively involved in the advancement of second-generation biodiesel, utilising non-edible plants, agricultural waste, animal fats, and waste oil as feedstocks. This approach underscores their commitment to sustainability while reducing reliance on traditional fossil fuels. Their efforts extend to the BioTfueL program, a collaborative initiative with Total, aimed at developing biodiesel and biokerosene from forestry waste. The program employs thermochemical conversion techniques to transform lignocellulosic biomass and torrified material into biofuel.

Achievements and Impact

Through the BioTfueL program, the company aimed to produce 200,000 metric tons of biodiesel and biojet fuel annually from one million metric tons of biomass by 2020. This initiative highlights commitment to scaling sustainable fuel production and addressing environmental challenges.

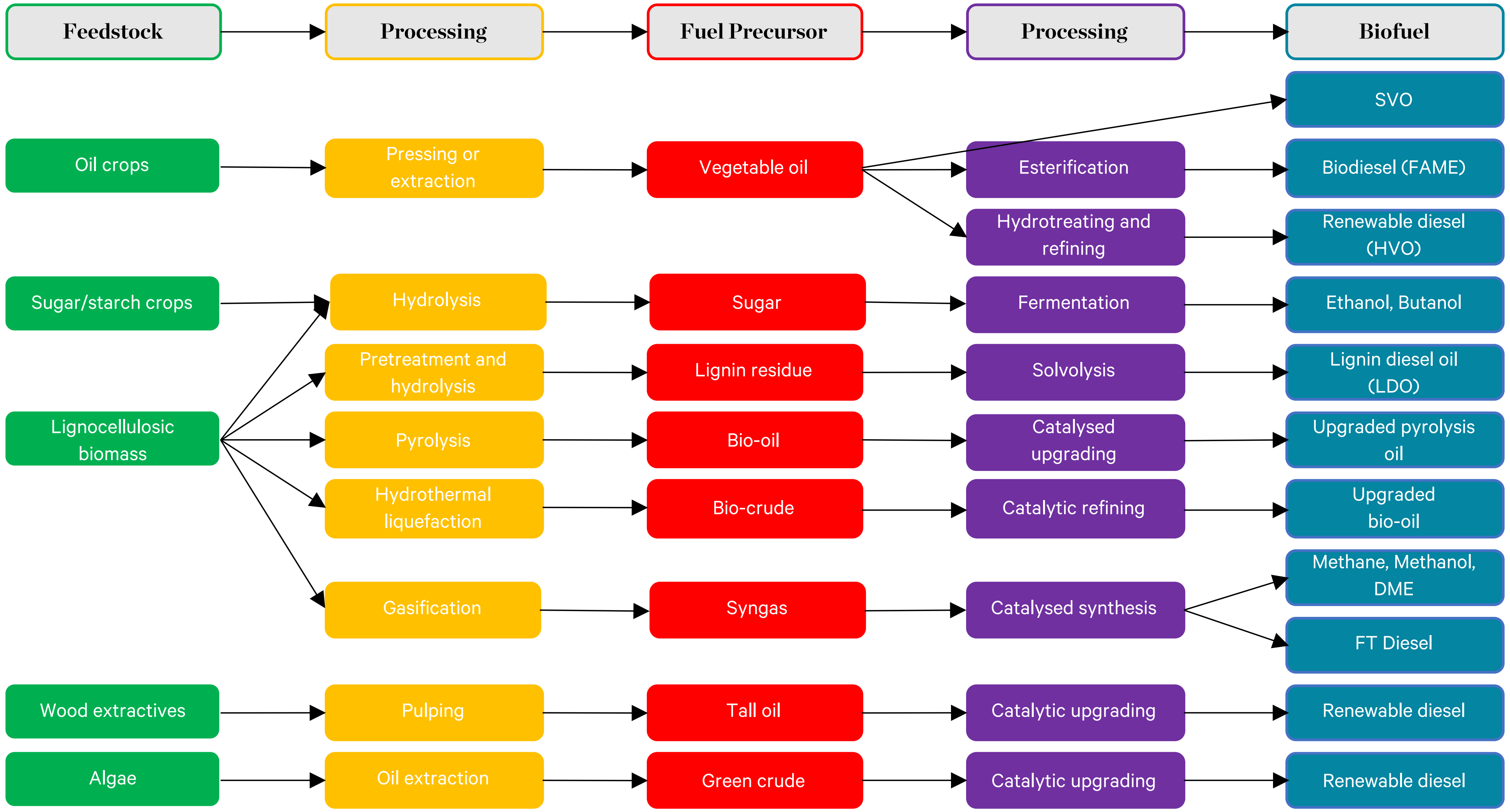
B | Biofuels

Production pathways

Technology Pathways and Feedstock Types[154]

The key characteristic of biomass is that it is a renewable resource with minimal quantities of sulphur, due to which biofuels have the potential to become an important part of the fuel mix in the shipping sector, reducing its dependence on fossil fuels as well as GHG emissions. Biofuels are derived from biologically renewable resources, with most biofuels being derived from plant based sugars, oils and terpenes, with a certain small amount derived from animal fat waste.

Figure 21: Overview of different feedstock conversion routes to marine biofuels including both conventional and advanced biofuels.



B | Biofuels

Production pathways

Typically, biofuel feedstocks can be placed in one of the two categories, namely Agricultural and Forestry:[155]

- **Oil crops, Sugar/starch crops and Lignocellulosic biomass:** All the three feedstocks are an agricultural resource, with oil and sugar/starch crops forming a part of food-crops, such as:
  - **Sugar crops:** sugarcane and barley
  - **Starch crops:** wheat, oats, corn and grain sorghum
  - **Oil crops:** canola, soybean and sunflower

Lignocellulosic biomass forms a part of non-food crops and is typically woody biomass used for salinity control on agricultural land. An example is the Mallee eucalyptus, which are short-rotation and fast-growing.

- **Wood extractives:** This forms a part of the forestry category of feedstocks where wood is harvested from native forests and plantations to form softwood or hardwood.

Another category of feedstocks are the organic waste and residues, which typically include harvest residues, agro-industrial waste, landfill gases, construction/demolition waste, municipal waste, etc.

Potential Competition of Feedstocks from other Fuel Production and Sectors

The broader biofuels market growth is expected to grow annually by 20% to reach 58 million metric tons by 2030, from 16.5 million metric tons in 2023, with the share of biofuels in total liquid fuel transportation growing from 5.6% to 6.4%. Similarly, use of marine biofuels is also expected to increase by 1.8 billion litres.[156]

However, these sectors' reliance on limited feedstocks, such as residue oils and used cooking oils, challenges the respective sector's ability to scale the use of biofuels. For example, demand for residue oils (including cooking oil, tallow and palm oil) is projected to increase by 70%, claiming ~80% of the supply potential, raising shortages and price pressures.[157]

Short-term solutions available but not pragmatic: Despite availability of alternative production pathways, such as vegetable oil-based processes or advanced technologies like alcohol-to-jet and Fischer-Tropsch methods, rising biofuel feedstock prices are unlikely to be mitigated as certain regulations (like EU RED III, Maritime initiatives) classify these as food crops, making them restricted for biofuel production.[158]

Mid-term solutions better placed to spread out costs: Policies supporting lower-emission feedstock pathways, sustainable agriculture practices (intercropping, cultivation of crops on marginal land) can address the growing demand. Additionally, the introduction of cellulosic ethanol and Fischer-Tropsch renewable diesel projects by 2030 is expected to increase biofuel production from emerging technologies by ~10x.

B | Biofuels

High level infrastructure requirments

High-Level Infrastructure Requirements for Biofuel[159]

A range of biofuels are expected to be a key element in the decarbonisation of the transportation sector, given the limitations of traditional biofuels.

Traditional biofuels like ethanol and biodiesel have limitations on the amount that can be blended with existing petroleum fuels. HVO (Hydrogenated Vegetable Oil) production technology is already a proven avenue for drop-in fuels, and can be considered as an approach to decarbonise the shipping sector. Although, limited feedstocks still pose a challenge to their uptake.

To address this, alternative methods for producing drop-in fuels using lignocellulosic feedstocks (known for their lower cost and greater availability) are actively being developed. These efforts emphasise thermochemical, biochemical, and hybrid approaches. For instance, thermochemical pathways turn biomass into pyrolysis oil, which can then be co-processed with existing petroleum. This pathway has the potential to lower production costs by utilising existing fossil fuel refining, distribution and storage infrastructure.

Fuel Transport Infrastructure[160]

Shipping ports serve as key hubs for global cargo distribution, with their growing size and number of ships demanding an expansion of the current infrastructure. In line with the increased ship demand is the rise in demand for marine fuels.

Marine fuel access varies by port. High-traffic ports benefit from regular supply, while smaller or seasonal ports often face irregular access due to limited infrastructure. Ports near large populations or manufacturing centers typically have the most advanced facilities and highest fuel demand. Fuel is transported via road, inland vessels, or pipelines for storage at port bunkering stations. Smaller ships refuel directly at the port, while larger ships rely on bunker vessels to transport and pump fuel onboard.

The infrastructure-led challenges which emerge in biofuel transportation are related to the geographic dislocation between the supply bases and demand areas. Some of these challenges exist in the form of:

- **Vegetable oils and animal fats** possess higher viscosities, which complicates their pumping and storage. Additionally, their instability makes them prone to degradation during storage, handling, and final usage.
- **FAME** is prone to oxidation and exhibits reduced flow properties at low temperatures, and deposits materials on exposed surfaces like filter elements, leading to multiple storage-related challenges.
- **Pyrolysis oil** requires acid-proof loading, unloading and handling equipment, requiring additional infrastructure investment.

Ships are long-term assets, and modifications to their storage, bunkering, and engine infrastructure involves significant costs. The expense associated with altering ship engines and fuel storage systems is anticipated to hinder the adoption of biofuels.

B | Biofuels

High level infrastructure requirments

An industry viability assessment observed that ship owners have an upper limit of 10% capital cost increase and want to maintain competitiveness at a USD 50/ tonne CO_2 carbon price, and negligible upstream emissions. Majority zero-to-low emission options, including biofuels do not meet this criteria. A potential option that emerges in this case is bioLNG, which can be supplied using existing LNG infrastructure, and LNG engines can accommodate without major modifications.[161]

B | Biofuels

Cost analysis

Market Pricing[162]
Short-term outlook: Market studies indicate that biofuel prices are consistently declining, with biodiesel and renewable diesel prices falling ~35% (versus 2022 average prices). While the prices are comparatively higher (~15%) compared to the 2010-19 period, the price declines still bear positive news for the biofuels industry. The key factors in the price decline are greater feedstock availability, along with decline in prices for sugar (~10%), corn (~35%) and vegetable oils (~30%) during 2022-24. This trend is expected to continue in the short-term.

Medium-term outlook: In the medium term, biodiesel and renewable diesel prices are projected to stay above historical averages due to sustained high demand for their feedstocks across marine shipping and other transportation sectors. Conversely, ethanol prices are expected to face less upward pressure, as feedstock production shares are predicted to remain stable, and demand for ethanol is anticipated to decline in certain markets.

Cost Breakdown[163]
Methanol is a key and highly versatile platform chemical in the chemical industry. Its primary applications include the production of other chemicals, such as gasoline additives, solvents, and antifreeze agent. A similar characteristic is displayed by biomethanol, which offers considerable reduction of GHG emissions and the possibility to be created from a wide range of feedstocks. However, one key challenge is its pricing, where its production price is estimated to be 1.5x – 4.0x higher than the cost of natural gas-based methanol (currently ranging from €100-200/t).

Current costs and cost projections
Two key cost-drivers of biomethanol are production costs and capital costs. Both the cost drivers exhibit unique pricing impacts:

- **Production costs:** The production costs of bio-methanol are highly influenced by local conditions, such as feedstock availability and pricing, electricity costs and sources, production scale, technology employed, and the desired product quality. Electricity can account for up to 65% of the production cost, especially in plants relying on CO_2 and electrolysis (depending on local conditions). This highlights the critical role of local factors and suggests that opportunities for cost-effective production may already exist in regions with advantageous conditions.

  Production cost estimates for bio-methanol vary significantly depending on feedstock and production setup. Wood-based production costs ranges from €160/t to €940/t, with higher costs linked to smaller-scale facilities. Waste-stream-based bio-methanol is relatively cheaper, ranging between €200/t and €500/t. Bio-methanol from CO_2 is the most expensive (€510-€900/t).

Cost analysis

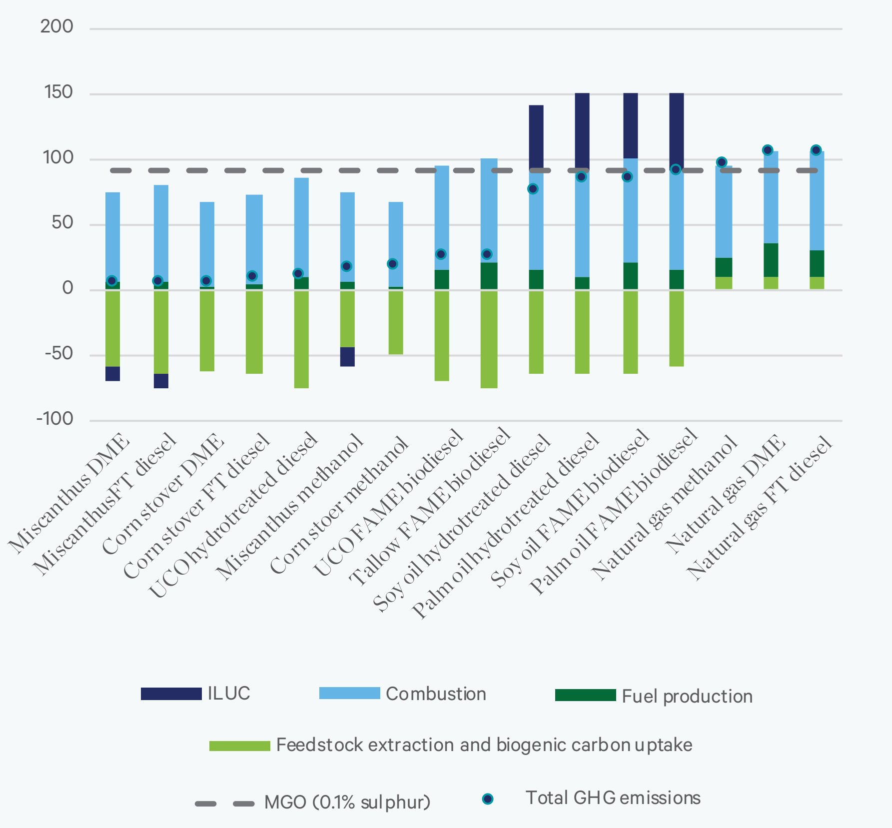
- **Capital costs**
  The capital costs (per unit of capacity) of bio-methanol production facilities are significantly higher compared to natural gas-based plants (3x – 4x). In cases of facilities utilising CO_2, costs are estimated to be 15x higher than most economical natural gas-based alternatives. However, these high costs are partly attributable to the smaller scale of such plants. Larger facilities with capacities of 30–40 kt/year are projected to achieve lower costs per unit of capacity.

  Additionally, according to research studies, bio-methanol plants are about 1.8x more expensive than bio-ethanol facilities for equivalent energy output. This highlights the economic challenges of bio-methanol production, although economies of scale and technological advancements are anticipated to improve cost efficiency in the future.

Emissions reductions potential

Emissions Profile of Renewable Diesel, Biomethanol and FAME

Figure 22: Lifecycle GHG emissions (100-year GWP) of the alternative liquid marine fuels and feedstocks analysed, by life-cycle stage[164]



Emissions from renewable diesel

Renewable diesel offers significant environmental benefits, particularly in reducing emissions. As a sulphur-free fuel it completely eliminates SO_x emissions when used in pure form. When blended with conventional fuels, these reductions are proportional to the blend percentage, making it adaptable for various applications.

- **Marine applications:** In marine engines biofuels have demonstrated the ability to reduce NO_x emissions by up to 20%, depending on factors such as engine load and speed. Studies also report particulate matter (PM) emissions reductions of up to 30%, attributed to the shorter carbon chains in renewable diesel when compared to MGO.[165]
- **On-road applications:** For on-road diesel engines, studies show NO_x reducti ons ranging from 6% to 18% and consistent PM reductions averaging 27% to 30%. However, variations exist based on operational conditions; one study reported a 26% increase in NO_x emissions, emphasising the importance of assessing performance in specific use cases. [166]

Emissions from biomethanol

Methanol, as an alternative fuel, offers significant environmental benefits across multiple sectors. It reduces key emissions such as SO_x by over 99%, PM by 95%, and NO_x by 60-80% in marine applications when compared to conventional fuel oil.[167]

Methanol can also power diesel engines, methanol-specific engines, and advanced fuel cell vehicles, further lowering emissions. These attributes position methanol as a sustainable solution for addressing regulatory and environmental challenges in both transportation and marine industries.

B | Biofuels

Emissions reductions potential

Emissions from FAME

Emissions from FAME vary based on feedstock type, blending ratios, and engine conditions. While FAME biodiesel reduces hydrocarbons (HC), carbon monoxide (CO), and sulphur emissions, it tends to increase NOx emissions, especially when derived from feedstocks with unsaturated fatty acid chains (e.g., soy, canola).[168]

Studies indicate that NOx emissions increase due to faster ignition timing associated with FAME, though methods like injection delay have been proposed to address this. Additionally, FAME particulates are smaller in size compared to fossil diesel, which may present different health considerations. Overall, FAME emissions provide environmental benefits but require careful management to mitigate trade-offs like NOx increases.

B | Biofuels

Wider identified applications

Biofuels have a broad range of applications beyond marine shipping, significantly impacting transportation, energy production, and sustainability initiatives. In the transportation sector, biofuels like ethanol and biodiesel are used extensively to reduce emissions. In energy production, biofuels serve as a renewable source for electricity generation. They are used in co-firing with coal or in dedicated biomass power plants, contributing to a diversified energy mix.

Sustainability initiatives benefit from biofuels through their ability to utilise agricultural residues, waste oils, and non-food biomass, promoting waste reduction and circular economy practices. Advanced biofuels, such as those derived from algae, could be promising due to high yields and minimal land use.

B | Biofuels

A view on overall feasibility

Currently, the use and production of biofuels in New Zealand is limited.[169]

New Zealand's use of biofuels comprises less than 0.1% of its total fuel use. New Zealand's production of biofuels between 2007 and 2022 is bimodal, featuring significant peaks in 2012 and 2020 as a result of policy developments at the time. Fonterra at one point produced 15 million litres of bio-ethanol per year, however this production has since been substituted. Southern Biofuels Limited, a small South Island based company founded in 2013, produces approximately half a million litres of biodiesel from used cooking oil. This demonstrates the limited scale of biofuel production in New Zealand at present.[170]

There are ongoing investigations around a proposed biorefinery project at Marsden Point. In October 2024, Channel Infrastructure NZ Limited annouced that it had entered into a conditional project development agreement with Seadra Energy Inc, who is partnering with consortium members Qantas, Renova Inc, Kent Plc, and ANZ (the "Seadra Consortium"), to develop a biorefinery at Channel's Marsden Point site. Should the project development agreement become unconditional, the proposed biorefinery project at Marsden Point would utilise some of Channel's decommissioned refinery assets (which would be refurbished and reconfigured), existing tankage, jetties and certain other infrastructure, as well as approximately 18-20 hectares of land on the site.

Assessing the feasibility of biofuels production and its application in the maritime sector within New Zealand involves evalauating several critical factors:

- **Domestic Feedstock Availability:** The New Zealand Biofuels Roadmap published by Scion in 2019 stated that credible large-scale production of biofuels is possible in New Zealand.[171] While there exists various biomass feedstock options, the most likely road to expand biofuel production in New Zealand, according to Scion Research, appears to be through non-food feedstocks, notably forestry grown on non arable land. Scion have conducted extensive studies into the potential for increasing domestic use of bioenergy and biofuels and have developed a model that can be used to optimise the site and size of a bioenergy plant based on New Zealand forests and residues.[172] An estimated 10-12 million cubic metres of woody biomass are produced domestically each year.[173]

B | Biofuels

A view on overall feasibility

- **Existing Infrastruture:** The infrastructure necessary for supporting biofuel production involves storage, transport, and processing facilities. Biofuels require limited changes to existing bunkering and storage infrastructure, which facilitates their integration as a transitional fuel. However, specific biofuels such as pyrolysis oil demand acid-proof equipment, indicating the need for additional infrastructure investment. In New Zealand, infrastructure investment would be required to build liquid biofuel production facilities and support the feedstock supply chain, especially to achieve production at a larger scale. The NZ Wood Fibre Futures Stage 2 Report estimated that the investment required for a large-scale liquid biofuels plant is expected to exceed $1b NZD.[174] This investment figure is broadly consistent with market engagement, which also suggested that a large scale biofuels plant would cost in excess of $1b USD.
- **Technological Readiness:** Technologies for producing drop-in biofuels from non-food feedstocks are currently less mature than other biofuel technologies. However, significant global research is driving rapid advancements in this area, with expectations that viable solutions will emerge within the required timeframes.[175]
- **Economic Considerations:** The economic considerations for biofuels in New Zealand's maritime sector reveal a complex landscape. While offering environmental benefits, biofuels face significant cost barriers, driven by high production and feedstock costs, with limited consumer willingness to pay the premium, despite offering a price advantage compared to other alternative fuels such as methanoal and ammonia. The New Zealand Emissions Trading Scheme (ETS) provides some support, but market engagement suggests that current carbon prices are insufficient. Strategic investments, policy enhancements, and technological advancements are essential to make biofuels a viable option for decarbonising shipping, ensuring New Zealand can meet its climate goals while maintaining economic competitiveness.
- **Market Demand:** The use of biomass in New Zealand and demand for biofuels is expected to grow as a result of the advantages associated with the energy source, including: the well-developed forestry sector and favourable growing conditions, reduced emissions as compared to fossil fuel energy sources, and relative affordability compared to other renewable fuels.[176] Biofuels currently lead in short-term commitments due to established supply chains and regulatory support, such as the ETS. Methanol, however, is seen as a long-term scalable option, with projects like HAMR Energy in Australia targeting 1 million tonnes by 2030. Both biofuels and methanol face feedstock availability challenges, given methanol's reliance on renewable hydrogen. For biofulel, competiton for feedstocks, particularly from other industries like aviation presents challenges. For example, a study conducted jointly by Air New Zealand and LanzaJet, an American waste-to-fuel start-up, found that New Zealand could produce up to 102 million litres of sustainable aviation fuel annually.[177] However, this volume of fuel would be sufficient to cover only a quarter of Air New Zealand's domestic aviation fuel needs.[178] Addressing feedstock shortages and price pressures is crucial for scaling biofuel use.

B | Biofuels

A view on overall feasibility

- **Regulatory Support:** In 2021, a biofuels obligation policy was established but was revoked before it could be implemented in 2023. Presently, biofuels benefit from several policy incentives: the Emissions Trading Scheme (ETS), an excise tax exemption for bioethanol, incentives from the National Land Transport Fund, and research and development support for institutions.[179]

Biofuels offer a promising avenue for sustainable energy, leveraging diverse feedstocks to reduce carbon emissions across a range of sectors. In New Zealand, the feasibility of biofuel production is largely influenced by the ability to secure a reliable and affordable feedstock supply, which according to previous analysis, shows some promise. However, a significant level of infrastructure investment required (notably for large production plants).

Market demand is also growing as industries seek environmentally friendly alternatives, and success hinges on acieving competitive pricing and the ability to establish reliable supply chains. While the regulatory environment could be seen as supportive, at least compared to other alternative fuels, further regulation and policy measures are necessary to reduce the cost of and increase uptake of biofuels in New Zealand.

While opportunities exists for domestic decarbonisation, including marine applications, where biofuels are a drop in fuel for existing diesel technology, market engagement highlighted competing sector demands for biofuels, and domestic producers' desires to retain flexibility to tailor production to maximise commercial outcomes (including the targeting of export markets).

Internationally, near term limited global production capacity and competion for supply means that biofuels are unlikely to meet international shipping decarbonistion requirements in isolation.

C | LNG

Overview and summary

Liquefied Natural Gas (LNG) is increasingly recognised as a viable alternative marine fuel, particularly in the context of global shipping's shift towards decarbonisation. Current global LNG production levels are approximately 474 million tonnes per annum (MTPA), with projections indicating an increase to around 667 MTPA by 2028, representing a growth of about 40%.[180] This expansion is driven by significant supply additions from major producers like the United States and Qatar, which are expected to reshape market dynamics.[181]

The global LNG market is poised for substantial growth, with estimates suggesting that new LNG vessel orders could see a 106% increase in 2024, and the number of LNG-fuelled ships is expected to double by 2028. This growth is largely supported by demand from Asia, which is projected to account for nearly 45% of incremental gas demand.[182]

This roadmap focuses primarily on fossil-fuel based LNG, outlining the current use of LNG as a marine fuel, infrastructure developments, and market activities required for integrating LNG into the marine industry. The roadmap concludes with a view on the overall feasibility of production and importation of LNG in New Zealand, informed by market engagement and research.

New Zealand has commercially produced natural gas since the 1950s. There are six principal gas fields, three onshore and three offshore, along with an additional 12 smaller onshore fields. At present, New Zealand's natural gas is sourced from the Taranaki region.[183] Although, this extracted gas is not processed into LNG and the conversion plants do not exist in New Zealand to do so.

LNG as an alternative marine fuel

Rationale for LNG in Shipping

- **Reduced Emissions:** LNG offers environmental benefits as a marine fuel, including a reduction of 20-25% in CO_2 emissions compared to traditional marine fuels. It also virtually eliminates sulphur oxides (SO_x) emissions and significantly reduces nitrogen oxides (NO_x), aligning with International Maritime Organisation (IMO) regulations aimed at reducing air pollution.[184]
- **International Availability:** LNG bunkering infrastructure is expanding globally, with fuel available in most major shipping hubs, improving availability and facilitating the transition to LNG-powered vessels.[185]

Key Barriers

In New Zealand, key barriers to LNG use as a marine fuel include:

- **Constrained Supply:** The domestic supply of natural gas is limited and faces competition from current users. To address energy security and affordability concerns, the Government has committed to a variety of actions, including reversing the ban on offshore oil and gas exploration and removing regulatory barriers to the construction of facilities needed to import LNG.[186]
- **Lack of Infrastructure:** New Zealand does not convert natural gas into LNG and does not have the facilities and infrastructure to do this. There are also no existing LNG import terminals in New Zealand. Infrastructure investment would be required whether New Zealand chooses to produce or import LNG for use as a marine fuel.

C | LNG

Background

Natural gas has traditionally played a key role as a power generation source, in addition to its industrial uses, such as chemical production. It accounts for just over 20% of global power generation supply, compared to just over 35% from coal and oil.[187] However, this share is expected to shift significantly in favour of natural gas.

As a lower-carbon energy source, natural gas has gained widespread adoption, particularly in developed economies. It is the cleanest-burning fossil fuel. In recent years, advancements in drilling technology have also made the extraction of unconventional gas reserves more economically viable.

One significant challenge that natural gas (similar to other commodities) faces is the reserves of the commodity not lying near major demand centers. This limits the natural gas available to be internationally traded (only ~30% of natural gas produced is internationally traded).

Currently there are two main technologies for transporting and trading natural gas, which are pipelines and liquified natural gas (also termed LNG). While international pipeline trade is twice the size of LNG trade, it remains economically unviable to conduct all international gas trade through pipelines due to the significant capital investment required.

LNG, on the other hand, offers a more cost-effective alternative. It can be transported using specialised tankers (consisting of liquid natural gas, where gas is cooled to a liquid at minus 160 degrees Celsius in large ‘trains’, reducing its volume by more than 600 times), making long-distance transportation more feasible than pipelines.

As the demand for LNG rises across the globe, LNG is expected to become the preferred transportation method for long-distance gas trade. In recent years, LNG has risen substantially as a share of both gas production and trade. Since 2000, global LNG trade has more than doubled, while pipeline trade has increased by one-third.[188]

Current Capacity and Key Players in the LNG Market[189]

LNG projects typically have long development timelines, with supply contracts extending 20 to 25 years, driven by expectations of sustained demand growth. In recent years, gas markets have faced concerns over supply security and price volatility, particularly following Russia’s supply cuts to Europe.

Starting in 2025, LNG projects are set for significant expansion, reshaping market dynamics. Projects already under construction or with final investment approval are expected to add 250 billion cubic meters of liquefaction capacity annually by 2030. The largest growth is projected between 2025 and 2027.

The United States and Qatar will account for 60% of this additional LNG, with most shipments targeting the Asian market. China alone has contracted an additional 85 billion cubic meters of LNG since 2022.

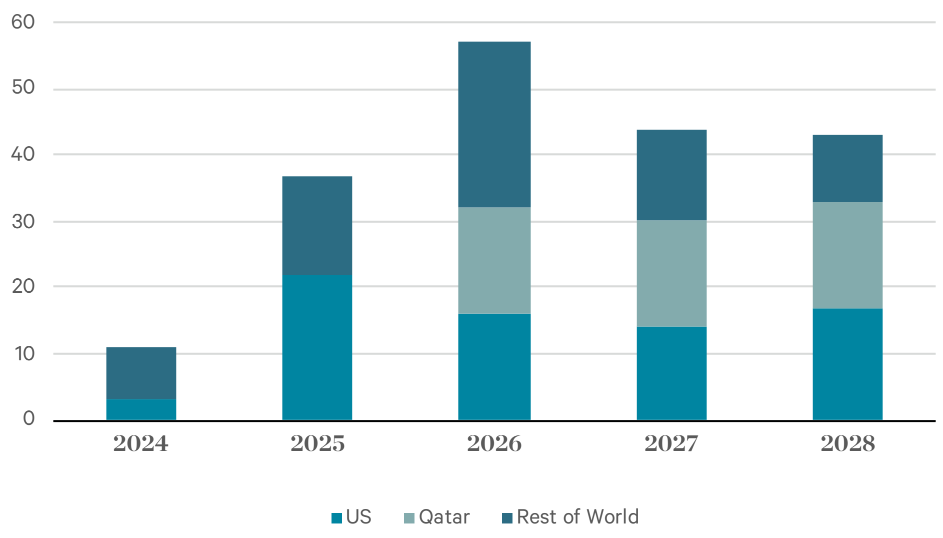
C | LNG

Background

Current Demand and Use of LNG[190]

According to the Institute for Energy Economics and Financial Analysis (IEEFA), global LNG production capacity is expected to increase from 474 MTPA (metric tonnes per annum) in 2024 to 667 MTPA by 2028, an increase of approximately 193 MTPA or 40%.

Figure 23: Global LNG Supply Additions 2024-2028 (MTPA)



From 2025 to 2028, the global LNG industry is expected to add nearly five times more liquefaction capacity than in the previous four years. The United States and Qatar will account for the majority of this expansion, significantly reshaping the market. As a result, Australia, which was the world's leading LNG exporter in 2021 and 2022, is projected to move down to third place among global suppliers.

Major LNG supply additions include:

- **United States:** Five LNG projects totalling over 71 MTPA in liquefaction capacity currently under construction.
- **Qatar:** The development of the North Field complex will increase Qatar's liquefaction capacity by 64 MTPA through 2030.
- **Russia:** The initial phase of the 20-MTPA Arctic LNG 2 project received its first gas in late 2023.
- **Canada:** The country's first commercial-scale LNG plant is slated to begin operations in 2025 or 2026.
- **Africa:** Five LNG projects have reached final investment decision (FID) or are under construction.

LNG demand in Europe, Japan, and South Korea—which accounted for over half of global consumption in 2023—is expected to decline in the long term. The global LNG market is facing challenges due to oversupply and lower prices. Structural barriers, such as long-term energy policies in Europe and Northeast Asia, as well as infrastructure and financial constraints in Asia are likely to dampen growth. The demand dynamics will vary across different regions, such as:

- **Europe:** After a spike in 2022 due to reduced Russian gas supplies, LNG demand remained steady in 2023. However, climate policies may impact demand post 2025 as Europe moves towards cleaner fuels.
- **Japan, South Korea and Taiwan:** Japan's LNG demand has already fallen 20% since 2018 and could decline further in light of the expansion of renewable and nuclear power (a trend similar to South Korea). In contrast, Taiwan's phase-out of nuclear power is expected to increase demand for LNG imports.

C | LNG

Background

- **China:** Multiple factors like domestic gas production, pipeline imports, and energy security policies may limit LNG imports. However, lower LNG prices in the short term could offset some of these constraints.
- **South Asia (India, Bangladesh, and Pakistan):** These regions may experience a demand rebound if LNG prices stay low. However, fiscal challenges and competition from other renewable energy sources create uncertainty in demand.

In contrast to developed economies, industry projections indicate rapid demand growth in emerging markets through 2040. For example, New Zealand is exploring LNG imports to address energy security concerns arising from a declining domestic gas supply. In August 2024, the New Zealand government announced the removal of regulatory barriers for LNG import facility construction. As a result, original development cost estimates have reportedly decreased significantly to between $80m and $180m – down from previous estimates of $140m to $624m for facilities at Marsden Point and Port Taranaki.

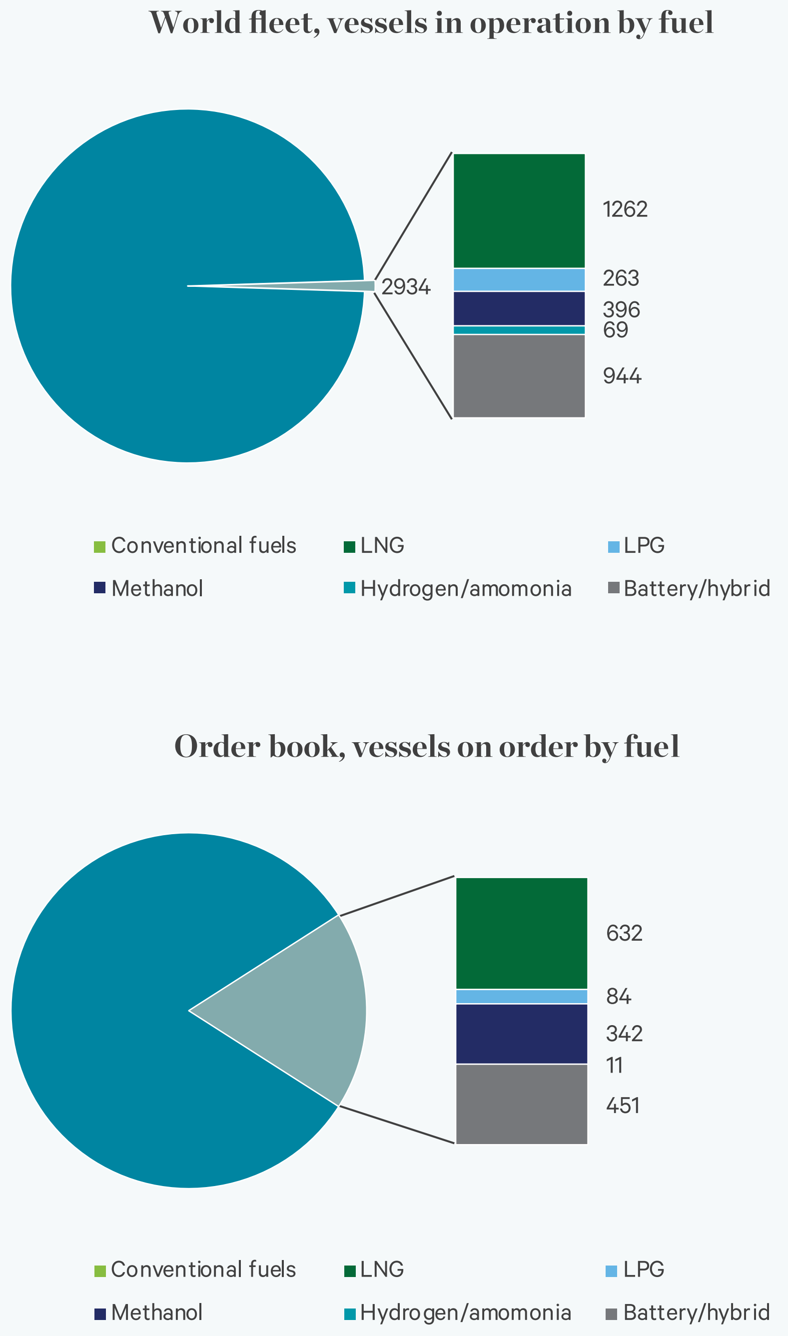
Recently, the Port suggested that development could begin for approximately $50m.

Market Sizing of LNG as a Shipping Fuel[191]

Preliminary data suggest that global gas demand increased by 2.8% (or approximately 115 bcm) in 2024. In addition, gas demand in the gas-rich markets of Eurasia and the Middle East expanded by around 3% in 2024. In the Americas, natural gas consumption rose by 1.7%, primarily driven by higher gas usage in the power sector.

Global gas demand growth is expected to slow in 2025, with an increase of 1.9%. However, LNG supply is projected to rise by 5% in 2025, led by increased production from North America. The future shipping market is expected to rely on a more diverse range of fuels, with LNG playing a significant role. The projections estimate ~106% increase in new LNG vessel orders in 2024, with the number of LNG-fueled ships expected to double by 2028.

Figure 24: World fleet, in terms of vessels in operation (by fuel) and Order book of vessels (by fuel)



C | LNG

CASE STUDY 1

Role of LNG in Maersk's Fleet Renewal Strategy [192]

Introduction

As the global shipping industry is shifting towards decarbonisation, alternative fuels such as Liquefied Natural Gas (LNG) are gaining traction. A.P. Moller-Maersk, a global maritime logistics provider, completed an order for 20 dual-fuel vessels in December 2024, signalling a strategic shift in its fleet renewal plan. This case study below explores the role of LNG in shipping, Maersk's approach to alternative fuels and the broader implications for the shipping industry.

Background of LNG in Shipping

LNG has emerged as a transitional fuel in the shipping sector due to its lower carbon emissions compared to traditional marine fuels. It offers a reduction of 20%-25% in CO_2 emissions, alongside significant reduction in sulphur oxides (SO_x) and nitrogen oxides (NO_x), helping meet International Maritime Organisation (IMO) regulations. However, challenges such as methane slip and infrastructure constraints remain key concerns.

Maersk's Fleet Renewal and LNG Integration

Maersk's fleet renewal plan is a comprehensive strategy aimed at modernising its vessels to enhance efficiency and reduce greenhouse gas emissions, aligning with its goal to achieve net-zero emissions by 2040.

Key Components of Maersk's Fleet Renewal Plan:

- **Introduction of Methanol-Powered Vessels:** Maersk has initiated the integration of methanol-powered vessels into its fleet. The new A-class series, consisting of 18 container ships built by Hyundai Heavy Industries, represents the largest container ships designed to run on methanol. The first of these, Ane Maersk, was delivered on January 26, 2024, followed by Astrid Maersk on April 4, 2024, with subsequent vessels scheduled for delivery through 2025.
- **Order of Dual-Fuel Vessels:** In December 2024, Maersk signed agreements for 20 dual-fuel container vessels equipped with liquefied gas propulsion systems, totalling a capacity of 300,000 TEU. These vessels, varying in size from 9,000 to 17,000 TEU, are scheduled for delivery between 2028 and 2030.
- This shift underscores Maersk's commitment to integrating lower-emission fuel options in its operations. However, Maersk has noted that the procurement of LNG ships did not signal an intention to run vessels on LNG over the longer term. Rather, that Maersk expect a mix of fuels to be in the shipping market for a time before the maritime industry is able to settle on the best alternative to conventional marine fuels.[193]

Through these strategic initiatives, Maersk is actively modernising its fleet to meet future operational demands and environmental standards, reinforcing its leadership in sustainable shipping practices.

C | LNG

CASE STUDY 1

Role of LNG in Maersk's Fleet Renewal Strategy [194]

Strategic Considerations for LNG Use

- **Decarbonisation Goals:** While LNG reduces emissions compared to conventional fuels, Maersk has primarily focused on methanol as a long-term alternative. The incorporation of LNG-capable vessels suggests a diversified approach, ensuring flexibility in fuel options.
- **Operational Efficiency:** The dual-fuel capability allows Maersk to operate vessels on LNG where feasible while retaining the ability to transition emerging low-carbon fuels as technology advances.
- **Regulatory Compliance:** By adopting LNG, Maersk ensures compliance with evolving IMO emissions regulations and regional environmental policies, particularly in emissions control areas (ECAs).
- **Infrastructure and Market Dynamics:** LNG bunkering infrastructure is expanding globally, providing better availability.

Industry Implications

- **Fuel Transition Strategy:** Maersk's dual-fuel approach reflects an industry-wide trend where shipping companies are hedging their bets on multiple fuel technologies to navigate the evolving regulatory landscape.
- **Investment in Alternative Fuels:** The vessel order reinforces the need for ongoing investment in LNG and other alternative fuel supply chains to ensure cost-effective and scalable decarbonisation solutions.
- **Competitive Positioning:** By securing LNG-capable vessels, Maersk enhances its operational flexibility while maintaining its leadership in sustainability-driven fleet modernisation.

C | LNG

CASE STUDY 2

Role of LNG in Hapag-Lloyd's Fleet Renewal[195]

Introduction

Hapag-Lloyd, a global container shipping company, has reinforced its commitment to sustainability by ordering 24 new container vessels equipped with liquefied gas dual-fuel propulsion systems and ammonia ready. This case study explores the significance of LNG in Hapag-Lloyd's fleet renewal and its impact on the company's sustainability strategy.

Hapag-Lloyd's LNG Strategy

Hapag-Lloyd's recent order of 24 new container ships represents a major investment in sustainability and operational efficiency:

- **Fleet Expansion and Modernisation:** The order includes 12 vessels (16,800 TEU) from Yangzijiang Shipbuilding Group and 12 vessels (9,200 TEU) from New Times Shipbuilding Company Ltd. The larger vessels will support capacity expansion, while the smaller ones will replace aging ships.
- **LNG Dual-Fuel Technology:** All vessels will feature state-of-the-art low-emission, high-pressure LNG dual-fuel engines, enhancing fuel efficiency and reducing environmental impact.
- **Biomethane and Ammonia-Readiness:** The ships can also operate on biomethane, potentially reducing CO_2-equivalent emissions by up to 95% and are designed to be ammonia-ready for future fuel transitions.

Strategic Considerations

- **Decarbonisation Targets:** Hapag-Lloyd aims to reduce its absolute greenhouse gas emissions from fleet operations by one-third by 2030 (compared to 2022) and achieve net-zero emissions by 2045. LNG adoption is a key step toward this goal.
- **Fuel Flexibility and Future Proofing:** The decision to make new vessels ammonia-ready ensures adaptability to evolving fuel technologies beyond LNG.
- **Regulatory Compliance and Competitive Edge:** The investment aligns with IMO 2030 and Paris Agreement commitments while strengthening Hapag-Lloyd's position as a leader in sustainable shipping.
- **Economic and Financial Commitment:** The project involves a $4 billion investment, with $3 billion in committed long-term financing, showcasing a strong financial commitment to green shipping.

C | LNG

CASE STUDY 3

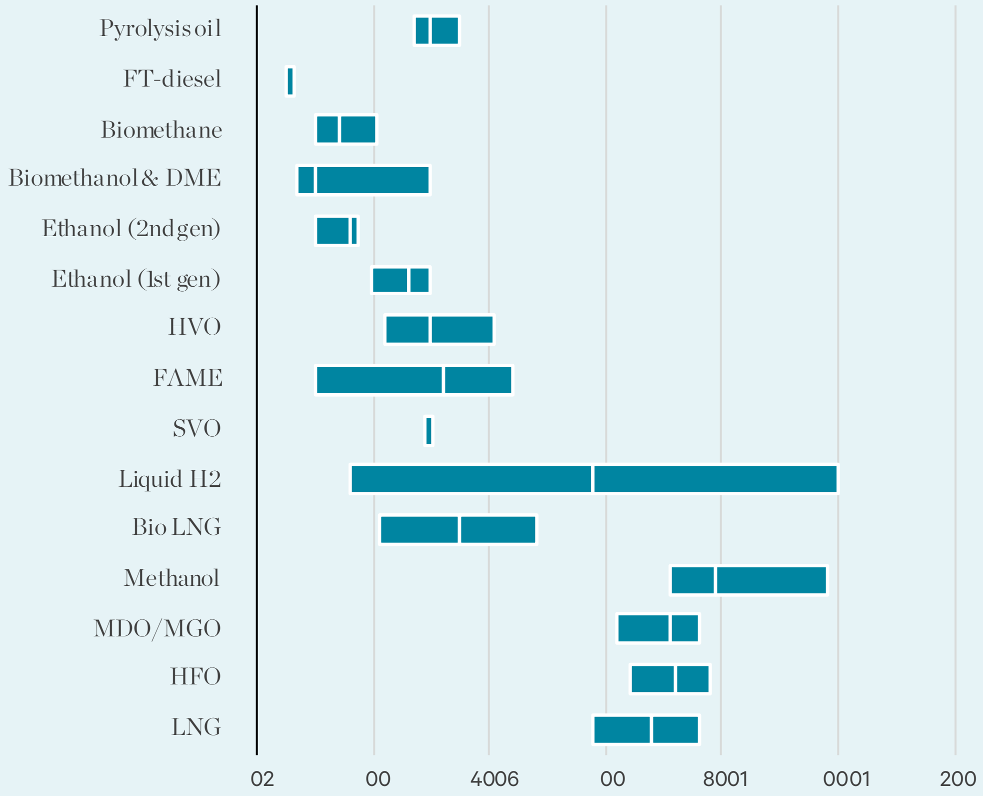
Challenges for LNG Use Due to its Emission Profile [196,197]

LNG is widely considered a better alternative to conventional marine fuels due to its low-carbon profile. However a key challenge in the context of decarbonisation is the high-presence of methane (considered to hold a higher global warming potential than CO_2) in LNG emissions. According to the Global Methane Pledge (undertaken by the EU and the US in 2021), there is a goal to reduce global methane emissions by ~30% below 2020 levels by 2030, while the EU has also added shipping to the EU Emissions Trading System.

Additionally, the two most abundant sources of renewable LNG (e-LNG and bio-LNG), are more expensive and not commercially feasible to produce currently, which could lead to them being replaced by synthetic drop-in diesel and methanol (from renewable sources). A particular advantage that drop-in diesel and methanol fuels offer is that there is no risk of methane-leakage or methane slip and they can be supplied via the existing shipping infrastructure.

In the shipping industry, while there is a near term benefit to move from conventional marine fuels to LNG (due to its lower-carbon profile), in the long-term, the industry might eventually shift away from fossil-based LNG to alternative renewable fuels (e.g. biofuels, methanol, hydrogen, etc.) to achieve the IMO GHG emission reduction targets. These renewable fuels have much lesser lifecycle emissions than fossil LNG and as a result LNG may be seen more as a transitional fuel and potentially replaced with these alternative renewable fuels.

Figure 25: Total life cycle GHG emissions per kWh of engine output for different fuels



High-level infrastructure requirements

LNG Infrastructure Requirements[198]

LNG imports are primarily facilitated through Floating Storage Regasification Units (FSRUs), which offer a straightforward solution for receiving and distributing LNG.

- Ships are specially fitted with storage units and regasification technologies (FSRUs) dock at port terminals.
- The FSRUs receive LNG from transport ships which dock alongside the ships fitted with storage units.
- The FSRUs store the LNG until required, after which it is regasified and delivered to the end user.

When considering a site for an LNG import terminal, key considerations include:

- **Infrastructure costs** – such as wharf upgrades or offshore mooring points
- **Delivery capacity** – including the availability and capacity of LNG pipelines
- **Proximity to end users** – particularly power generators and industrial consumers

Repurposing of LNG to Deliver Low-Carbon Energy[199]

Uncertainty remains regarding the long-term role of gas infrastructure in energy transitions. Future strategies must account for the potential of both existing and new infrastructure to accommodate different types of gases in a low-emissions future.

The IEA's Sustainable Development Scenario (SDS) outlines a pathway for the global energy sector to reach net-zero CO_2 emissions by 2070, while simulataneously addressing universal access to modern energy and reducing air pollution. Under the SDS:

- The share of electricity in final consumption is projected to increase from 19% today to 30% by 2040.
- Electricity supply will be increasingly decarbonised through renewables (wind and solar PV), bioenergy, hydropower, and nuclear.
- Despite these shifts, 50% of the final energy consumption in 2040 will still be met by liquids and gases.

In the context of repurposing gas grids to support low-carbon electricity, it may be possible in areas which have significant resources to generate renewable electricity and relatively lesser winter heating requirements. However, substitution of electricity with gas is currently challenging and costly. Currently, gas networks are the primary delivery mechanism for energy to consumers worldwide. In Europe and the US, for instance, gas networks provide electricity to more end-users than electricity networks.

C | LNG

High-level infrastructure requirements

In the transition to a low-carbon energy system, two primary options for decarbonising the gas supply are low-carbon hydrogen and biomethane:

- **Low-carbon hydrogen:** There is a recent surge in demand for low-carbon hydrogen, however production remains expensive. A potential cost-effective approach is to blend low-carbon hydrogen into existing gas grids. As there is no dedicated infrastructure to transport hydrogen, this is where the gas infrastructure, i.e. the natural gas grid in many countries could be useful to transport hydrogen. The resultant approach would deliver lower unit costs in comparison to dedicated hydrogen pipelines. However, regulatory constraints on hydrogen blending currently limit the amount that can be mixed with natural gas. In many countries, blending is capped at 2% hydrogen content.
- **Biomethane:** This is considered to be a near-pure source of methane, is indistinguishable from natural gas and so can be used without the need for any changes in transmission and distribution infrastructure or end-use equipment.

The growth in low-carbon hydrogen and biomethane provides a way to maintain continued investment in gas infrastructure in the SDS. However, there are certain challenges in repurposing the infrastructure for these applications, such as:

- **Uncertainties about the optimal configuration of the gas grid**, including the costs involved in maintaining its role as a flexible delivery mechanism for large quantities of energy.
- **Implications for investment in storage and delivery capacity**, processing and separation requirements, blending tolerances, and choices about end-use equipment.
- **The uptake of technologies that create interdependences between gas and electricity networks** driven by technologies such as electrolysers or hybrid heat pumps.
- **Location and size of biomethane and hydrogen production facilities** become crucial variables for the scale and types of infrastructure investments.

Potential for Liquefied E-Methane[200]

As the potential for alternative green fuels starts gaining prominence, one such green fuel is e-methane. In a power-to-gas process, green hydrogen (hydrogen produced using renewable electricity powered electrolysis of water) is further processed into e-methane by combining the hydrogen with biogenic carbon dioxide (CO2 from naturally occurring carbon cycles rather than from fossil-fuels). E-methane produced in this way is fully renewable and will replace fossil fuel usage in transportation, maritime and industrial sectors.

One key advantage of e-methane is that it is chemically identical to natural gas. In its liquefied form (LNG), it can be transported using existing infrastructure, including pipelines, ships, and trucks, and used directly in equipment designed for natural gas.

Additionally, e-methane can be used seamlessly in gas engines currently running on natural gas, LNG, or Bio-LNG (LBG). It can also be blended in at any ratio, without requiring modifications or additional investment in new equipment—making it a cost-effective solution for companies already operating gas-powered vehicles and ships.

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Cost analysis

Q1 2025 Pricing Projections[201]

Natural gas demand rebounded to structural growth in 2024, following the 2022-23 gas supply shock (triggered by the reduction in Russian gas deliveries, leading to a surge in gas prices). However, the IEA expects a slowdown in global gas market growth in 2025, with the demand increasing by 1.9%. Similarly to 2024, this growth is largely supported by Asia, which alone is expected to account for almost 45% of incremental gas demand.

Despite this, below-average growth in liquefied natural gas (LNG) output has kept supply tight, while extreme weather events have added to market strains. Geopolitical tensions have continued to fuel price volatility.

As per DNV's Alternative Insights Platform (open resource providing maritime industry with development and uptake of altermative fuels and technologies), fossil LNG prices (natural gas extracted from fossil resources) rose significantly from 2015–2019 levels (€200–€400/t) to record highs in 2021 (€1,400/t) due to high demand, supply constraints, and shipping costs.

By 2030, prices are expected to return closer to pre-pandemic levels, around €350/t.

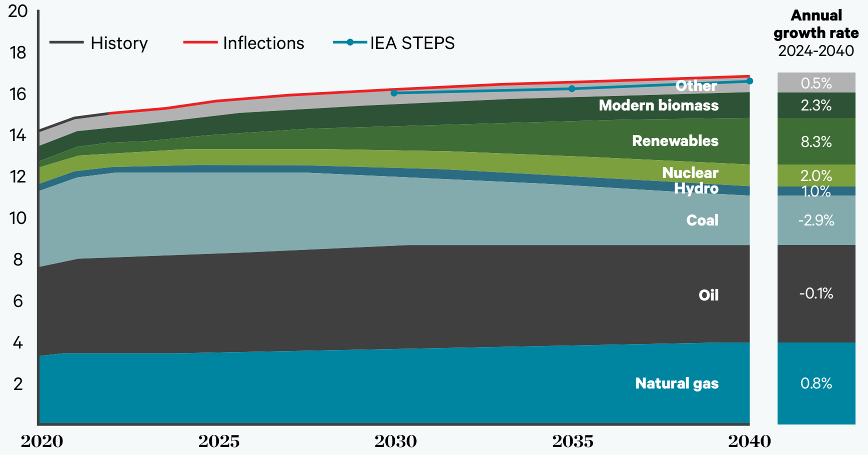
In the more sustainable context, 2030 estimates suggest that e-LNG (LNG produced using renewable electricity) could be supplied at ~ €2,350/t, which is almost 7x the price of fossil-LNG making it commercially unviable. However, an approach suggests that subsidising some of this cost, for instance, the European Union offering a €1,200/t to purchase renewable LNG could result in 4% of 2030 LNG demand being met by renewable LNG (primarily bio-LNG, LNG produced by liquefying bio-methane). A better situation emerges if the European Union doubles the subsidy, which would translate into ~90% of the 2030 LNG demand being met by bio-LNG.

Pricing Evolution in the Medium to Long Term[202, 203]

The LNG industry, particularly in the United States, has become a significant and expanding sector of the U.S. economy over the past decade, with LNG exports contributing ~$400 billion to GDP.

This growth has led to a substantial increase in LNG export capacity, which is projected to double between 2025 and 2030. Given this expansion, natural gas is expected to remain a key component of the global energy mix through 2040.

Figure 26: Global primary energy demand by fuel (base case)
Billion Matric Tonnes of Oil Equivalent (Btoe)



Main assumptions and results

2.6%
Global GDP (CAGR 2023-40)

10x
Renewables growth rate in energy max vs. natural gas long term

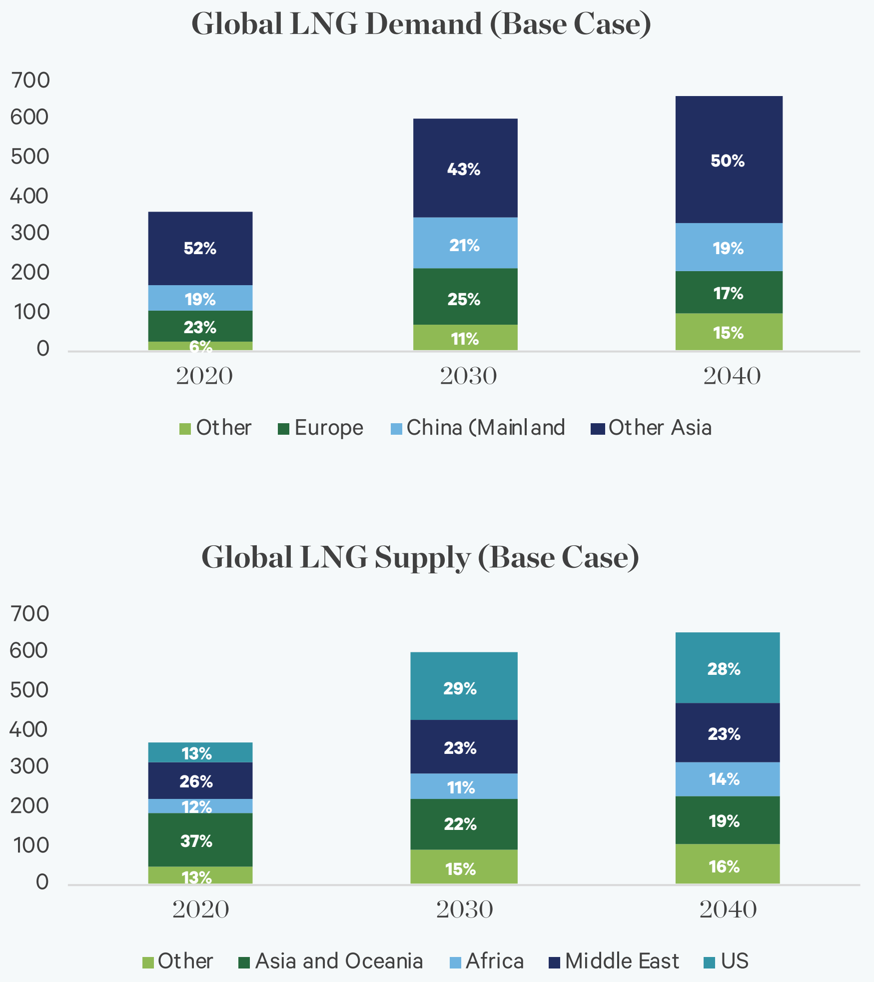
-13%
GHG emissions (2040 vs. 2023)

C | LNG

Cost analysis

The demand growth is primarily being driven by Europe and Asia to meet energy security and energy transition needs, with the US being the leading supplier to address this demand.

Figure 27: Global LNG demand and supply projections (base case)



Supply Chain Optimisation[204]

Despite LNG market's growth, there are persistent market inefficiencies including rigid long-term contracts, inflexible delivery schedules, and high transportation and storage costs. These constraints limit the ability of LNG supply chains to adapt to short-term price fluctuations, often resulting in suboptimal cargo flows and higher transport expenses.

A strategy that companies can apply to optimise LNG supply chains and achieve transportation cost savings amid high LNG price is to build a diversified and flexible LNG portfolio, including multiple supply and offtake positions.

Additionally, enhancing trading and optimisation capabilities can improve logistics, better align supply with market conditions, and minimise inefficiencies.

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Pathway to port [205]

LNG bunkering differs from conventional oil fuels (with flash points above 60oC). It requires compatibility between the bunker suppliers and the vessel receiving the fuel. Currently, large bunker ships enable bunkering rates of ~1,600m3/h. There are four different methods of LNG bunkering, each with their own advantages/disadvantages:

- **Ship-to-ship:** This is the most desirable option wherein LNG can be transferred in large volumes while at anchorage or berth, with the capacity of bunkering vessels also being high, within the range of 1,000m3 to 10,000m3 (with bunkering rates of 1,000 to 2500m3/h). The only disadvantage to this option is the high investment in infrastructure and specialised vessels.
- **Truck-to-ship:** This is a flexible low-investment option wherein LNG can be transported via truck to the receiving vessel, however, the volume of LNG that can be transported is limited (~40 m3), with the transfer rates also being low (~90m3/h).
- **Terminal-to-ship:** This is another option which offers large volume bunkering along with high bunkering rates, wherein a ship is bunkered through a dedicated bunkering facility such as a terminal or jetty and the terminal is connected to the ship through rigid pipes via flexible hose or using a loading arm. This option also includes high-investment in infrastructure.
- **Portable LNG tank-to-ship:** This option involves exchanging portable tank systems such as 40-foot ISO containers or standard trailers, offering a flexible and low-capital alternative to fixed infrastructure. The bunkering volume is limited to the capacity of individual containers, making it more suitable for smaller-scale operations. Since there is no direct LNG flow, the bunkering rate depends on the efficiency of handling and connection procedures, potentially leading to long turnaround times.

C | LNG

Emissions reduction potential

Emissions Profile of LNG[206]

LNG has witnessed increasing demand as a marine fuel, primarily due to the efforts to comply with the IMO's (International Maritime Organisation) emission regulations, which limit the sulfur content of marine fuels along with nitrogen oxide emissions. The same regulation's Annex VI Chapter 4 limits CO_2 intensity of new ships under the Energy Efficiency Design Index.

LNG is compliant with all the requirements as it contains only trace amount of sulfur, has low nitrogen oxide emissions (when burned in low-pressure injection dual fuel engines) and emits about 25% less CO_2 than conventional marine fuels.

On the contrary, LNG is mostly methane, which is a potent greenhouse gas, with a GWP (Global warming potential) of ~30X greater than CO2 (over a 100-year time period).

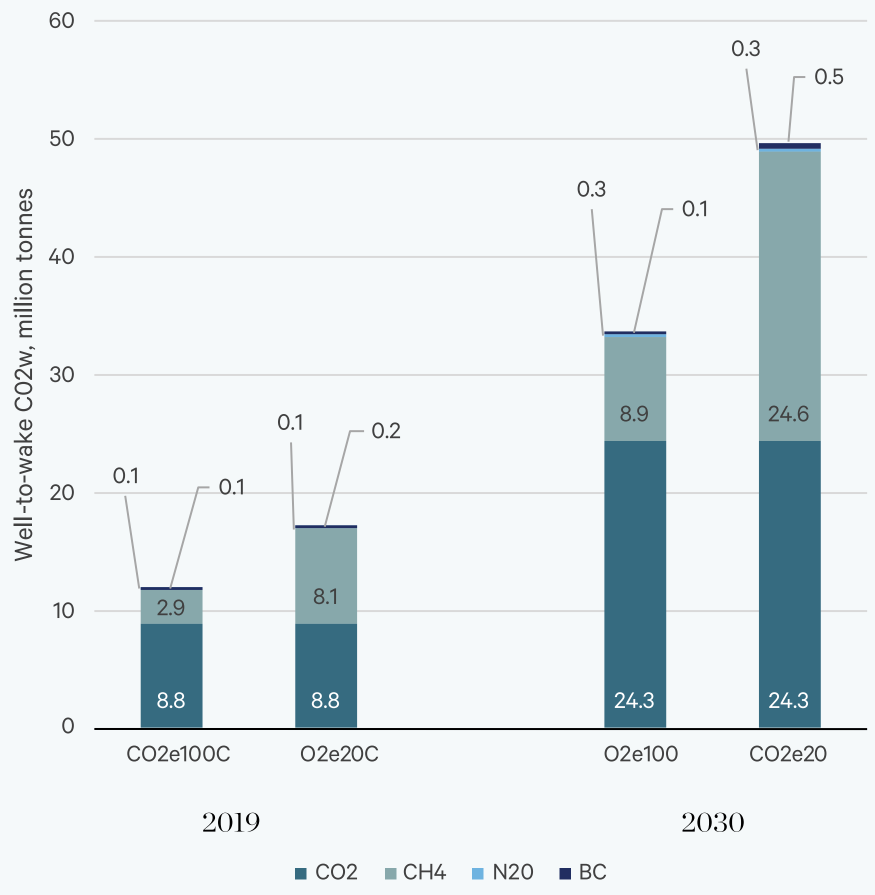
Lifecycle Emissions14

LNG's lifecycle emissions are measured as Well-to-Wake (WTW) emissions, which account for cumulative emissions across key stages in the LNG's lifecycle:

- **Well-to-Tank (WTT):** includes emissions from production, processing, transportation and storage before LNG reaches the ship.
- **Tank-to-Wake (TTW):** Covers emissions from burning LNG in the ship's engine, including methane that escapes unburned (methane slip).

Across the different types of LNG (fossil LNG, bio-LNG and e-LNG), the GHG considerations, emission sources and methane slip impact can vary due to the different production pathways and resources used for production. The figure to the right shows WTW CO_2e emissions based on GWP 100 and GWP 20 (measuring the GWP of the respective gas over a 100 or 20 year time period). In the current projected growth scenario, Fossil LNG's WTW emissions are expected to grow 3X between 2019 – 2030.

Figure 28: Well-to-wake CO_2e emissions for LNG-fueled ships



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Wider identified applications

Beyond its use as a marine fuel, LNG has several other significant applications. It plays a key role in power generation, accounting for just over 20% of global power supply,[207] and is used extensively in industrial processes such as chemical production. LNG's ability to be transported via specialised tankers makes it a preferred method for long-distance gas trade, especially where pipelines are not feasible due to high capital costs. This flexibility in transportation supports its growing share in both production and trade globally.

Additionally, LNG is important in addressing energy security and transition needs, particularly in regions with limited access to pipeline infrastructure. It is expected to remain a key component of the global energy mix through 2040,[208] driven by demand from Europe and Asia. LNG is also utilised in heating and electricity generation, providing a cleaner-burning alternative to coal and oil. The integration of LNG into various sectors underscores its significance as a transitional fuel towards low-carbon energy systems and highlights its versatility in supporting diverse energy needs.

In New Zealand, natural gas is used in the production of petrochemicals, for electricity generation and co-generation, plant and industry use, and SME consumption.[209]

C | LNG

A view on overall feasability

Natural gas has been produced commercially in New Zealand since 1959. There are 6 main natural gas fields (3 onshore and 3 offshore) and a further 12 smaller onshore fields. Currently, all-natural gas produced in New Zealand comes from the Taranaki region.[210] However, this gas is not converted into LNG and Energy NZ suggests that liquefaction facilities are most economic when built for the bulk export of LNG, not solely for marine bunkering.[211]

Assessing the feasibility of LNG production or importation and its application in the maritime sector within New Zealand involves evaluating several critical factors:

- **Global Supply of LNG – (Importing LNG is possible but may face challenges in cost and availability, particularly for large-scale maritime use):** From an import feasibility perspective, New Zealand would need to be able to secure a reliable and cost competitive source of LNG. Global supply and demand are expected to increase, which potentially poses challenges for New Zealand in securing LNG, especially at sufficient volumes to support the marine industry.
- **Domestic Natural Gas Availability – (Declining reserves make local LNG production impractical, pushing the country toward imports as a more immediate solution):** New Zealand is exploring LNG imports to address energy security concerns due to declining domestic gas supply. The availability of natural is key for local LNG production.
- **Existing Infrastructure – (The absence of LNG-specific infrastructure poses a major barrier to both production and bunkering, requiring substantial capital investment):** While there is existing infrastructure to support production, transportation, and use of natural gas, there are not domestic facilities to produce LNG. Additional infrastructure investments, such as wharf upgrades and pipeline capacity expansions, would also be necessary to support bunkering of LNG.
- **Technological Readiness – (Technological barriers are minimal, as New Zealand can leverage existing solutions to fast-track LNG capabilities):** Internationally, LNG technology is mature, with well-established methods for liquefaction and regasification. New Zealand can leverage these technologies.

C | LNG

A view on overall feasability

- **Economic Considerations – (Importing LNG for domestic use may be economically viable, but bunkering for international shipping faces cost-related challenges):** Development costs for LNG import facilities in New Zealand appear to have decreased, looking at examples mentioned earlier for Port Taranaki and Marsden Point, suggesting a more economically feasible environment for future projects.
- **Market Demand – (Domestic shipping could benefit from LNG, but international demand may not justify the investment):** There is significant international demand for LNG, and a projected increase in the number of orders for LNG capable ships. Domestic demand for imported LNG is fuelled by energy security concerns and the need for reliable energy sources. Domestic supply of natural gas is already insufficient to meet domestic demand, and without current users of natural gas transitioning to other feedstocks, producing sufficient LNG for the marine industry is not feasible.
- **Regulatory Support – (Regulatory backing enhances the feasibility of LNG imports, though it does not directly address production challenges):** While not on the production side, the New Zealand Government has shown regulatory support by removing barries for LNG import facility construction, indicating a conducive environment for development of domestic infrastructure to support the receipt, transport, and use of LNG.

New Zealand's potential for LNG production faces significant challenges, particularly due to declining natural gas supply and insufficient infrastructure. While the country has a history of natural gas production, the current landscape indicates that exploring LNG imports may be a more feasible solution. The recent indicated intention to remove regulatory barriers for LNG import facility construction supports the shift, however this was focused on enabling New Zealand to address options for immediate energy security concerns arising from constrained domestic supplies. Though the high costs of importing LNG may present a challenge.[212]

Importing LNG is actively being investigated in light of reducing domestic gas supplies, though the focus to date has been on energy security. However, the economic viability of using imported LNG is raising questions given the very high costs associated with developing the necessary receival and regasification infrastructure. These costs highlight the necessity for scale, which New Zealand lacks. Moreover, as a transitional fuel, LNG provides limited emissions reductions when derived from natural gas. Consequently, importing LNG for shipping appears impractical, given the proximity of other hubs near large-scale production.

D | Methanol

Overview and summary

Renewable methanol is increasingly recognised as a viable alternative fuel in the transition towards sustainable maritime transport. Currently, global methanol production stands at 98 million tonnes (Mt) annually, with projections to reach 500 Mt by 2050.[213] While approximately 99% of this production uses fossil fuels, primarily natural gas and coal, due to their lower costs compared to renewable alternatives, there is a significant and growing push towards renewable methanol to address climate change and reduce carbon emissions.

This roadmap focuses on low to zero carbon methanol variants, outlining the production pathways, infrastructure developments, and market activities required for integrating renewable methanol into the marine industry. This roadmap concludes with a view on the overall feasibility of production of renewable methanol in New Zealand, informed by market engagement and research.

According to the Methanol Institute, the global renewable methanol production pipeline (including low-carbon methanol) is projected to reach 45 Mt by 2030. This pipeline includes approximately 210 renewable methanol projects, with an anticipated capacity of 35 Mt by 2030 (54% via green e-methanol and 46% via bio-methanol). However, estimates suggest actual renewable methanol capacity will be between 7 and 14 Mt by 2030.[214]

Methanol is similar to conventional marine fuel in terms of handling and hazards, though it has about half the volumetric energy density, meaning about twice the amount of on board storage is required.[215] The on board requirements for methanol as a fuel are less complex than some of the other alternative marine fuel options, due to being non-cryogenic, liquid at ambient temperatures, and not needing specific or costly materials for tanks and pipes. In addition, methanol already meets operational safety and engine compatibility requirements.

In New Zealand, the only methanol manufacturer is Methanex, based in Taranaki. Currently, they produce methanol from natural gas, a non-renewable source, and export around 95% of their production.[216] However, Methanex and others such as Hiringa Energy are exploring the possibility and feasibility of producing green methanol in New Zealand.

D | Methanol

Methanol as an alternative marine fuel

Methanol, particularly renewable variants, emerges as a viable solution due to its lower emissions profile and compatibility with existing maritime technologies.

Rationale for Methanol in Shipping

Environmental Benefits

- **Reduced Emissions:** Marine methanol offers significant environmental benefits compared to heavy fuel oil and marine gas oil, achieving a 99% reduction in sulphur oxides (SOx), a 95% reduction in particulate matter (PM), and up to an 80% reduction in nitrogen oxides (NOx) emissions. Methanol inherently contains no sulphur, which virtually eliminates SOx emissions. Its combustion does not produce SOx or PM emissions; any minimal emissions that do occur result from the small quantity of diesel (3-5 %) used as pilot fuel.[217]
- **Carbon Neutrality:** Renewable methanol, derived from biomass or captured carbon dioxide (CO_2), offers a carbon-neutral or low-carbon alternative. Production from renewable sources such as biomethane, solid biomass, and municipal solid waste (MSW) significantly reduces the carbon footprint, typically achieving 10-40 g CO_2 eq/MJ. Some pathways can result in negative emissions; for example, methanol derived from biomethane sourced from cow manure achieves -55 g CO_2 eq/MJ. This suggests that these processes either actively remove CO_2 from the atmosphere or prevent emissions that would otherwise occur in alternative processes.[218]

Operational Advantages

- **Infrastructure Compatibility:** Methanol can be stored and transported using existing infrastructure with minimal modifications. This includes mild steel or stainless-steel tanks and current bunkering facilities, facilitating a smoother transition for the marine sector.
- **Engine Adaptability:** Methanol-ready engines are commercially available, with manufacturers like MAN Energy Solutions offering dual-fuel capabilities. These engines require minimal modifications, enabling ships to operate on methanol without extensive retrofitting. According to the DNV, a world leading classification society and recognised advisor for the maritime industry, as of early 2024 there were 267 confirmed methanol-fuelled ships in operation or on order, with the majority being container ships.[219]

D | Methanol

Methanol as an alternative marine fuel

Key Barriers

While methanol provides a suitable alternative fuel for marine shipping, several key barriers hinder production and adoption at scale:

- **Higher Production Costs:** Renewable methanol production costs are significantly higher than fossil-fuel based methanol and conventional fossil-fuel based marine fuels, posing economic challenges. In New Zealand, a large driver of this cost difference is the high cost of renewable electricity, which is a key component in the production pathway. High production costs and limited willingness to pay need to be addressed to make green methanol competitive with traditional and other alternative fuels.
- **Feedstock Supply Chain Challenges:** Difficulties in securing a sustainable and adequate supply of feedstock such as woody biomass impact production reliability, cost, and scale. Expanding biogenic carbon (carbon stored within and released by organic matter) sources and investing in infrastructure to support these feedstocks are critical for enabling production of renewable methanol, especially at scale.
- **Cost of Infrastructure Development**: A key barrier for renewable methanol production in New Zealand is the substantial investment required to build facilities and infrastructure capable of meeting the marine shipping industry's demands. While Methanex has a plant capacity of 2,000,000 tons annually, developing new plants entails high costs and significant financial commitments, yet these plants are expected to yield only a limited amount of green methanol per day. Stakeholder engagement indicated that a large plant would cost about $1,100m and produce only 300 tons of green methanol per day.

Shipping Sector Alignment and Green Corridors

One of the most compelling use cases for renewable methanol is the shipping sector, which is under pressure to meet stringent emission controls. Initiatives like the UK's Green Shipping Corridor exemplify the integration of renewable methanol into maritime operations. This project, aligned with the Clydebank Declaration at COP26, aims to establish zero-emission shipping routes between ports by 2026. The Liverpool-Belfast corridor, spanning 130 nautical miles, is expected to be the first, involving 29 pilot projects focused on developing green fuels, port infrastructure, and vessel technology.[220]

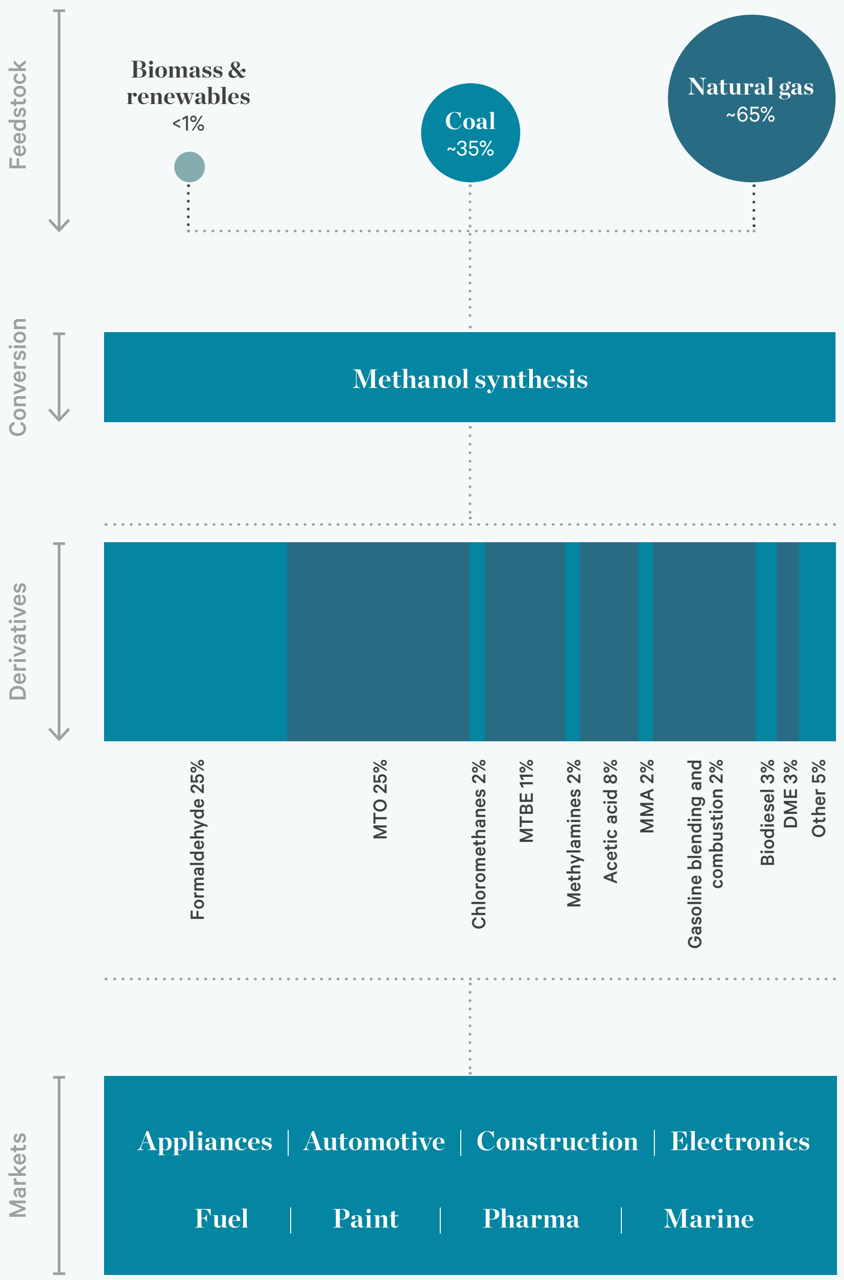
D | Methanol

Background [222,223,224,225,226]

Methanol is used across a wide variety of markets, primarily as a raw material and/or fuel:

- **Raw material:** More than 60% of methanol globally is used to synthesise base chemicals such as formaldehyde, acetic acid, methyl methacrylate, ethylene and propylene which are then further synthesised for applications within plastics, automotive, construction, electronics, etc.
- **Fuel:** More than 30% of methanol globally is used as a fuel, of which ~14% consumption can be attributed to direct methanol usage as a fuel (growing from ~1% in 2000) due to its high-octane rating, or as methyl tert-butyl ether (MTBE) and dimethyl ether (DME) as a gasoline additive

Figure 29: Feedstocks and application of methanol



Despite approximately 99% of methanol's current production coming from fossil fuels (coal and natural gas), there is a growing push for renewable methanol. This shift is largely driven by global efforts to mitigate climate change by reducing carbon emissions.

To this effect, there are currently three ways by which renewable methanol can be produced:

- **Low carbon methanol:** Derived by either decarbonising or limiting carbon emissions from carbon-intensive steps during conventional methanol production, such as decarbonising the 'reforming to syngas' step or injecting captured carbon into methanol synthesis loop.
- **Bio-methanol:** Sourced from biomass, using feedstocks such as agricultural and forest waste, biogas from landfill, pulp, and paper industry waste, etc.
- **Green e-methanol:** Derived from the carbon captured through renewable sources such as bio-energy carbon capture and storage (BECCS), direct air capture (DAC) and green hydrogen (hydrogen produced using renewable electricity).

D | Methanol

Background

Key projects include:

- **European Energy's e-methanol Plant in Denmark:** A large-scale commercial green methanol plant which converts renewable electricity from solar panels into e-methanol. The plant features three 17.5 MW electrolysers to produce 6,000 tonnes of hydrogen per year from 90,000 tonnes of water. The hydrogen is subsequently combined with biogenic CO2 through a methanol synthesis process to produce e-methanol.
- **Sumitomo SHI FW's Biorefinery in Portugal:** A biorefinery, aiming to produce 80,000 tonnes of renewable methanol annually and utilises locally sourced biomass residues and renewable electricity from a photovoltaic solar park.
- **Iberdrola's GREEN MEIGA Project:** Focused on producing green methanol from renewable hydrogen and target its applications in the chemical industry and maritime transport.
- **Harakeke Renewable Energy Project in New Zealand:** The proposed project is to construct and operate a staged wind and solar farm, hydrogen and methanol plant near Whanganui and to convert to green hydrogen and green methanol for commercial supply. The project aims to produce 90,000 tonnes of green methanol annually.[221]

Market Activity for Use of Renewable Methanol

Growing demand for carbon-neutral shipping fuels has the potential to drive interest in renewable methanol. Major shipping companies are setting net-zero goals, and developing renewable fuel-capable ships has become a focal point. This shift is reflected in the increasing order book for methanol-powered vessels, especially within the container ship segment.

Figure 30: Snapshot of green methanol vessel orderbook (indicative)

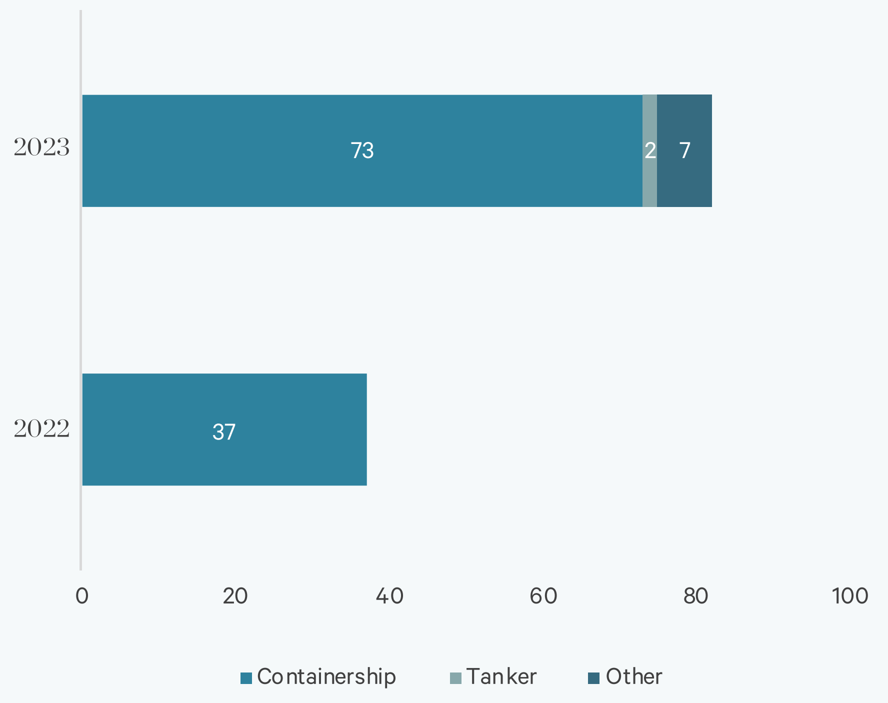
Company	HQ	Sector	Net-zero target	Green mathanol ships on order
MAERSK	Denmark	Container	2040	25
EVERGREEN	Taiwan	Container	2050	24
COSCO SHIPPING	Mainland China	Container, bulk carrier, tanker	2060	12
CMA CGM	France	Container, tanker	2050	12
HMM	South Korea	Container	2050	9

D | Methanol

Background

Container ships form the largest share of green methanol-powered ships, with lesser interest from tanker and bulk carrier companies. A key factor behind tanker-based companies still preferring fossil-fuel powered vessels is the discrepancy in cost competitiveness of renewable methanol.

Figure 31: Green methanol orderbook, by ship type



The use of renewable methanol as a fuel for marine shipping is probably just a starting point, with investment activity in the space growing across several use cases:

- **Fossil-free plastics:** Maersk Investment Group announced in October 2024, the funding of a new company producing fossil-free plastics from green methanol. The company plans to spend US$1.6bn to build a 300,000 tonnes/year plant in Belgium by 2028.
- **E-methanol supply chain:** Mitsui O.S.K Lines (Japanese shipping company also known as MOL) announced in March 2024, a partnership with HIF (global e-fuels company) and Idemitsu Kosan (Japanese petroleum company) to develop the supply chain for e-methanol (and e-Fuel). This collaboration has a focus on synthetic methanol production using captured CO_2 and developing CO_2 marine transport solutions in an effort to support a sustainable supply chain.

UK's Green Shipping Corridor

The potential offered by renewable methanol is significant, with the UK's green shipping corridor a good case in point to understand its potential.

In line with the Clydebank Declaration at COP26 (agreement to establish zero-emission shipping routes between ports), the UK Government has committed to establish six green shipping corridors by 2026.

Among the six corridors, the Liverpool-Belfast corridor, spanning 130 nautical miles is expected to be the first green corridor, with the project running 29 pilot projects aimed at developing green fuels, port infrastructure and vessel technology. The project aims to cut GHG emissions from shipping operations, drive innovation in clean maritime technologies and establish a blueprint for future green corridors. It aligns with UK Government initiatives such as the Clean Maritime Demonstration Programme (CMDP) to accelerate decarbonisation and port infrastructure upgrades. Under the CMDP programme the government has allocated £206M in grants since 2022 in clean maritime projects, including feasibility studies for UK-Europe green corridors, set to conclude by Spring 2025. The project involves deployment of alternative fuels, including the use of green fuels which could propel demand for renewable methanol.

D | Methanol

CASE STUDY 1

Kasso Power-to-X (PtX) Project – Denmark [227,228,229,230]

Overview and capacity

Kasso Power-to-X (PtX) is one of Europe's largest Power-to-Liquids (PtL) projects and is approaching completion, as of October 2024. Once fully operational, this pioneering project will be capable of producing around 42,000 tonnes of electro-methanol (e-methanol) per year, in addition to supplying district heating to the town of Abenra.

- Green electricity from the 304 MWp Solar Park Kasso will power the 54 MW electrolyser capacity at the Kasso PtX plant once operational. Siemens Energy has designed, supplied, and would oversee the commissioning of the electrolysis system at Kasso PtX.
- As a groundbreaking initiative, this project has generated widespread interest and is paving the way for future e-methanol projects.
- European Energy is the main project developer, overseeing the entire value chain, in collaboration with PtX technology developer and e-fuel producer REintegrate.
- CO_2 Source: Intermittent renewable electricity is used to produce green hydrogen through water electrolysis, which is then reacted with captured biogenic carbon dioxide (CO_2) to produce e-methanol at scale. Additionally, the process supplies heat for district heating and offers power grid balancing services.

Offtakers

Denmark has become a hub for methanol, particularly in methanol mobility, with European Energy securing several offtake agreements across various sectors for e-methanol to be shipped via tanker truck and/or vessel from the Port of Abenra.

- A legacy agreement with Circle K Denmark, the Danish subsidiary of global fuel retailer Circle K, involves purchasing 50 million litres over five years from PtX technology developer and e-fuel producer REintegrate.
    - In late 2021, European Energy acquired full ownership of REintegrate and is utilising its reactor technology at the Kasso PtX facility.
- In 2021, Compatriot global container shipping major, A.P. Moller – Maersk secured a deal to supply 10,000 tonnes per annum of methanol to fuel "Laura Maersk," the world's first methanol-enabled container vessel, named in September 2023.
    - European Energy and Maersk have strengthened their partnership and plan to explore e-methanol plants in North and South America, with a combined annual production capacity of up to 300,000 tonnes for Maersk container vessels.
- Other offtakes include e-methanol as a feedstock to replace fossil-derived methanol in plastics production, with companies like the LEGO Group and Novo Nordisk involved.
    - The LEGO Group plans to explore using e-methanol for select elements in its toy portfolio, aiming for prototype development and long-term commercialisation. Novo Nordisk intends to replace fossil-based plastic with lower-carbon alternatives for medical devices like insulin pens.

D | Methanol

CASE STUDY 1

Kasso Power-to-X (PtX) Project – Denmark

Investments and divestments

In 2022, European Energy secured €53 million from the Danish Green Investment Fund (DGIF) for its Power-to-X (PtX) facility in Kasso. The fund's financing is part of the overall investment in the facility. Regarding divestment, as of September 2023, Mitsui & Co. Ltd. acquired a 49% stake in Kasso MidCo ApS, the holding company for SPK and Kasso PtX. Moreover, European Energy has since completed a transaction with Mitsubishi HC Capital, in which Mitsubishi acquires a 20% stake and invests approximately €700 million in new equity.

D | Methanol

CASE STUDY 2

Orsted FlagshipONE Project – Sweden [231,232,233,234]

Overview and capacity

The FlagshipONE electro-fuels project, led by the Denmark-based energy utility Orsted A/S, is situated in Ornskoldsvik in northern Sweden. However, the project was halted due to several major factors.

- FlagshipONE was projected to produce up to 55,000 tonnes of e-methanol annually, enabling shipping industry off-takers to achieve a reduction of over 95% in carbon emissions compared to the use of traditional fossil fuels.
- In December 2022, Orsted made a Final Investment Decision (FID) to proceed with the FlagshipONE e-methanol project and acquired the remaining 55% stake from Liquid Wind AB, the original developer.
- FlagshipONE intended to use biogenic carbon dioxide (CO2) from the biomass-fired combined heat and power (CHP) plant and capture the residual heat from the power-to-liquids process.

Reason for the project's cancellation

Although the groundbreaking ceremony in May 2023 signified the commencement of construction for FlagshipONE, the project ultimately failed for several reasons, resulting in cancellation fees of DKK 300 million ($44 million) and impairments of DKK 1.5 billion.

- Substantially increased project costs and the inability to secure long-term offtake contracts at sustainable pricing.
- Ship operators were unwilling to absorb the high costs of sustainable methanol, given the limited ability to pass on the additional expenses to their customers.
- On August 14, Platts bunker assessments for 0.5% sulphur fuel oil, the most widely used marine fuel globally, were priced at $13.39/Gj in Rotterdam, compared to $18.01/Gj for fossil-based methanol. Industry estimates indicate that sustainable methanol would cost at least two to five times more. Platts is a division of S&P Global Commodity Insights.
- While much of the necessary EU regulation is in place, short-and medium-term regulatory requirements, such as sub-quotas for e-fuels and greenhouse gas reduction targets fail to provide a sufficiently clear incentive. Additionally, national implementation and enforcement have not yet been established, according to Orsted regional CEO for Europe Olivia Breese. As a result, timelines no longer align with the most advanced projects, where developers face challenges in finding offtakers willing to meet the industry production costs for such commercial-scale, first-of-a-kind projects.

D | Methanol

CASE STUDY 2

Orsted FlagshipONE Project – Sweden

The significance of FlagshipONE's cancellation

Orsted's FlagshipONE e-methanol project was initially hailed as revolutionary, with the Final Investment Decision (FID) made in December 2022, meeting key criteria such as affordable clean electricity, EU Renewable Fuels of Non-Biological Origin (RFNBO) qualification, permits, grid connection, access to CO_2, and strong sponsor and public sector backing. Despite these factors, the project will not proceed, with its cancellation drawing attention from the global e-fuels community. Some key observations include:

- **Misalignment between e-fuels producers and Offtakers:** The industrialisation and commercialisation of the liquid e-fuels offtake market has been slower than anticipated. Currently, e-SAF and shipping fuel are the most promising near-term uses for e-methanol. Orsted's decision suggests that the terms negotiated with Offtakers were insufficient to create a viable business case, with the duration of offtake contracts being a key point of contention.
- **Good or bad news for hydrogen developers?** The cancellation of the FlagshipONE e-methanol project highlights the complexities of aligning market participants. While the public lack full insight into the development process and decisions made by FlagshipONE and other projects, Orsted's shift away from e-fuels seems more driven by strategic re-alignment than e-fuel market challenges. The company believes e-fuels will mature with further regulatory evolution, continuing to focus on green hydrogen. Orsted's exit may benefit other e-fuel developers, prompting policymakers to reconsider if current incentives are sufficient to achieve the desired pace and scale of e-fuel adoption for meeting political targets.

D | Methanol

Production Pathways [235]

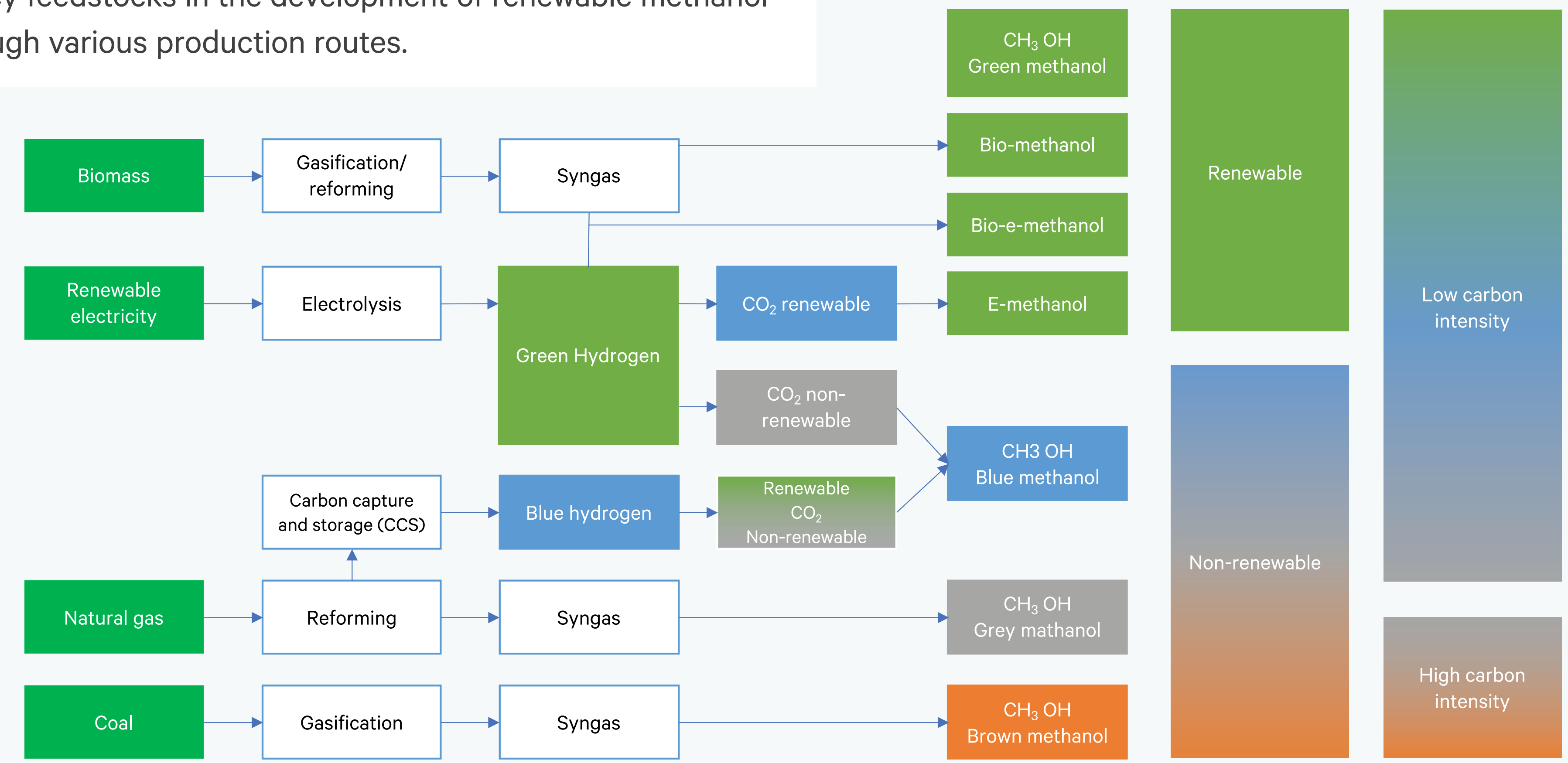
Methanol is predominantly produced from fossil fuels, such as coal and natural gas, which have a significant carbon footprint. However, several alternative methods have emerged to produce methanol from renewable sources, with lower carbon intensity. These methods include bio-methanol, derived from biomass, and green methanol, produced by capturing CO_2 from renewable sources through technologies like Bioenergy with Carbon Capture and Storage (BECCS) or Direct Air Capture (DAC).

Bio-methanol and e-methanol, both derived from renewable feedstocks and processes, are chemically identical to fossil-fuel-based methanol but offer significantly lower greenhouse gas (GHG) emissions over their lifecycle, as detailed in the overview section. This makes them attractive alternatives in reducing the overall carbon footprint of the chemical and energy sectors.

To classify methanol as a truly renewable resource, both the feedstock and the energy used in its production must come from sustainable sources, such as biomass, solar, wind, or geothermal energy.

A significant challenge in this transition is finding cost-effective feedstocks, as renewable methanol production must also be economically competitive with fossil fuel-based methanol. This is why hydrogen and carbon have emerged as key feedstocks in the development of renewable methanol through various production routes.

Figure 32: Pathways to methanol and renewable methanol production



D | Methanol

Production Pathways

Typical process flow of methanol formation

While there are three key steps to methanol formation (renewable/conventional), namely feedstock pretreatment, gasification and gas conditioning and cleaning, the process may vary based on the type of feedstock being used. A typical process may be understood as below:

- **Feedstock pretreatment:** Solid feedstocks must be homogenised before entering the gasifier to ensure process control and efficient feeder system design. This helps overcome challenges related to maintaining consistent flow under pressure. Gasifier pressure is typically maintained at 5-10 bar with minimal use of inert gas for efficiency. In contrast, liquid feedstocks, like black liquor from pulp mills, allow for simpler feeding systems that can operate at much higher pressures (30-60 bar).
- **Gasification:** During gasification, feedstocks are converted into syngas in a high-temperature gasifier. Heat is supplied either by partial oxidation with pure oxygen or via indirect heat exchange. Gasifier technologies are classified into non-slagging (800-900°C) and slagging (>1,000°C) types. Non-slagging gasifiers avoid slag melting, which can reduce efficiency but prevent blockages. In contrast, slagging gasifiers operate at higher temperatures, producing a floating slag that helps minimise tar and methane formation.
- **Gas conditioning and cleaning:** Aftertreatment requirements vary depending on the gasifier type and feedstock composition. Biomass materials or municipal solid waste (MSW) can introduce impurities that affect downstream processes, making aftertreatment especially important for non-slagging gasifiers.

D | Methanol

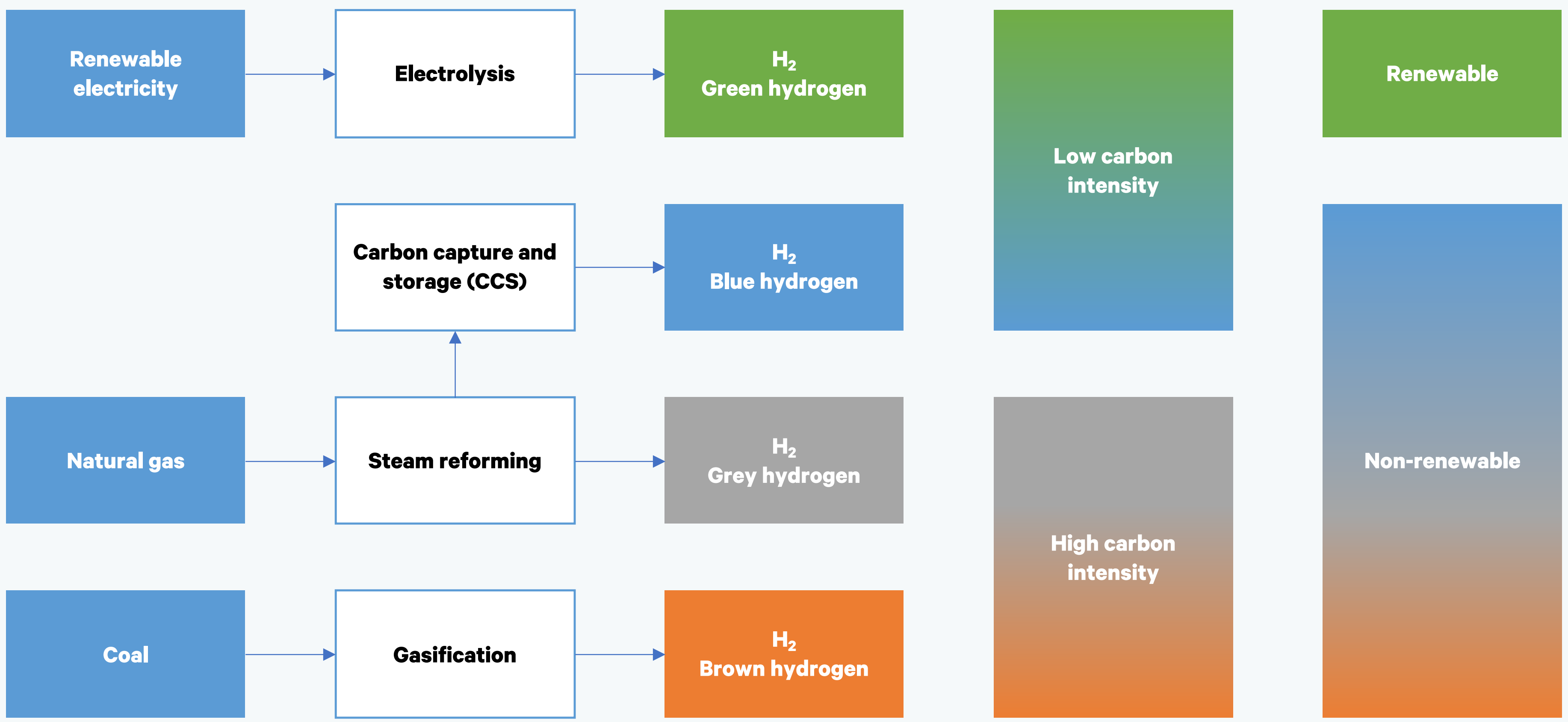
Production Pathways

Feedstock 1: Hydrogen

Currently, the majority of hydrogen production comes from fossil fuels, including blue, brown, and grey hydrogen. Only about 4% is generated through electrolysis, which can be powered by either the electrical grid or renewable energy sources to produce green hydrogen.

Renewable methanol, in particular, can be obtained through biomass gasification to produce bio-methanol. When combined with green hydrogen from electrolysis, it results in bio-e-methanol. Another approach involves producing low-carbon methanol by using blue hydrogen (derived from natural gas) combined with captured carbon from processes like CCS or DAC, often referred to as blue methanol. While renewable methanol is carbon-neutral, blue methanol represents a lower-carbon alternative rather than a completely emission-free solution.

Figure 33: Types of hydrogen, basis production processes



D | Methanol

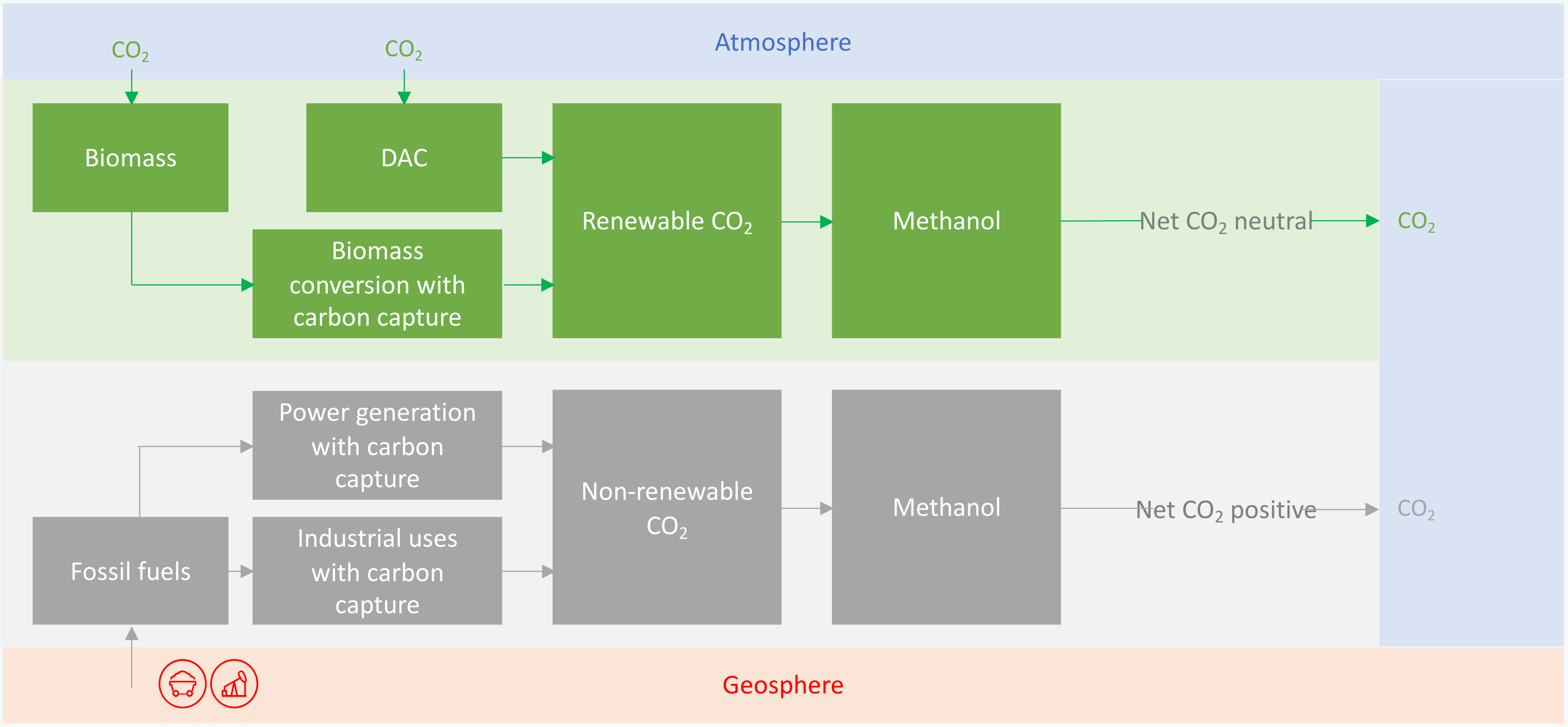
Production Pathways

Feedstock 2: Carbon

CO_2 for the production of renewable or e-methanol can be sourced from two main categories. The first includes carbon emissions from industrial facilities such as power plants, steel mills, and cement factories. In this case, CO_2 is considered acceptable for methanol production because it is being recycled rather than released into the atmosphere, resulting in low-carbon methanol.

Alternatively, CO_2 can be sourced directly from biomass or captured from the air through direct air capture (DAC). These sources typically emit CO_2 as off-gases, which would otherwise be released into the atmosphere—often at high concentrations but under atmospheric pressure. When CO_2 from these processes is captured for storage or utilisation, the approach is referred to as bioenergy with carbon capture and storage (BECCS).

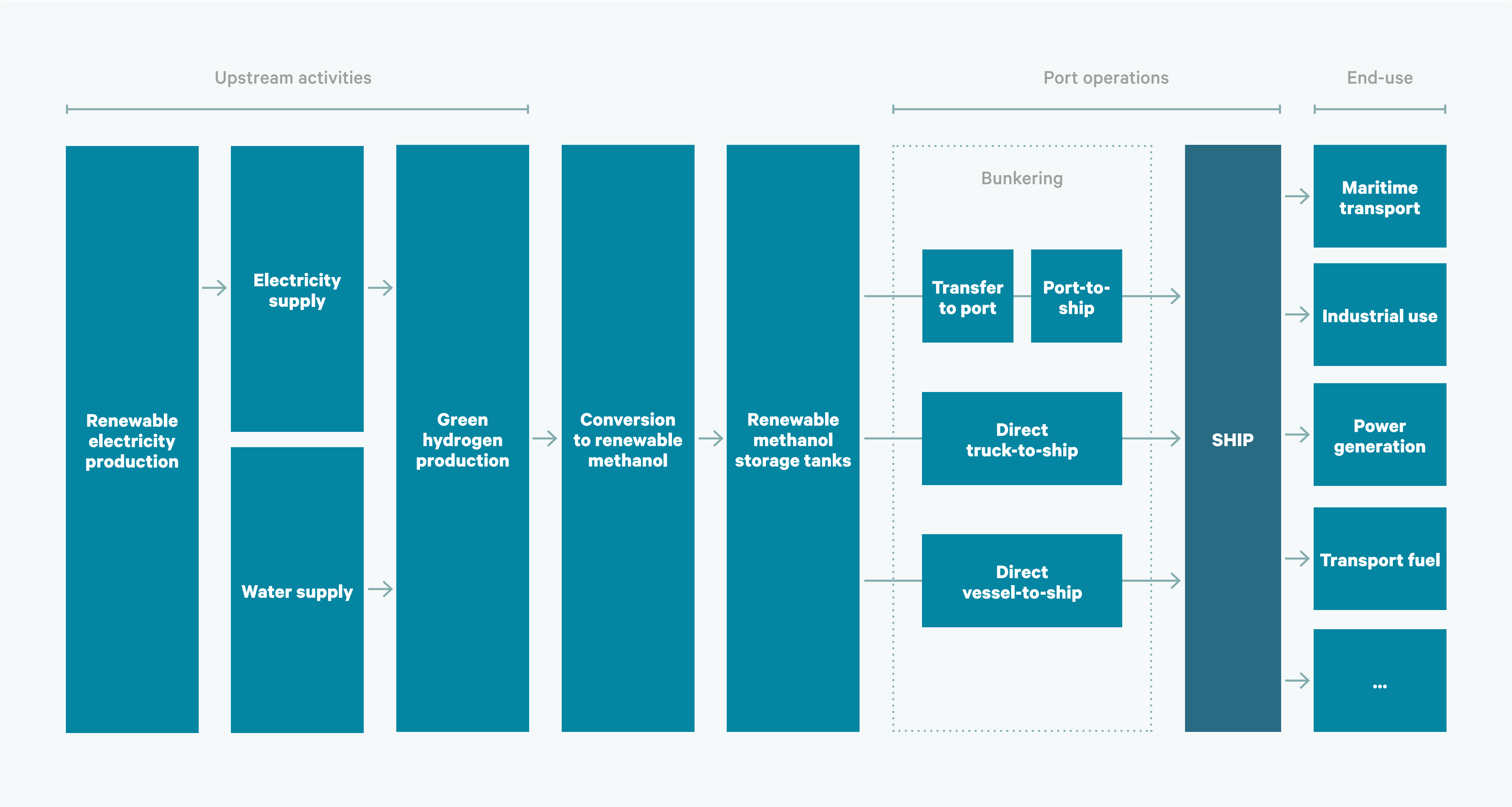
Figure 34: CO2 feedstock for the production of e-methanol



D | Methanol

High-Level Infrastructure Requirements [236,237,238]

Figure 35: Green methanol value chain



Methanol, including renewable methanol is an easy to handle, liquid fuel which is compatible with most engine types. Considering the high usage of conventional methanol versus the renewable version, and the strong pivot towards renewable methanol, raises the question of understanding how much change is required in the methanol value chain to bring in more renewable methanol into the chain.

When looking at the value chain of liquid fuels, storage and transportation form the key components. In the case of renewable methanol, it can be stored under ambient conditions within steel chemical tanks and be transported using existing shipping infrastructure. It requires only minor, low-cost, modifications to existing bunkering infrastructure and fuel supply systems, such as storage tanks, pipelines, fuel pumps, and bunkering barges.

D | Methanol

High-Level Infrastructure Requirements

Overview of Infrastructure Required at Port

The fossil-fuel based methanol produced by Methanex is currently exported out of Port Taranaki using methanol fuelled ocean tankers. These tankers are refuelled by Methanex and are not refuelled by the Port itself. Port Taranaki does not bunker methanol as a marine fuel, but does have tanks that could be modified to be able to store methanol for the purpose of bunkering ships. Other ports around New Zealand also have tanks that could be repurposed to store methanol and use for bunkering vessels.

The development of port infrastructure for methanol is essential to support the maritime industry's transition to low-carbon fuels. As a readily available, liquid fuel compatible with existing engines, methanol offers a cost-effective pathway for decarbonising shipping. Ensuring adequate storage, safe fuel handling, efficient transportation, and reliable bunkering infrastructure will be key to scaling its adoption in global ports:

- **Storage:** Methanol is typically stored in mild steel or stainless-steel tanks to prevent corrosion and contamination, with storage capacity based on different supply chain methods:
    - Small-scale storage (1,000–10,000 m³): For local demand or pilot projects.
    - Medium-scale (10,000–50,000 m³): For regional distribution.
    - Large-scale (>50,000 m³): For major bunkering hubs.
- **Fuel-handling and safety systems:** Critical for ensuring the safe, efficient, and environmentally responsible transfer of methanol, it includes the following systems:
    - Pumping & transfer systems: Specialised methanol-compatible pumps made of stainless steel or other non-corrosive materials are used, along with leak detection systems.
    - Vapour recovery units: These units minimise emissions and control volatile organic compounds.
    - Fire and explosion protection: Due to methanol's flammable nature, ports require fireproof coatings, emergency shut-off systems, flame arrestors and firefighting foam systems.
    - Personnel safety measures: Strict handling procedures, anti-static equipment, and training for operators on methanol-specific hazards are essential.

D | Methanol

High-Level Infrastructure Requirements

- **Transfer from plant to port:** Methanol is transported from production plants to ports using two primary methods:

Pipelines

Advantages

- Preferred for large-scale, continuous supply chains.
- Uses corrosion-resistant materials to handle methanol's properties.
- Equipped with leak detection systems, metering stations, and pressure controls to ensure safe and efficient transfer.
- Common in industrial hubs where methanol production facilities are near ports.

Tank Truck Transport

Advantages

- Suitable for shorter distances or smaller supply volumes.
- Uses dedicated methanol tankers with stainless steel or lined tanks to prevent contamination.
- Equipped with vapor recovery systems to minimise emissions.

Disadvantages

- Requires strict loading/unloading procedures to ensure safety and prevent spills.

- **Bunkering barges/vessels:** Methanol bunkering barges are designed with stainless steel or epoxy-coated tanks to prevent contamination and are also equipped with inert gas blanketing or nitrogen systems to manage fire risks.

D | Methanol

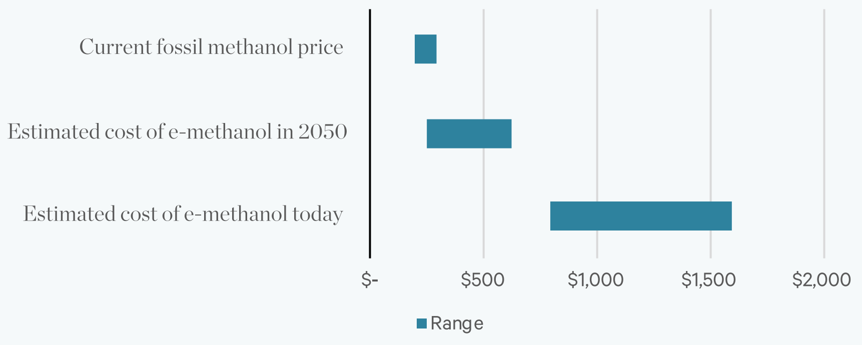
Cost Analysis [239]

E-Methanol Cost Overview

In the short term, producing methanol from biomass and waste is the most cost-effective option in many areas. However, biomass and waste resources, while abundant, cannot meet global energy needs alone. The greatest potential for renewable methanol production lies in hydrogenating CO_2, which does not face the same feedstock limitations.

E-methanol prices range between USD 300 and 1,000 per tonne, with plant sizes ranging from 4,000 t/y to 1.8 million t/y capacity. Lower estimates are linked to low electricity costs and/or revenue from oxygen sales. Each tonne of methanol produced generates 1.5 t of oxygen, which could offset short-term production costs. However, as oxygen availability increases, supply may exceed demand, reducing prices. Costs are also influenced by costs of CO_2 and H_2, depending on how the e-methanol is produced. The figure to the right illustrates these cost dynamics.

Figure 36: Cost of methanol as a function of hydrogen and CO2 cost.



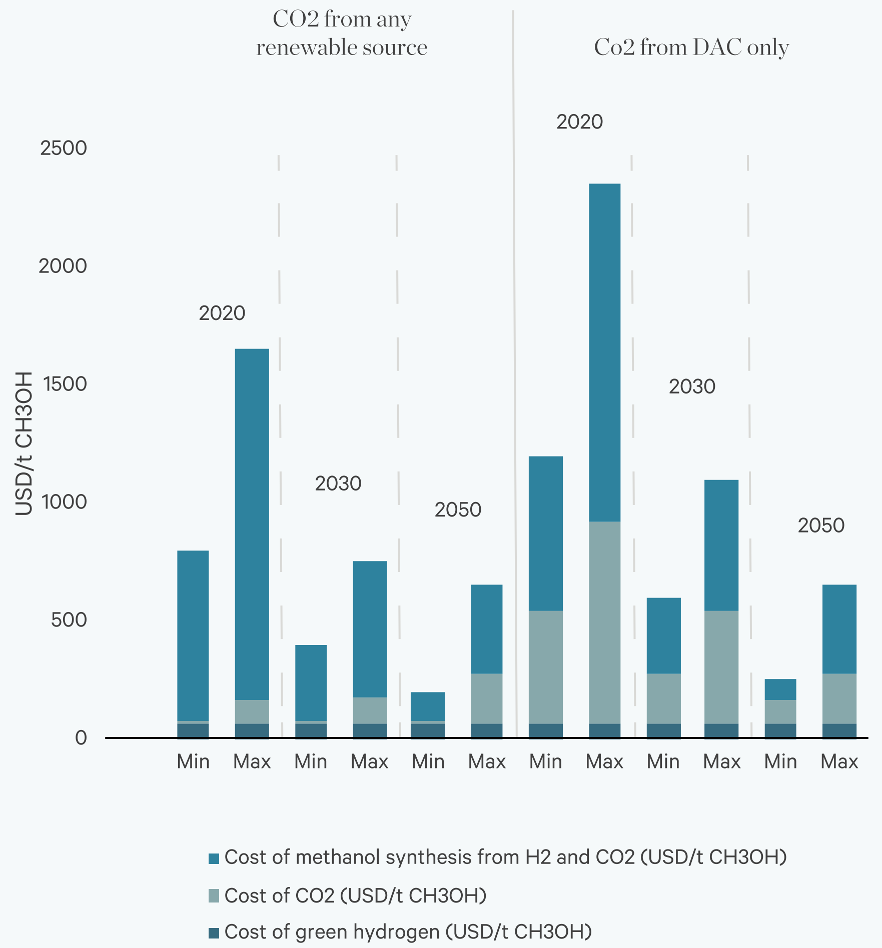
Impact of hydrogen and CO_2 pricing on renewable methanol: The cost of e-methanol production can be estimated by adding the costs of hydrogen, CO2, and their production in a large-scale methanol synthesis unit (USD 50/t e-methanol). In addition, future renewable methanol costs can be estimated based on projected hydrogen and CO_2 costs, as shown in the image below. The cost of renewable CO2 depends on its source. Initially, inexpensive CO_2 sources like bioethanol and biogas will be used, but these have limited availability. As CO_2-derived fuel production increases, costlier sources such as pulp and paper, waste-to-energy plants, biomass combustion, and Direct Air Capture (DAC) will be needed. Availability and cost will also be influenced by competition with other Carbon Capture and Utilisation (CCU) and Carbon Capture and Storage (CCS) technologies. Moreover, Carbon credits can significantly impact the cost of renewable methanol. A carbon credit of USD 100/t CO2 can reduce methanol costs by USD 172/t, based on avoided CO_2-eq emissions from e-methanol versus natural gas methanol production. As carbon credits become more widespread, they could enhance the competitiveness of renewable methanol.

The capital cost per unit of capacity is somewhat higher for the e-methanol plants. The costs of e-methanol are relatively high compared to natural gas-based methanol plants. Most e-methanol plants considered so far are small, with capacities of 12-300 t/d, while large-scale natural gas and coal plants typically produce 2,500-5,000 t/d. Even small-scale natural gas plants have higher production costs per ton (Sorensen, 2015). As e-methanol plants scale up to capacities like traditional plants, costs are expected to decrease.

D | Methanol

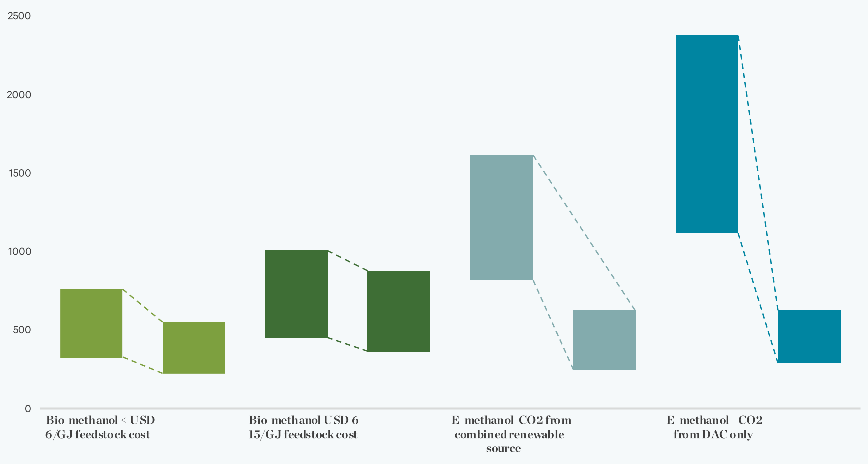
Cost Analysis

Figure 37: Estimated costs of renewable e-methanol through 2050, based on the renewable CO_2 source.



The cost of producing bio-methanol from biomass and MSW is estimated between USD 327 and USD 764/t, mentioned in the image below, with feedstock prices up to USD 6/GJ, which is the upper limit for biomass and MSW in Europe and the US. At feedstock prices of USD 6-15/GJ, production costs may rise to around USD 1,000/t. With process improvements, costs could range from USD 227/t to USD 553/t for lower feedstock prices, and higher for the upper range.

Figure 38: Estimated costs of producing bio-methanol from biomass and MSW



Current e-methanol production from hydrogen and CO_2 is estimated at USD 800-1,600/t, potentially higher if CO_2 is sourced solely from DAC. The cost depends largely on hydrogen and CO2 prices. CO_2 costs vary by source (biogenic, DAC, industrial, etc.), while hydrogen costs are closely tied to electricity prices, electrolyser utilisation, and electrolyser costs. With expected declines in renewable power prices, e-methanol costs are projected to drop to USD 250-630/t by 2050, without CO2 credits. Like bio-methanol, co-producing brown/grey (fossil) and green e-methanol could help introduce green e-methanol at a more affordable cost.

D | Methanol

Pathway to port [240]

Bunkering as a process is primarily focused on supplying fuel to ships for their propulsion and operations. It includes the storage, handling, and transport of fuel, including heavy fuels and alternative fuels, like renewable methanol.

Figure 39: Types of bunkering methods

Truck to ship
Ship-to-ship Bunkering
Land Storage Tank

Figure 40: Advantages and disadvantages of different bunkering methods

Method	Advantages	Disadvantages
Truck-to-Ship: This is the most used method for methanol bunkering, where fuel is transferred from a tanker truck to a ship using hoses and pumping equipment. It is highly flexible and scalable, requiring minimal infrastructure—only a fuel truck and basic port facilities. This makes it ideal for smaller vessels and short-sea shipping. However, its capacity is limited due to the lower fuel volume of trucks, and the bunkering process is relatively slow.	• Bunkering directly at berth • Low investment • Experience in place	• Low bunkering rates • Low volumes
Ship-to-Ship: In this method, a dedicated bunker vessel supplies fuel directly to a receiving ship, either at port or offshore. This approach enables bulk fuel transfers and helps reduce port congestion by facilitating offshore bunkering. However, it requires a specialised fleet of bunker vessels, which are expensive to operate and maintain.	• High flexibility • High bunkering rates • High bunkering volume • Bunkering directly at berth or anchor	• High investment
Terminal-to-Ship: This method involves transferring fuel via pipelines from a shore-based terminal to a ship docked at the port. It offers faster bunkering speeds and can handle large fuel volumes efficiently, making it a cost-effective option for major ports. However, it demands significant infrastructure investment and is primarily suitable for large, high-traffic ports.	• High tank capacity • Fast bunkering	• Fixed location • High investment

D | Methanol

Pathway to port

Developments in Bunkering Vessels
Bunkering is undergoing several developments in alignment with the transformation being witnessed by the marine transportation industry, particularly around environmental standards, and efficiency gains. Some key developments include:

Green Bunkering: With stricter emission regulations (such as the IMO 2020 for reducing the allowable sulphur content in marine fuels) and the associated penalties, bunkering vessels for methanol, ammonia, biofuels, and hydrogen are being developed along with carbon capture and storage integration on bunkering vessels.

For instance, Maersk announced a fleet expansion to 18 vessels, including dual-fuel methanol vessels with the objective of establishing early methanol bunkering networks and driving global adoption of green methanol in shipping.

Another example is of a UK-government-funded SPINE project (Shipping and Port Interfaces in New Era), which aims to address challenges in maritime decarbonisation, under which a 10,000m^3 methanol bunkering vessel is being developed, which would have a semi-automated crane system for efficient fuel transfer, designed for large ships and is focused on enhancing methanol bunkering infrastructure.

Hybrid-electric bunkering: New bunkering are incorporating hybrid-electric propulsion systems to reduce emissions during fuel transfers. They use battery-assisted operations for port manoeuvring to minimise environmental impact.

D | Methanol

Pathway to port

Transport of Methanol from Plant to Port
Methanol, being a volatile and flammable liquid, must be transported safely from production facilities to ports. It has also been classified as a hazardous material under international regulations (e.g. ADR in Europe, DOT in the US). There are different methods of transport, with the selection criteria including distance, volume, infrastructure availability, cost, and regulatory compliance:

- **Road transport:** Tanker trucks offer transport flexibility, particularly for short to medium distance transport. Different types of trucks offer different facilities, such as:
    - Stainless Steel Tanker Trucks: Preferred for their resistance to methanol's corrosive properties and are equipped with insulation and vapor recovery systems to manage emissions.
    - Aluminium Tanker Trucks: Lighter than stainless steel and can accommodate higher volume, however, they require appropriate linings to prevent corrosion from methanol.
    - ISO Tank Containers: Standardised containers suitable for intermodal transport, including road, rail, and sea. They typically have a capacity of 2,400-2,600 Liters and are designed for hazardous materials.
- **Pipeline transport** offers a continuous method of transporting methanol, particularly suited for long distance transport. Pipelines can be directly connected to port facilities. While it offers cost-effectiveness and safety, it does require a high initial investment.
- **Rail transport:** offers an effective mode of transport for medium to long distances, where tank cars are used to transport methanol. The tank cars need to be specially designed and equipped with pressure relief devices to accommodate thermal expansion during transport.

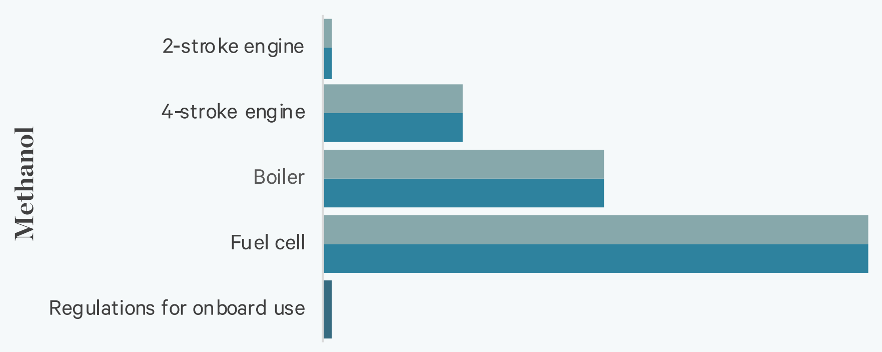
D | Methanol

Readiness Of Onboard Technologies [241,242,243,244,245]

Overview (Methanol Engines)
Methanol engines are becoming increasingly important due to their potential to serve as a more sustainable and environmentally friendly alternative to traditional fossil fuel-powered engines. For example: Vessel engine manufacturers like MAN Energy Solutions, have already commercialised dual-fuel, methanol-ready two-stroke engines, with some in operation since 2016. MAN Energy Solutions currently has 82 methanol dual-fuel engines in its order book, with an additional 120 orders under development. These engines require no internal modifications to run on methanol; changes are limited to the injectors, cylinder heads, and fuel delivery system. In addition, the company also offers methanol retrofits for four-stroke engines, overcoming fuel system and injection challenges. Methanol four-stroke engines are seen for use in ferries, fishing boats, and cruise ships, while two-stroke dual-fuel engines are ideal for methanol tankers, container ships, and other ship applications.

Technology Readiness
The commercial availability of methanol-powered two-stroke and four-stroke engines is significant, as both are commonly used in shipping. Two-stroke engines are approximately 1.8 times more powerful than four-stroke engines for the same weight and can operate more efficiently on low-grade fuel, requiring less maintenance and reducing operational costs.

Figure 41: Anticipated availability of alternative marine fuel technologies



In addition, it has been noted that several companies, including Waterfront Shipping Canada, have successfully operated dual-fuel methanol two-stroke engines for over 145,000 hours. The company has 19 vessels capable of running on methanol fuel. Test results indicate that methanol provides approximately 2% better specific fuel oil consumption compared to conventional fuels.

Marinvest Shipping, a partner of Waterfront Shipping, has been using methanol for five years. The reliability of dual-fuel engines is improved by automatic failover between fuel types, activating if an issue with one fuel is detected, such as the presence of methanol vapours. However, dual-fuel engines have more components than single-fuel engines, which can result in up to 7% increase in maintenance costs.

D | Methanol

Readiness Of Onboard Technologies

Advantages and disadvantages

Each aspect has its advantages and disadvantages. The following table outlines the pros and cons of different types of engines.

	Advantages	Disadvantages
2-Stroke Engines	• Represents a tested and optimised engine design, backed by over 600,000 running hours on methanol. • Lighter and more space-efficient than a four-stroke engine. • Offers a notable power increase with an excellent power-to-weight ratio. • The engine generates less friction on components during operation, resulting in improved mechanical efficiency.	• Engines consume more fuel, with only a small portion of fresh charges mixing with exhaust gases. • Operation may result in significant vibration or noise. • Engines have a limited power band, which is the range of speeds at which it operates most efficiently. • The engine has a shorter lifespan due to higher wear and tear. • A two-stroke engine burns less cleanly, resulting in higher levels of air pollution compared to a four-stroke engine.
4-Stroke Engines	• Engines produce higher torque at lower RPM during operation. • The engine consumes fuel once every four strokes, making it a more fuel-efficient option. • Engines produce less pollution as they do not require oil or lubricant to be mixed with the fuel. • These engines are highly durable and can endure greater wear and tear.	• The extra components in the four-stroke design make these engines heavier than the two-stroke version. • The engine has more components and valves, which makes repairs and maintenance costlier. • The engine needs frequent maintenance, resulting in higher costs for products and services. • This engine design includes a gear and chain mechanism, which can lead to challenges during maintenance.
Fuel Cells	• A more compact design and various configuration options, optimising space. • High energy conversion, efficiency, and system power density • Modular design that enables scalability and provides redundancy. • No moving parts, reducing maintenance. • No NOX, SOX, or PM emissions. Companies like Blue World Technologies, e1 Marine, Advent Technologies, and Freudenberg Fuel Cell have developed methanol fuel cells for maritime applications. Fuel cell systems with on-board methanol reformers are currently being implemented in pilot projects across the United States, Europe, and China.	• Lower efficiency: Methanol fuel cells typically have lower energy conversion efficiency than hydrogen fuel cells, requiring more methanol to generate the same amount of power. • Toxicity and safety concerns: Methanol is a hazardous and flammable liquid, necessitating strict safety precautions during storage, handling, and refuelling. • Limited infrastructure: Although methanol production is increasing, the infrastructure for its distribution and bunkering on ships may not be as advanced as that for traditional marine fuels.

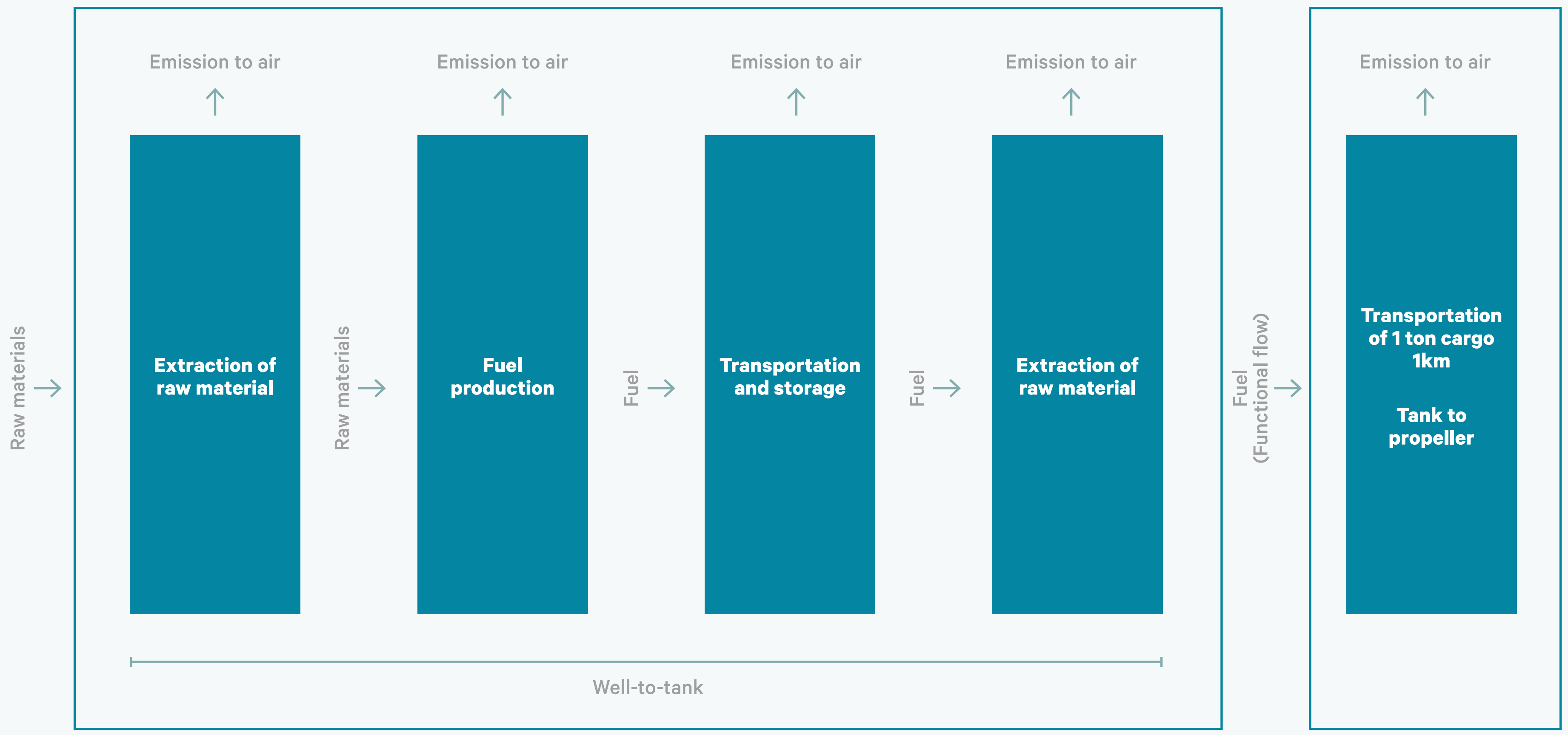
D | Methanol

Emissions Reduction Potential [246,247]

Reducing greenhouse gas (GHG) and pollutant emissions in shipping with Marine Methanol

It is widely recognised that fuel combustion produces emissions. However, the emissions associated with extraction, processing, and distribution are frequently overlooked. To gain a comprehensive understanding of the climate change impact of each fuel, it is crucial to consider emissions throughout the entire fuel lifecycle.

Figure 42: Methodology for assessing emissions is known as well-to-propeller or well-to-wake.



D | Methanol

Emissions Reduction Potential

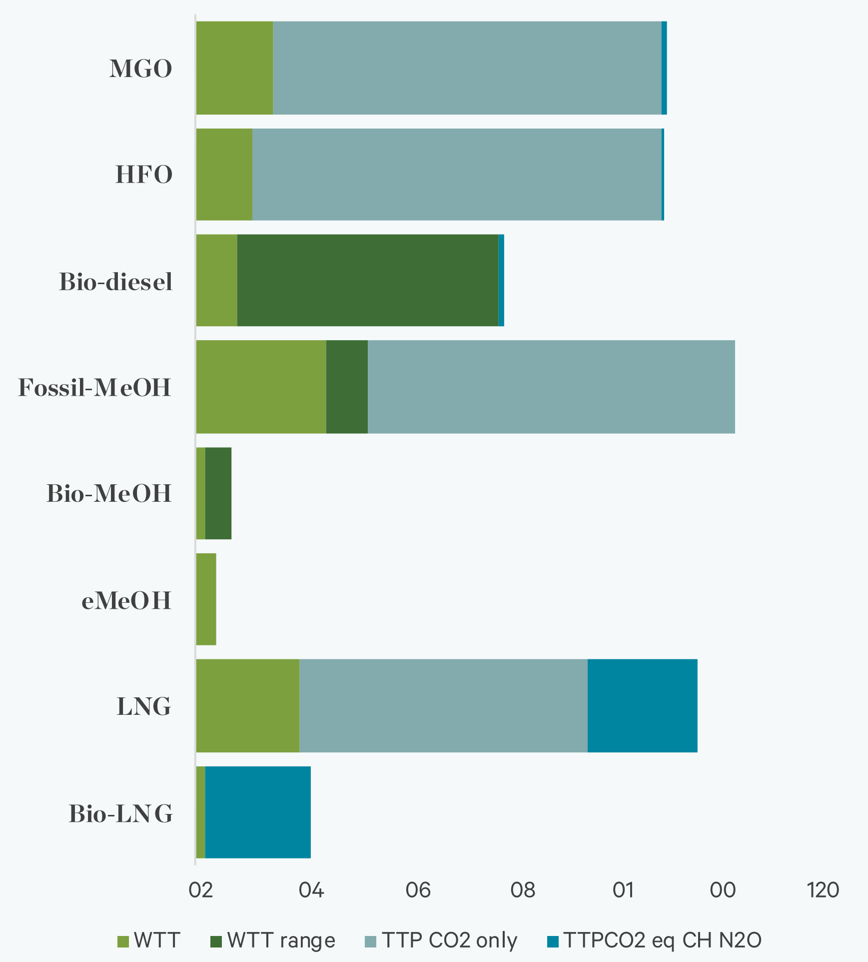
Furthermore, CO_2 is not the sole greenhouse gas emitted during this process. Depending on the feedstock and method of fuel utilisation, methane (CH_4) and nitrous oxide (N_2O) may also be released. Consequently, the impact of various greenhouse gases is standardised by considering their global warming potential (GWP) over a 100-year period and is expressed in grams of CO_2-equivalent.

Additionally, as a potential future fuel for maritime applications, methanol offers several advantages for vessel owners and operators:

- It significantly reduces emissions of Nitrogen oxides (NO_x), Sulphur oxides (SO_x), and particulates.
- It is straightforward to store and manage aboard a vessel.
- Storage and handling facilities are readily available near most major ports.

The use of methanol in ships results in minimal SO_x emissions, as the methanol molecule (CH_3OH) contains no sulphur. Any SO_x emissions that do occur are attributed to the diesel used as pilot fuel in dual-fuel engines, rather than the methanol itself. Marine methanol fuel is fully compliant with the IMO's regulations, which are based on a "Basket of candidate mid-term measures". These include both technical solutions, such as a GHG fuel standard and/or the enhancement of the IMO's carbon intensity measures, specifically concerning SO_x emissions.

Figure 43: Well-to-Propeller Emissions of Different Fuels (gCO_2eq/MJ)



D | Methanol

Emissions Reduction Potential

NOx emissions from methanol are significantly lower than those produced by the combustion of HFO or Marine Gas Oil (MGO). However, methanol does not fully meet the Tier 3 NOx emission standards unless it is mixed with water during the combustion process. According to MAN Energy Solutions, operators can achieve Tier 3 NO_x emission levels by using a mixture of methanol (25% to 40%), water, and 3% to 5% diesel as pilot fuel.[248]

The table below presents the pollutant emissions from HFO, MGO, Methanol, and LNG (g/kWh, tank-to-propeller).

g/kWH	HFO 0.5% S	MGO 0.1% s Tier II	MGO 0.1% s Tier III	Methanol Tier II	Methanol Tier III	LNG Tier III
NO_x	12.8	9	2-3	5	2.2	2
SO_x	2.0	0.36	0.36	0.007	0.007	0.009
PM10	0.74	0.23	0.23	0.034	0.034	0.02

D | Methanol

Wider identified applications

Renewable methanol, produced from sustainable sources such as biomass, carbon dioxide, and renewable energy, offers a versatile alternative to fossil-based fuels across various sectors beyond maritime applications. In the transportation industry, it serves as a low-carbon fuel for road vehicles, including buses, trucks, and even passenger cars, either as a direct fuel or blended with gasoline to reduce emissions. Additionally, renewable methanol acts as a valuable chemical feedstock in the production of plastics, adhesives, and pharmaceuticals, facilitating the creation of a wide range of essential products with a reduced environmental footprint.

Beyond transportation and manufacturing, renewable methanol plays a significant role in energy storage and power generation. It can be utilised in fuel cells to produce electricity with high efficiency and minimal emissions, supporting the shift towards cleaner energy systems. Furthermore, renewable methanol contributes to carbon recycling efforts by capturing and utilising carbon dioxide emissions, thereby helping to mitigate climate change.

D | Methanol

A view on overall feasibility

In New Zealand, the only methanol manufacturer is Methanex, based in Taranaki. Currently, they produce methanol from natural gas, a non-renewable source, and export around 95% of their production.[249] Methanex expect 500,000 – 700,000 tonnes of production in 2025 (less than half of their annual plant capacity), though this is dependent on gas availability and any on selling of gas to the electricity market that may occur to support domestic energy needs.[250]

Assessing the feasibility of renewable methanol production and its application in the maritime sector within New Zealand involves evaluating several critical factors:

- **Renewable Electricity Availability:** New Zealand boasts a robust renewable energy infrastructure, predominantly powered by hydroelectricity, geothermal, wind, and solar energy. A 2024 MBIE report has projected that the renewable share of electricity generation could reach between 96.2% – 98.3% by 2050, up from 87.1% in 2022.[251] Leveraging this abundant renewable resource base is essential for producing green hydrogen via electrolysis, a key component in green methanol synthesis. While New Zealand has an advantage in terms of renewable electricity supply, additional investment will be needed, and the relatively high cost of this renewable electricity will need to be addressed.[252]
- **Domestic Feedstock Availability:** Market engagement has indicated that the easier pathway to produce renewable methanol in New Zealand would be to use biogas to create biomethanol, since existing infrastructure is able to support this as current methanol production uses natural gas. However, securing a steady and sustainable supply of biogenic carbon is challenging. Waste and food scraps have been explored as potential feedstocks for biogas, though the volumes required to meet substantial production needs exceed current availability. For instance, biogas from Auckland's food scraps could produce around 2,000 tonnes of methanol, according to market engagement, compared to the plant's annual capacity of 2.2 million tonnes.[253] Due to the scale required to support marine shipping, the most viable feedstock in New Zealand appears to be woody biomass, with reports estimating that 10 – 12 million cubic metres are produced domestically annually.[254]

D | Methanol

A view on overall feasibility

- **Existing Infrastructure:**
  - Production: Methanex's existing production infrastructure has significant capacity, but expanding biogas sourcing and processing would require substantial investment. Building new renewable methanol production plants would also require significant investment, and would likely be at a relatively small scale initially compared to the demands of the shipping industry. Stakeholder engagement indicated that a large plant would cost about $1,100m and produce only 300 tonnes of green methanol per day – large container ships use approximately 200 tonnes a day.[255]
  - Bunkering: New Zealand's port facilities and shipping networks provide a conducive environment for integrating methanol as a marine fuel. Minor modifications to existing bunkering infrastructure, such as adapting storage tanks and fuel handling systems for methanol compatibility, enhance feasibility without necessitating extensive overhauls. For example, Methanex currently exports its product through Port Taranaki, and while the Port doesn't bunker Methanol currently, market engagement indicated that minor adjustments would be needed to convert existing storage tanks to methanol tanks.
- **Technological Readiness:** Methanol-ready engine technologies, such as dual-fuel engines, are commercially available and have been successfully implemented globally. This technological maturity supports the practical application of methanol. On the production side, while technologies are proven at demonstration scales, transitioning to large-scale production necessitates further advancements and cost reductions.
- **Economic Considerations:** High production costs for green methanol remain a significant obstacle. The production costs for renewable methanol are dependent on the raw material and the production process. Stakeholder engagement suggested that prices for renewable methanol in New Zealand could be as much as 4-5 times higher than conventional marine fuel and that there is limited consumer and industry willingness to bear the additional costs associated with green methanol. Regulation is needed to bridge the gap both locally and overseas. While the IMO greenhouse gas levy promises to do this internationally, stakeholder engagement makes clear that a more stringent carbon price in New Zealand, via the Emissions Trading Scheme, is needed to also incentivise market demand and therefore supply locally. Costs of bio-methanol and e-methanol are expected to decrease as production capacity increases, and by 2050 estimates have productions costs for both types as comparable to the current costs of certain fossil fuels, on a price per unit of energy basis.[256]
- **Market Demand:** The current demand for green methanol in New Zealand's maritime sector – including coastal shipping, international ships en route through New Zealand, and vessels transporting New Zealand exports – is insufficient to drive large-scale production. Without increased demand, achieving economies of scale necessary to reduce costs remains challenging. The domestic navigation fuel oil consumed in 2024 was only 0.27% of total fuel consumption in New Zealand.[257]

A view on overall feasibility

- **Regulatory Support:** Methanex's presence in New Zealand ensures that safety regulations around methanol handling are in place, and protocols for methanol-powered ships have been recognised. Methanol handling and storage are regulated under the Health and Safety at Work Act (2015) and its associated regulations, with WorkSafe being a key organisation that enforces these. WorkSafe also has specific requirements for methanol such as workplace exposure standards[258] and safety data sheets. However, global regulations are needed to drive industry-wide adoption and ensure competitive parity.

While the technological capability to produce green methanol in New Zealand exists, significant economic and infrastructural challenges impact its feasibility at a large scale. Significant capital investment associated with a large-scale plant, high production costs driven by the high cost of renewable electricity, and limited willingness to pay need to be addressed to make green methanol competitive with traditional and other alternative fuels. Additionally, expanding biogenic carbon sources and investing in infrastructure to support these feedstocks are critical for enabling production of renewable methanol, especially at scale.

These challenges are exacerbated by the need to be cost competitive with any green methanol production overseas. Combined with the fact that green methanol is likely to be within a suit of alternative fuels for international shipping, focusing on large scale production of green methanol within New Zealand is likely to be a risky proposition.

E | Ammonia

Overview and summary

Ammonia is primarily understood through the lens of global agricultural systems, considering its significant contribution to it. Currently ~70% of ammonia globally is used for fertilisers, with the remaining 30% distributed across industrial applications. A large share of ammonia production currently is via fossil-fuels. More than 70% of ammonia is produced using natural-gas based steam reforming, with the second-most common process being coal gasification.[259]

By 2030, ammonia is expected to play a significant role as a low-carbon shipping fuel, with announced capacity projections ranging from 17 to 114 million tonnes per annum (MTPA). Estimates suggest that 17 MTPA is explicitly allocated for fuel, with 98 MTPA still in an uncertain zone regarding its use for fuel. A scenario analysis estimates potential demand within three ranges: Low (3.6–20.6 MTPA), Realistic (4.2–25.2 MTPA), and High (6–29.4 MTPA).[260] Compared to conventional marine fuels, ammonia has about one third of the volumetric energy density, so would require about three times the onboard storage space.[261]

Under the realistic scenario, a minimum supply of 4.2 MTPA is projected for fuel-dedicated ammonia, serving as a baseline. The upper limit in this scenario combines ammonia from fuel-specific projects (4.2 MTPA) and a portion of mixed-use ammonia (21 MTPA), resulting in a maximum available supply of 25.2 MTPA for shipping fuel.[262]

This roadmap focuses on low-carbon ammonia, outling the production pathways, infrastructure developments and market activities required for integrating ammonia into the maritime industry. The roadmap concludes with a view on the overall feasibility of production of ammonia in New Zealand, informed by market engagement and research.

In New Zealand, there is an ammonia-urea manufacturing plant, which is located at Kapuni in Taranaki. This plant converts atmospheric nitrogen to ammonia and then to urea, but is powered using natural gas from the region.[263] There are several companies and start-ups exploring opportunities to develop low-carbon ammonia.[264]

E | Ammonia

Ammonia as an alternative marine fuel

Rationale for Ammonia in Shipping

- **Decarbonisation Potential:** Green ammonia produced via electrolysis achieves the lowest well-to-wake emissions, reducing greenhouse gas emissions by 61%-77% (assuming 100% renewable electricity), compared to conventional fuels.[265]
- **Renewable Production:** The global production of ammonia is projected to reach 200 metric tonnes (Mt) by 2025, with renewable ammonia expected to account for about 80% of demand by 2050.[266]
- **Economic Viability in the Long Term:** Although current costs are high, advancements in ammonia production technologies and falling renewable energy prices are expected to make renewable ammonia increasingly competitive.[267]

Key Challenges in Producing and Bunkering Ammonia

- **Regulatory Framework:** Establishing ammonia-specific bunkering guidelines, workforce training, and licensing mechanisms is essential to ensure safe handling.[268]
- **Infrastructure Needs:** Ammonia's corrosive nature requires specialised storage equipment resistant to stress corrosion cracking. Existing infrastructure may need retrofitting or new facilities to accommodate ammonia safely.[269]
- **Safety Concerns:** There are a variety of safety measures required, especially for ammonia bunkering operations, including double barriers on ships, designated bunkering stations with gas-tight enclosures, and ventilation systems.[270]

E | Ammonia

Background

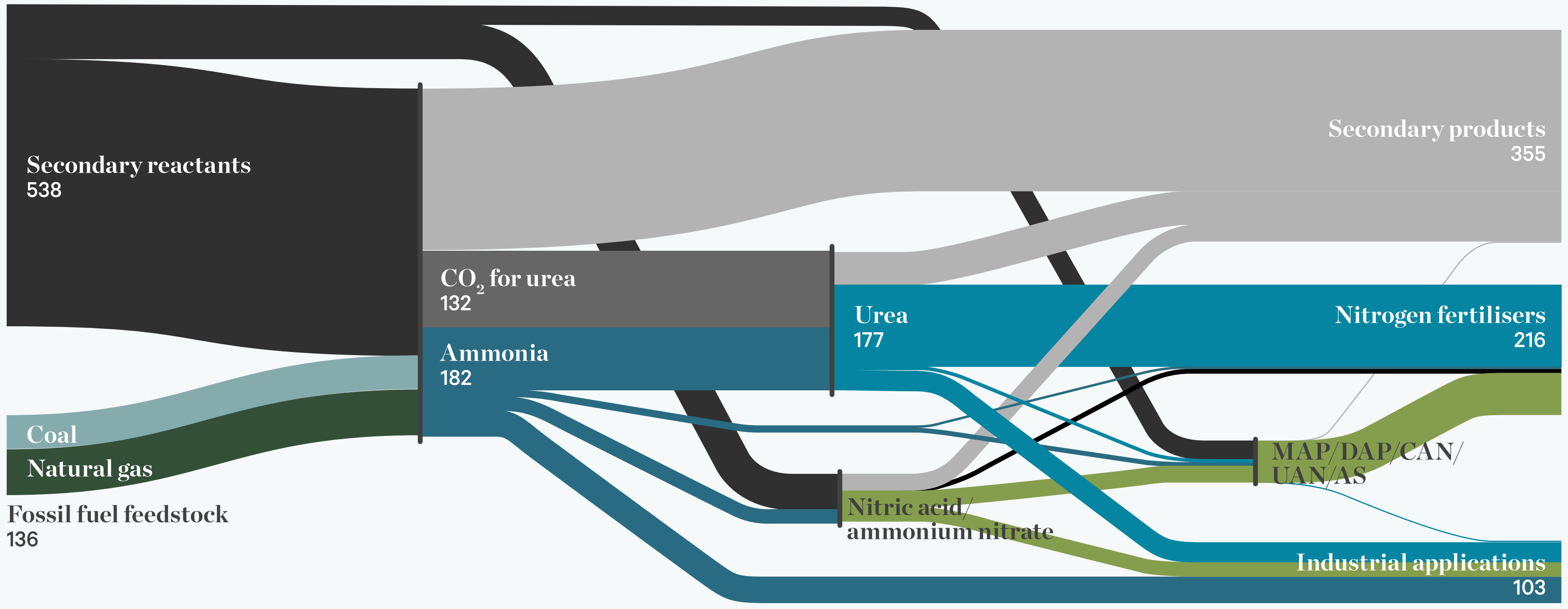
Current Demand and Use of Ammonia[271]

In the context of near-zero emissions, new production methods like electrolysis, methane pyrolysis and fossil-based routes with carbon capture and storage are emerging. However, a key impediment for these routes is their cost-intensive nature.

A closer look at the ammonia supply chain indicates that only ~2% of total ammonia demand is for direct application. The key uses of Ammonia are, as follows:

- **Urea:** Majority of ammonia is combined with other inputs to produce other nitrogen-based fertilisers and industrial products (primarily urea, occupying 55% share of ammonia demand).
- **Nitric Acid and Ammonium Nitrate:** Roughly 80% of nitric acid is used to produce ammonium nitrate, with two-thirds dedicated to fertiliser applications.

Figure 44: Mass flows in the ammonia supply chain from fossil fuel feedstocks to nitrogen fertilisers and industrial products



The thickness of the lines in the Sankey diagram are proportional to the magnitude of the mass flows. All numeric values are in million tonnes per year of production using production data for 2019. Only the fossil fuel quantities consumed as feedstock are shown; the diagram does not represent process anergy inputs. MAP=monoammonium phosphate; DAP=diammonium phosphate; CAN=calcium ammonium nitrate; UAN=urea ammonium nitrate; AS=ammonium sulphate.

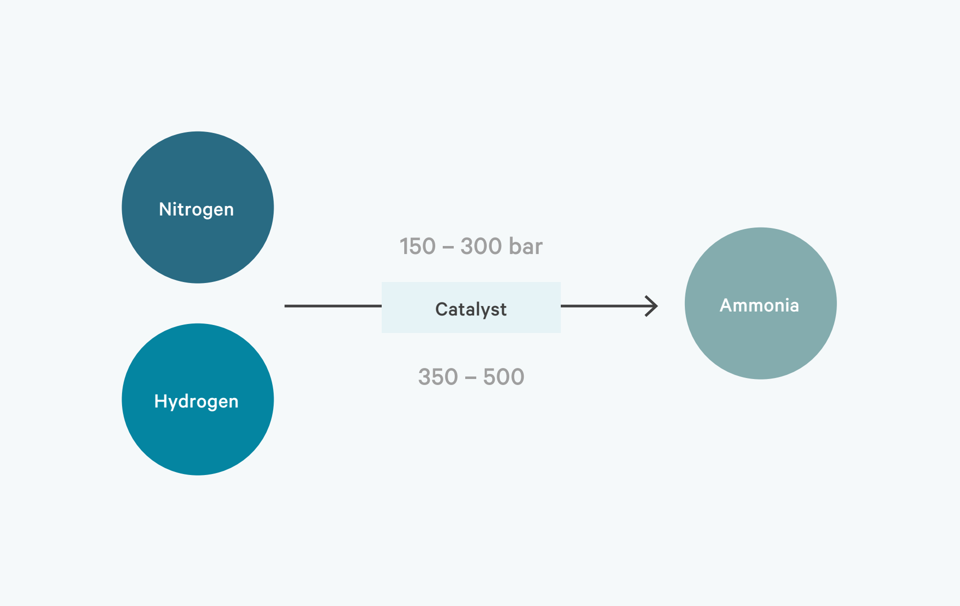
E | Ammonia

Background

Types of Ammonia[272]
There are multiple pathways to produce ammonia. The ammonia produced by these different methods could be called by different names, such as:

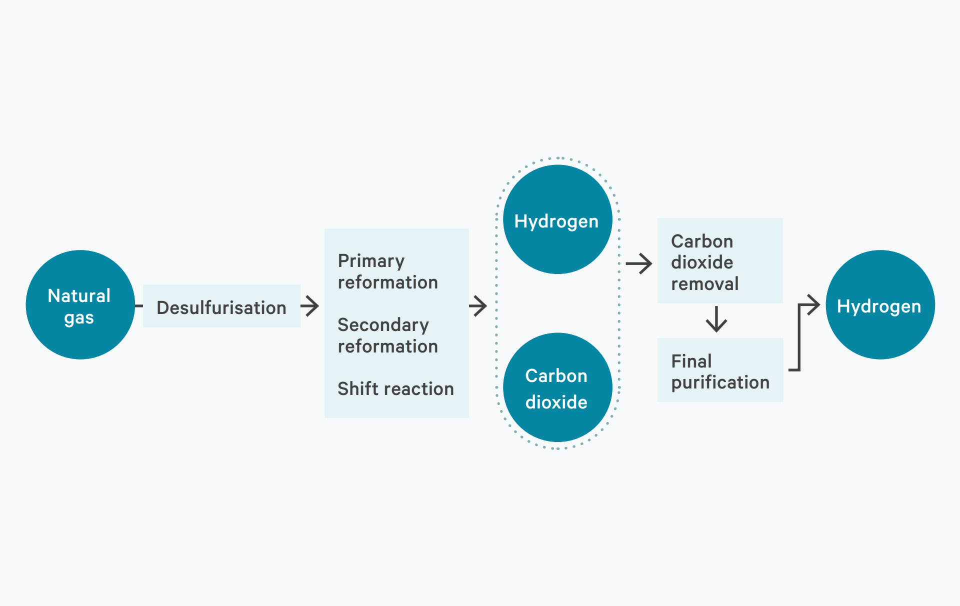
Brown Ammonia
This is a high carbon ammonia produced through coal gasification. Commercially its production relies on the Haber-Bosch process which involves a catalytic reaction of hydrogen and nitrogen at high temperature and pressure. The process is significantly energy-intensive with 90% of carbon emissions stemming from hydrogen production.

Figure 45: Schematic of the Haber-Bosch Ammonia synthesis reaction



Grey Ammonia
This is also a high carbon ammonia produced using fossil fuels, like natural gas. A process called steam reformation (also called Steam Methane Reforming/SMR) is performed on natural gas to produce hydrogen and carbon dioxide. While SMR inherently does not reduce carbon dioxide, different technologies like carbon capture and storage can be deployed for carbon reduction.

Figure 46: Schematic of hydrogen production via steam methane reformation



E | Ammonia

Background

Low-carbon Ammonia
Ammonia which is made using sustainable means like renewable electricity, water, air or captured carbon from manufacturing. Green and Blue ammonia are discussed further in a later section.

Market Sizing of Low-Carbon Ammonia over the Medium to Long Term with Reference to Shipping

Demand areas of low-carbon Ammonia:[273] A key fact that positions ammonia favourably for renewable production is its unchanged chemical structure, regardless of whether it is produced through fossil-fuel-based or renewable methods. The global production of ammonia is expected to reach 200Mt by 2025, with total demand projections of 688Mt by 2050 (under a 1.50 C scenario). Of this figure, renewable ammonia is expected to account for ~80% of the demand. This transition aligns with the growing capacity of renewable ammonia plants, which is currently expected to reach 15Mt by 2030.

- **Urea:** Switching to renewable ammonia for urea production, which constitutes 55% of ammonia demand, faces challenges as fossil-based ammonia for urea production cannot be simply replaced by renewable ammonia, as carbon dioxide produced as part of the ammonia production process needs to be captured. This may require use of circular carbon sources (like biomass or direct air capture) with a potential shift from urea towards nitrates.
- **Energy markets:** The increasing use of renewable ammonia is expected to accelerate the transition of sectors like chemical, power, transport towards a sustainable circular economy.
- **Stationary power:** The use of renewable ammonia is expected to find a demand base in power generation. In Japan, for instance, ~3-5 Mt per year will be used for stationary power generation in gas turbines and coal-fired power plants by 2030, with demand rising to 30 Mt by 2050.

E | Ammonia

CASE STUDY 1

Corpus Christi's Potential as a Green Ammonia Bunkering Hub [274]

Introduction

Corpus Christi port presents a significant opportunity to become a green ammonia bunkering hub in alignment with IMO's 5% net-zero GHG emission goal for 2030. Local green ammonia production is anticipated to reach 1.2 million tons annually by 2030, positioning the port as a key player in low-carbon shipping and fuelling initiatives. This case study explores the port's readiness, infrastructure requirements, regulatory framework, fuel sourcing challenges and strategic recommendations.

Potential for Green Ammonia Bunkering

- **IMO goal alignment:** To meet the IMO's 5% GHG emission reduction goal, approximately 80,000 tons/year of green ammonia would be required for bunkering at Corpus Christi by 2030. This equates to a small fraction of expected local production but represents a critical offtake market to reduce developers' risks.
- **Market share opportunities:** Corpus Christi has potential to compete with larger regional bunkering hubs like Houston and Louisiana, leveraging its local production and cost advantages.

Port Readiness and Infrastructure

- **Current status:** Corpus Christi is rated between PRL two and three on the IAPH Port Readiness Level (PRL) scale of nine, signalling early-stage interest and information gathering.
- **Infrastructure needs:** The port lacks dedicated ammonia storage facilities. Options include retrofitting existing LPG storage infrastructure or building new facilities.
- **Synergies:** Shared infrastructure for bunkering and ammonia exports could lower investment costs and reduce delivered costs of ammonia bunkers by ~30%.

E | Ammonia

CASE STUDY 1

Corpus Christi's Potential as a Green Ammonia Bunkering Hub [275]

Challenges

- **Regulatory framework:** Establishing ammonia-specific bunkering guidelines, workforce training, and licensing mechanisms remains critical.
- **Fuel sourcing risks:** Green ammonia production depends on scalable water supplies, transmission grid upgrades, and consistency of policies like the IRA.
- **Demand activation:** Limited immediate uptake, but collaboration with Transatlantic Clean Hydrogen Trade Coalition strengthens export potential and production kickstart.

Actions the Port is Aiming to Progress

Catalysing supply

- Develop a regulatory framework leveraging best practices from ports like Rotterdam and Singapore
- Conduct ammonia bunkering trials to build stakeholder confidence.
- Explore subsidies or low-cost financing for infrastructure through initiatives like the Bipartisan Infrastructure Law.

Activating demand

- Provide incentives (e.g., reduced port fees and preferential berthing) for zero-emission vessels.
- Align with global green shipping corridors to enhance investment attractiveness.
- Engage first-mover ship operators to expand the bunker market beyond ammonia carriers.

Corpus Christi is evaluating the ability to be a leading green ammonia bunkering hub. However, to do so, challenges around synchronising infrastructure development with export projects and leveraging its strategic location will need to be overcome to accelerate the transition to low-cost green ammonia.

E | Ammonia

CASE STUDY 2

Woodside Halted Two Green Ammonia Production Projects in Australia and New Zealand [276]

Introduction

Woodside Energy (an Australia-based O&G company) has shelved two major green hydrogen projects in Australia and New Zealand, with a combined capacity of 2.3 GW. These projects include 1.7 GW H2Tas in Tasmania (a proposed facility for green hydrogen and ammonia production) and a 600 MW Southern Green Hydrogen (a partnership with New Zealand government-owned utility Meridian Energy) in New Zealand.

The combined capacity of these projects represented a significant opportunity for green ammonia production, critical to supporting decarbonisation efforts in international shipping. However, various economic, environmental, and regulatory challenges led to the discontinuation of both initiatives, highlighting the fragility of current green ammonia development efforts.

Key Challenges

- **High dependence on renewable energy:** The H2Tas project, planned to produce 600 tonnes of ammonia daily, was deemed unviable due to insufficient renewable energy generation in Tasmania. Electrolysis-based production requires a stable and ample supply of renewable energy, which Woodside cited as lacking.
- **Challenging economics:** The Southern Green Hydrogen project in New Zealand aimed to produce 500,000 tonnes of ammonia annually yet faced escalating production costs. Woodside admitted that the economics of green hydrogen were not competitive with market expectations, reflecting a global struggle to bridge the gap between production costs and customer willingness to pay.
- **Regulatory and environmental constraints:** Stricter environmental requirements and the need for scope modifications further complicated both projects. H2Tas required substantial re-planning, forcing Woodside to withdraw its environmental applications.
- **Market hesitancy:** Feasibility studies for ammonia exports to Japan showed promise, but Woodside's decision underscores hesitancy in committing to green hydrogen-based ammonia amid uncertain demand and high investment risks.

E | Ammonia

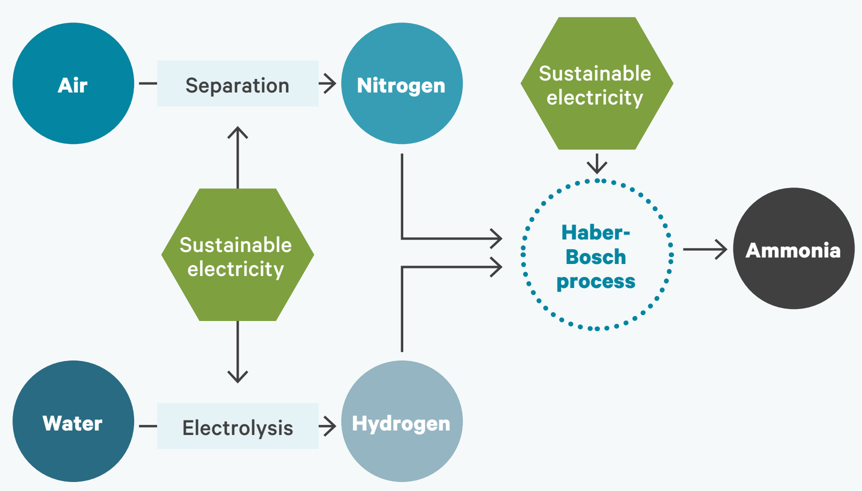
Production pathways

Green Ammonia[277]

A key part of making ammonia green is the sourcing of hydrogen. To be called green, the hydrogen is produced through the electrolysis of water. Another essential component, nitrogen, is obtained directly from air using air separation units (this accounts for 2-3% of energy use). Subsequently, Ammonia is produced using the Haber-Bosch process, powered by renewable electricity.

IEA estimates that the electrolysis process is cost-competitive with the steam methane reformation process with carbon capture at electricity prices between 1.5 to 5.0 USD cents/kWh (1.2 to 4.0 GBP pence/ kWh); and with steam methane without carbon capture at 1 to 4 USD cents/kWh (0.8 to 3.1 GBP pence/kWh; assuming gas prices 3 to 10 USD cents/MMBtu (2.3 to 7.7 GBP pence/MMBtu).

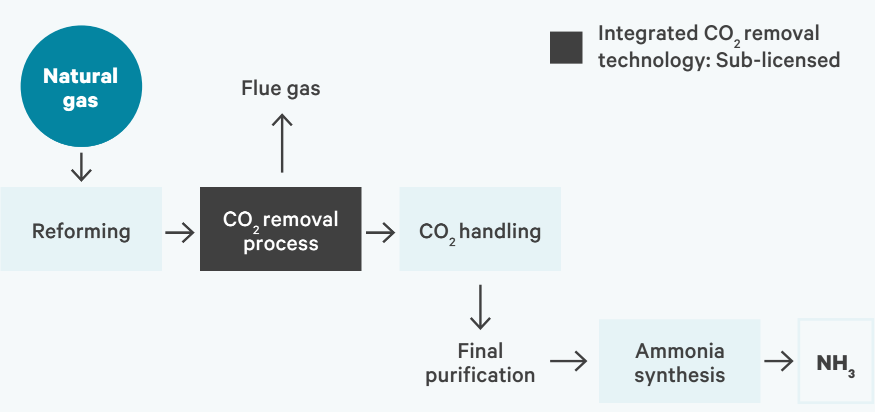
Figure 47: Schematic of green ammonia production based upon hydrogen production from water electrolysis and the full decarbonisation of the Haber-Bosch process



Blue Ammonia[278]

Blue ammonia is formed by using blue hydrogen from the steam methane reforming process (along with the use of carbon capture and storage). While up to 90% of carbon dioxide could be captured, the upstream greenhouse gas emissions associated with natural gas extraction limit the life-cycle emission reductions for combined steam methane reforming and carbon capture and storage to 60 – 85%.

Figure 48: Schematic of blue ammonia production



E | Ammonia

High-level infrastructure requirements

Overview of Key Infrastructure Required to Produce Low-Carbon Ammonia[279]

Ammonia is commonly traded as a commodity product with cargo terminals for loading/unloading ammonia already available across the globe. The toxic and corrosive nature of ammonia make it challenging to store, given the consequences of leakage handling, inspection, and maintenance safety. Due to its corrosive nature, it is important to select tanks/storage equipment that resist stress corrosion cracking.

The following tank types have been developed for transportation of LNG under IMO provisions, but are also under consideration/testing for carrying Ammonia:

- **Tank A:** This is an independent tank based on conventional ship structure design principles. It has a design pressure of 0.7 bar. This tank reduces excessive sloshing of ammonia on the tank walls, along with a secondary liquid-tight barrier to protect tank from structural failure.
- **Tank B:** This is similar to tank A (with same design pressure of 0.7 bar), with certain provisions such as a leak-before-failure approach, focused on preventing leakage before-hand instead of keeping safety provisions in times of leakage.
- **Tank C:** This tank has a design pressure of 2.0 bar. This is a much safer tank with low probability of cracks/leakage.
- **Membrane tank:** The tank boundary consists of multiple layers of insulation and two barriers, and is glued into the preconstructed tank compartment. It has a design pressure of 0.7 bar.

Figure 49: Overview of ammonia tank types

Feature	Independent tanks			Integral tank
	IMO Type A	**IMO Type B**	**IMO Type C**	**Membrane**
Geometry	Self-supporting independent prismatic tank with option of inclined boundaries		Pressure vessel (cylindrical, bi-lobe, tri-lobe design)	Prismatic tank, built in the supporting ship structure
Space utilization	Good		Low – Moderate	Good
Temperature/ pressure	-33°C / < 0.7 bar		NA / > 0.2 bar (overpressure possible)	-33°C / < 0.7 bar
Barriers	2 barriers; second barrier enclosing the tank, able to contain liquid gas for 15 days	2 barriers; partial second barrier, designed to contain liquid phase of ammonia fuel for 15 days	1 barrier	2 barriers; second barrier enclosing the tank
Design complexity	Moderate	High	Low – Moderate	Moderate
Manufacturing	Pre-fabrication – independent of ship structure		Pre-fabrication – independent of ship structure; may be located on deck	Construction of the tank inside the pre-manufactured tank compartment
Material	Stainless steel	Stainless steel	Stainless steel, carbon manganese steel	Stainless steel, Nickel steel (Invar)
Sloshing risk	Small due to swash bulkhead		Small due to shape, volume, and swash bulkheads	Significant
Main challenges	Second barrier, handling of leakages	Design complexity	Weight and space utilization	Sloshing and serial construction

E | Ammonia

High-level infrastructure requirements

Safety in handling Ammonia

Ammonia is considered to be a toxic and corrosive product, hence, significant safety measures are required for shipping vessels which may use ammonia as an energy source. There are largely four elements of the safety concept of Ammonia:

- **Segregation:** This concept protects fuel installation from external events. It indicates that the fuel tanks must be arranged in a manner to avoid damage during collisions, grounding, or other mechanical failures. Additionally, they must be positioned away from areas which are prone to fire or explosion risks.
- **Double barriers:** This concept protects the ships against leakages. It involves the use of a double barrier with the tank forming the first barrier, and along with a full/partial second barrier to protect the crew, ship and environment from fuel spills.
- **Leakage detection:** This concept gives warnings and enables automatic safety actions.
- **Automatic isolation of leakages:** This concept is focused on reducing the consequences of a leakage.

Bunkering considerations

Ammonia bunkering operations differ from conventional bunkering of oil-based fuels which have flash points above 60°C. This option is typically used to supply refrigerated ammonia:

- **Compatibility:** Bunkering of ammonia requires compatibility between the bunker supplier and the vessel to be bunkered.
- **Designated stations:** It requires designated bunkering stations with gas-tight enclosures to limit the extent of ammonia leakage.
- **Access:** Access to the bunkering station must be provided through an external water screen with water supply available at all times.
- **Ventilation systems:** There needs to be an appropriate venting system in instances of ammonia leakage.

There are largely three bunkering options which would be available for ammonia, such as:

Ship-to-ship: This option allows the transfer of ammonia in large volumes to a receiving vessel at anchorage or at berth. The maximum transfer rate is dependant on the size of the transfer hose. The bunker vessels are equipped with systems to handle boil-off gas returning from the receiving vessel. This option can be used to typically supply refrigerated ammonia.

Truck-to-ship: This is typically a flexible solution; however the amount of ammonia that can be transported is limited, with one ship may requiring multiple truckloads. This option could be used to supply fully pressurised ammonia.

Terminal-to-ship: The receiving ship bunkers ammonia from a dedicated bunkering facility, through rigid pipes and flexible hoses. This method allows high bunkering rates in short-times and can be used to supply refrigerated ammonia.

E | Ammonia

Cost analysis

Pricing of Different Types of Ammonia[280]

The cost of conventional ammonia production can be divided into the following components:

- **Fixed operating costs:** This is typically in the range of 40-70 USD/MT, including storage cost, however it is dependent upon the plant size and geographic location and is expected to be higher for small plants.
- **Cost of energy:** This is the highest contributor to ammonia's cost. The specific energy consumption for a modern stand-alone ammonia plant including utilities and off site is approximately 8.4 MWh/MT (28.6 MM BTU/MT) giving an energy cost in the range 70 – 200 USD/MT for natural gas prices of 2.5 – 7.0 USD/MM BTU.
- **Potential CO2 emission penalties:** Estimates suggest that this could be in the range of 25-75 USD/tonne of CO_2 emissions. Considering a typical plant producing 2 tons CO2 /tonnes NH3, the anticipated CO_2 penalty cost could be in the range of 50-150 USD/MT NH3.

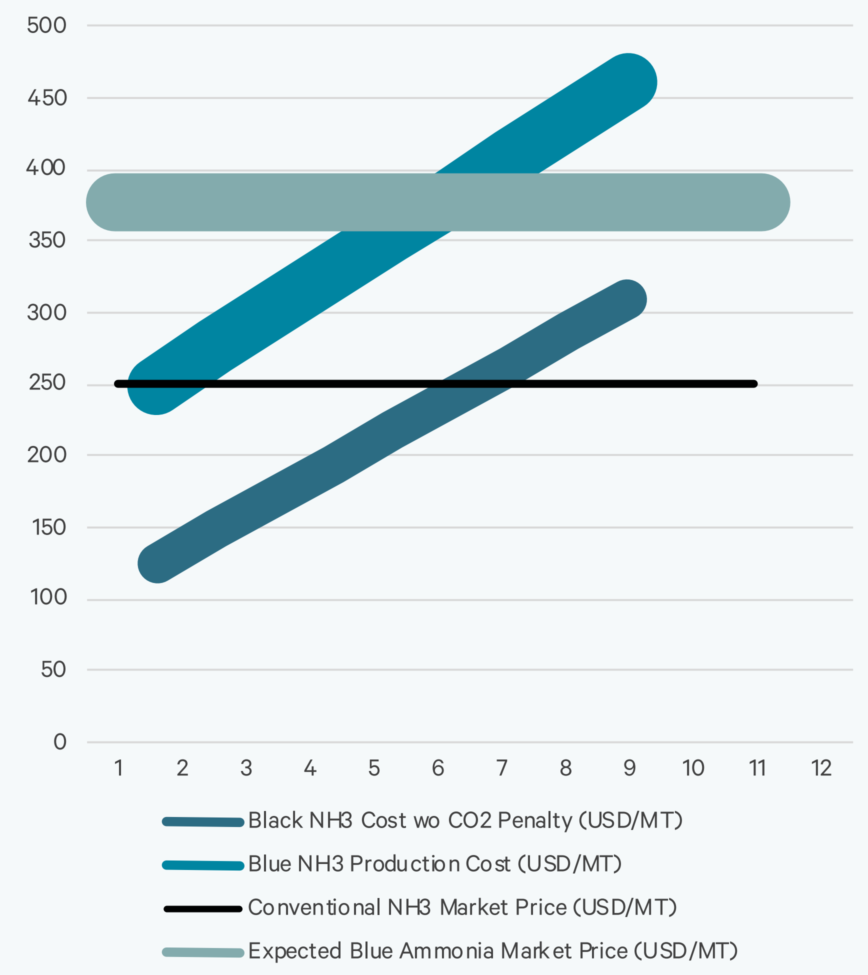
Blue Ammonia

The cost of blue ammonia can be calculated considering the various cost drivers associated, such as:

- Cost of conventional ammonia without CO_2 penalty.
- Cost of CO_2 capture from flue gases (0.8 tonnes CO_2/ tonnes NH3).
- Cost of CO2 liquefaction, short-term storage, transport and long-term storage (2 tonnes CO_2/tonnes NH3).

While the conventional ammonia market price is currently determined by the production cost in locations with a natural gas cost of 6-7 USD/MMBTU, the same process can be applied for blue ammonia.

Figure 50: Estimated production cost and market price of conventional and blue ammonia



E | Ammonia

Cost analysis

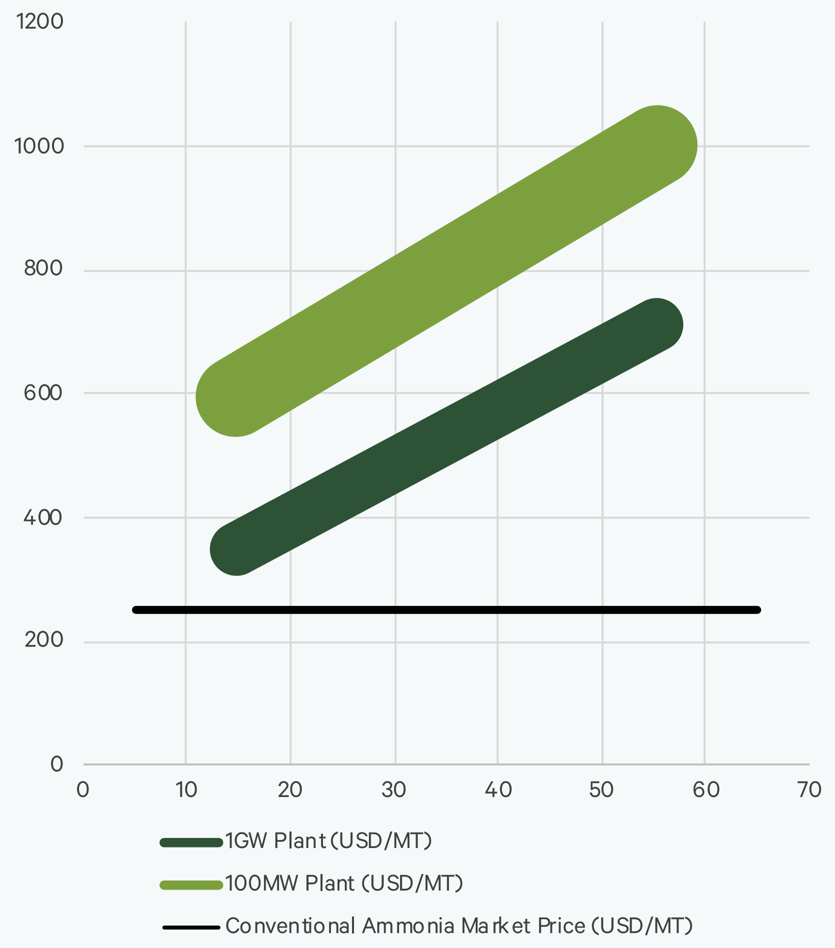
Green Ammonia

The cost of green ammonia can be calculated as:

- Cost of capital investment.
- Fixed operating costs including staff, overhead, maintenance, insurance and storage.
- Cost of energy.

Estimates indicate that smaller ammonia plants starting from 2025 would give rise to a green ammonia cost in the range of 650-850 USD/MT. By 2030, larger plants will come live and the green ammonia cost could drop to 400-600 USD/MT, which by 2040 could drop further to 275-450 USD/MT.

Figure 51: Estimated production cost of green ammonia



E | Ammonia

Cost analysis

Medium-to-Long Term Evolution in Ammonia Pricing[281]
Ammonia is expected to be a potential alternative fuel for shipping; however, it currently faces high production and deployment costs compared to fossil fuels. Significant expenses arise from capital investments in ammonia plants, with electrolysers accounting for 60% of the costs, as well as the installation of specialised bunkering facilities since ammonia is incompatible with existing infrastructure.

Currently, the production cost of natural gas-based ammonia ranges between USD 21.29/MWh and USD 65.81/MWh, whereas renewable e-ammonia costs are much higher (estimated at USD 143/MWh to USD 219/MWh). However, these costs are projected to decrease significantly by 2050 to USD 67/MWh to USD 114/MWh. Additionally, ammonia offers advantages in storage and distribution costs, positioning it as a potentially cost-effective fuel option in the long term.

The anticipated advancements in the sector, such as the development of ammonia engines and the scale-up in ammonia production, are expected to bring substantial cost reductions. As production technologies mature, renewable ammonia will become increasingly competitive, benefiting from falling renewable energy prices and lower electrolyser costs. These factors underline ammonia's potential as a pivotal decarbonisation tool for international shipping in the medium and long term.

E | Ammonia

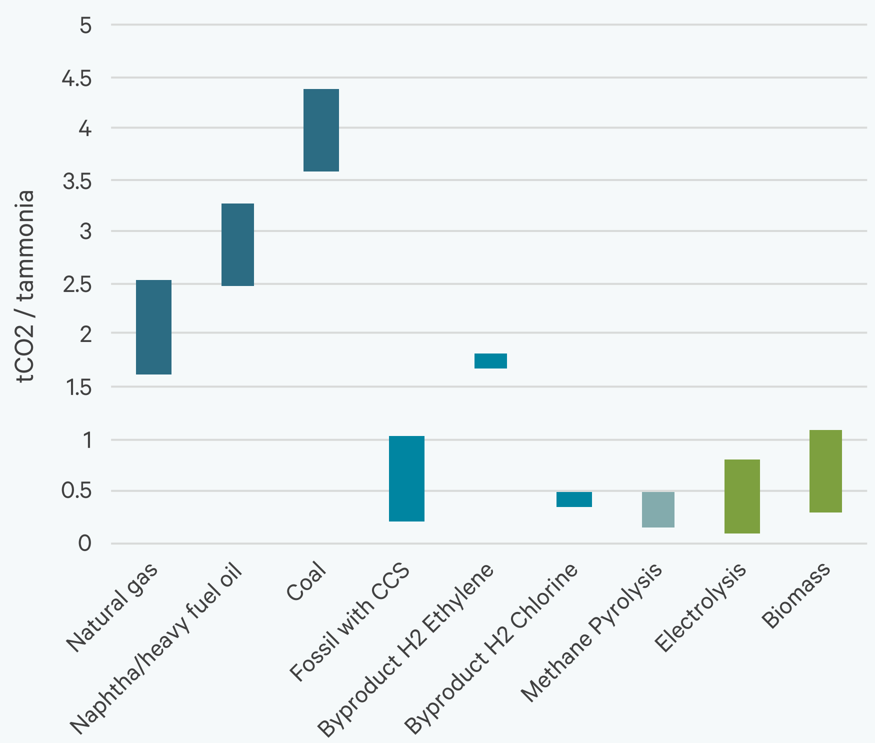
Emissions reduction potential

Emission Profile of Low-Carbon Ammonia[282]

Currently, ammonia production generates around 0.5 Gt of CO_2-equivalent annually (Royal Society, 2020), thereby accounting for 1% of global greenhouse gas emissions. When calculating the carbon footprint for ammonia (fossil-fuel based or renewable ammonia) certain determinants, such as the following are key:

- **Production pathway:** The greenhouse gas emissions for both renewable ammonia and fossil-based ammonia with CCS (carbon-capture and storage) are much lower than those for fossil-based ammonia without emission mitigation. For example, SMR-based ammonia production results in at least 1.6 tonnes of CO_2 per tonne of ammonia.
- **Embedded emissions:** Additionally, depending on the infrastructure for natural gas production, processing, and transport, methane emissions can be substantial, up to 0.9 tonnes of CO_2-equivalent per tonne of ammonia. This is a hidden CO_2-equivalent emission that should be accounted for when determining the carbon footprint for ammonia production.
- **Upstream ammonia leaks** are identical in the case of ammonia production with or without CCS (carbon-capture and storage).
- **Logistics:** Accounting for emissions from transport, utilising today's infrastructure, can add up to 10 grams of CO_2-equivalent per megajoule (MJ) of ammonia.

Figure 52: Illustrative ranges of estimated greenhouse gas emissions of ammonia production from various feedstocks



Note: Data are represented as median values with standard deviation, and are drawn from multiple literature references based on various methodologies and boundary assumptions. The development of Guarantees of Origin with standardised calculation methods are required to verify the actual emissions intensity of ammonia from any specific production unit

E | Ammonia

Emissions reduction potential

Lifecycle Analysis[283]
Ammonia's lifecycle analysis considers its greenhouse gas (GHG) emissions throughout its production, supply, and combustion stages—referred to as **well-to-tank (WtT)** and **tank-to-wake (TtW)** emissions. Combined, these constitute the **well-to-wake (WtW)** emissions, offering a complete picture of ammonia's environmental impact.

The production pathway of ammonia, whether through green methods like electrolysis or conventional methods like steam methane reforming (SMR), significantly influences these emissions. Additionally, ammonia combustion generates both CO_2 and N_2O, the latter being a potent GHG.

The lifecyle emissions of ammonia can be analysed under two conditions, as follows:

- **Outside SECA and NECA (Sulphur/Nitrogen Emission Control Areas):** Herein, taking the example of a Ammonia-fueled 4-stroke engine, it generates **189 g CO_2-eq/kWh** in GHG emissions, with the majority (70%) attributed to N2O from ammonia combustion.
- **Inside SECA and NECA:** This necessitates the use of selective catalytic reduction systems, thereby reducing ammonia combustion emissions to **110 g CO2-eq/kWh**, primarily by mitigating N_2O release.

Apart from this, ammonia's WtW emissions can also vary based on the production pathways:

- **Green ammonia** produced via electrolysis achieves the lowest WtW emissions, reducing GHG emissions by ~61% **(285 g CO_2-eq/kWh)** compared to conventional fuels.
- **Blue ammonia** derived from SMR with CCS (Carbon capture and storage) achieves a reduction of 20 – 31%.

E | Ammonia

Wider identified applications

Ammonia plays a vital role in various sectors beyond its application as a marine fuel. In agriculture, ammonia is predominantly used for fertiliser production, as mentioned, with approximately 70% of global ammonia dedicated to this purpose.[284] In the energy markets, renewable ammonia is anticipated to significantly contribute to power generation, particularly in Japan, as discussed earlier, where projections indicate that 3-5 million tonnes per year will be utilised for stationary power generation by 2030, increasing to 30 million tonnes by 2050.[285] Industrially, ammonia is integral to chemical processes, serving as a precursor in the production of various nitrogen-based fertilisers and industrial products.

E | Ammonia

A view on overall feasibility

New Zealand's only ammonia-urea manufacturing plant produces approximately 220,000 – 250,000 tonnes of agricultural urea annually, all of which is used domestically.[286] The hydrogen used for ammonia production is currently produced using natural gas.[287] While companies are exploring ammonia production from renewable sources, these are early stage and small scale currently. Further work would be needed in New Zealand to better understand the costs and feasibility of the factors belows.

Assessing the feasibility of low-carbon ammonia production and its application in the maritime sector within New Zealand involves evaluating several critical factors:

- **Renewable electricity availability:** Current capacity for renewable energy generation in New Zealand is likely insufficient to support large-scale green ammonia production at prices aligned with market expecations or willingness to pay.
- **Domestic feedstock availability:** CO_2 sources for blue ammonia production are available through carbon capture and storage technologies. Utilising carbon capture technologies in local industries could enhance the feasibility of blue ammonia production, though this requires substantial infrastructure and investment.
- **Existing infrastructure:** Current ammonia storage and transportation facilities are limited, necessitating upgrades or new infrastructure to handle low-carbon ammonia safely. Options include retrofitting existing LPG storage infrastructure or building new facilities. Capital investments in ammonia plants would be signficant.
- **Economic considerations:** Low-carbon ammonia currently faces high production and deployment costs compared to fossil fuels.
- **Market demand:** Competition with other alternative fuels in the shipping industry remains a challenge, requiring strategic positioning and market activation efforts. Demand for low-carbon ammonia for use within New Zealand is unclear, especially outside of current use cases, but is not significant for transport fuel at this stage.
- **Regulatory support:** Regulations like the Health and Safety at Work (Hazardous Substances) Regulations govern ammonia use but lack maritime bunkering guidelines. Developing standards akin to the IMO's IGF Code for LNG could ensure safety and encourage investment. Alignment with initiatives like the Clydebank Declaration's green shipping corridors could also attract funding.

In New Zealand, the transition to low-carbon ammonia production presents both opportunities and challenges. The country's ammonia-urea manufacturing plant currently relies on natural gas for hydrogen production, but the potential for low-carbon ammonia is significant. However, renewable electricity availability and cost remains a major barrier, as current generation capacity does not meet the demands of large-scale green ammonia production. Existing ammonia storage and transportation facilities require upgrades to safely handle low-carbon alternatives, and economic considerations highlight the high production costs compared to fossil fuels. Near term market demand for low-carbon ammonia in maritime applications remains uncertain, especially with competition from other alternative fuels, reflecting relative bunkering, safety and vessel design requirements.

F | List of stakeholders and participants

Aviation

- Air New Zealand

Energy and Fuel

- BP NZ
- Channel Infrastructure
- Genesis
- HAMR
- Hiringa
- Methanex
- Ternary
- Seadra Energy Inc
- Woodside

Finance and Banking

- ASB
- ANZ
- BNZ
- Morrison
- MUFG
- NZ Super Fund

Government and Related

- Australian Renewable Energy Agency (AU)
- Clean Energy Finance Corporation (AU)
- Department of Climate Change, Energy, the Environment and Water (AU)
- Department of Infrastructure, Transport, Regional Development, Communications and the Arts (AU)
- Energy Efficiency and Conservation Authority
- Infrastructure Commission
- Maritime NZ
- Ministry for the Environment
- Ministry for Primary Industries
- Ministry of Business, Innovation, and Employment
- Ministry of Foreign Affairs and Trade
- Ministry of Transport
- New Zealand Trade and Enterprise

Importers / Exporters

- BYD
- Fonterra
- Forest Owners Association
- Indevin
- Ravensdown
- Sealord
- Silver Fern Farms
- T&G Global
- Zespri

Landside Logistics

- Kotahi
- StraitNZ

Ports and Related

- Lyttelton Port Company
- Marsden Maritime Holdings
- Maritime Industry Australia Ltd
- Maritime & Port Authority of Singapore
- Port of Auckland
- Port of Melbourne
- Port of Tauranga
- Port Taranaki

Research

- Scion
- Centre for Zero Carbon Shipping
- Council of Cargo Owners

Shipping Lines

- ANL & CMA-CGM
- Maersk
- Pacific International Lines
- Swire

Tourism

- RealNZ

G | Glossary of terms

ANL	Australian National Line
ANZ	Australia and New Zealand Banking Group Ltd
ARENA	Australian Renewable Energy Agency
AUD	Australian Dollar
B100	Biodiesel fuel consisting of 100% biodiesel
B50	Biodiesel fuel blend containing 50% biodiesel and 50% conventional diesel
BANZ	Bioenergy Association of New Zealand
BECCS	Bioenergy with Carbon Capture and Storage
CEFC	Clean Energy Finance Corporation
CfD	Contract for Differences
CGE	Computable general equilibrium
CII	Carbon Intensity Indicator
CIP	Copenhagen Infrastructure Partners
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DAC	Direct air capture
DCCEEW	Australian Department of Climate Change, Energy, the Environment and Water
DEVEX	Development expenditure
DFAT	Australian Department of Foreign Affairs and Trade
DNV	Det Norske Veritas
EECA	Energy Efficiency and Conservation Authority
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing Ship Index
ETS	Emissions trading scheme
EU	European union
FCC	Fresh Carriers Co., Ltd
GDP	Gross domestic product
GHG	Greenhouse gas
GJ	Gigajoule
GT	Gross tonnage
H & S	Health and safety
HyPE	Hydrological predictions for the environment
ICE	Internal combustion engine
IEA ETP	International Energy Agency's Energy Technology Perspectives report
IMO	International Maritime Organisation
IRA	United States' Inflation Reduction Act
IRENA	International Renewable Energy Agency
JPY	Japanese Yen
LDCs	Least developed countries
LNG	Liquefied Natural Gas
LPG	Liquefied petroleum gas
MARPOL	International Convention for the Prevention of Pollution from Ships
MBIE	Ministry of Business, Innovation & Employment
MFAT	Ministry of Foreign Affairs and Trade
MfE	Ministry for the Environment
MoT	Ministry of Transport
Mt	Million tonnes
MTPA	Million tonnes per annum
NASA	American National Aeronautics and Space Administration
NOx	Nitrogen oxides
NPV	Net present value
NZ	New Zealand
NZD	New Zealand Dollar
NZTE	New Zealand Trade and Enterprise
PJ	Petajoule
PPP	Public-private partnership
R&D	Research and development
SAF	Sustainable aviation fuel
SIDS	Small island developing states
SOLAS	International Convention for the Safety of Life at Sea
SOx	Sulphur oxides
STCW	Standards of Training, Certification, and Watchkeeping for Seafarers
TEU	Twenty-foot equivalent unit
TRL	Technology readiness levels
UAE	United Arab Emirates
UNCTAD	United Nations Trade and Development
UNFCCC	United Nations Framework Convention on Climate Change
US / USA	The United States of America
USD	United States Dollar
USD/tCO23	United States Dollar per tonne of carbon dioxide equivalent
V	Volt

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