Decarbonisation Pathways for the Global Maritime Industry

Recommendations for Action and Collaboration

Developed by the International Advisory Panel on Maritime Decarbonisation

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SMF Singapore Maritime Foundation

Contents

Foreword

Addressing climate change has become an urgent global priority. Within the maritime sector, the International Maritime Organization (IMO) is contributing to the global effort against climate change and has adopted mandatory measures to reduce greenhouse gas emissions.

Comparing to a 2008 baseline, the IMO's target is to reduce the carbon intensity of international shipping by at least 40% by 2030, and 70% by 2050. Looking beyond carbon intensity to total emissions, which takes into account likely growth in GDP and world fleet size, the IMO also aims by 2050 to reduce total greenhouse gas emissions from international shipping by at least 50%, and to achieve zero emissions as soon as possible within this century.

The complex nature of decarbonisation requires a coordinated global effort, bringing together relevant stakeholders to effect change. In July 2020, the Singapore Maritime Foundation (SMF), with the support of the Maritime and Port Authority of Singapore (MPA), formed an International Advisory Panel (IAP) to define actions to support maritime decarbonisation. The IAP comprises around 30 industry leaders from Singapore and overseas. These individuals represent shipping companies, port operators, academia, class societies, insurance and finance players, energy companies, engine makers, shipyards, shipping associations, and government.

The IAP members, with additional input from experts in related fields, have worked to develop a strategy for maritime decarbonisation. This report identifies pathways to decarbonisation and policy options to accelerate solutions. Its purpose is to serve as a guide for a range of stakeholders, including private industry players, government bodies, and others within and outside the maritime sector who are interested in this important effort.

As a premier global hub port and leading international maritime centre, Singapore can play a role in supporting the industry to meet the IMO's decarbonisation goals for 2030 and 2050, and ideally to exceed them. The IAP has also highlighted critical success factors for Singapore to be a centre of excellence and to help the global maritime industry pursue opportunities arising from decarbonisation.

The IAP has sought to avoid a prescriptive approach that dictates which technologies or standards should be adopted. Such decisions require deeper study and consultation with relevant stakeholders, and should also take into account the fact that different solutions may apply in different circumstances. The IAP has instead focused on establishing collaborative initiatives that will result in action, accelerating momentum in the maritime sector's decarbonisation efforts and ensuring sustained progress in this area.

Andreas Sohmen-Pao
Co-chair, IAP

Wong Weng Sun
Co-chair, IAP

The International Advisory Panel on Maritime Decarbonisation (IAP)

Mr Andreas Sohmen-Pao
Co-Chair

Chairman,
Singapore Maritime Foundation;
Chairman, BW Group

Mr Wong Weng Sun
Co-Chair

Chairman of the Board &
Governing Council,
Singapore Maritime Institute;
President & Chief Executive
Officer, Sembcorp Marine

Dr Gu Hai

Vice President,
American Bureau of Shipping

Mr Mark Jackson

Chief Executive Officer,
Baltic Exchange

Mr Alexander Saverys

Chief Executive Officer,
CMB

Mr Jan Dieleman

President,
Cargill Ocean Transportation

Mr Geir Bjørkeli

Chief Executive Officer,
Corvus Energy

Mr Zhu Jian Dong

Chairman & President,
COSCO Shipping
(South East Asia) Pte Ltd

Dr Pierre C Sames

Group Research and
Development Director,
DNV

Mr Odin Kwon

Chief Technology Officer,
Daewoo Shipbuilding & Marine
Engineering, Co. Ltd

Mr Cyril Ducau

Chief Executive Officer,
Eastern Pacific Shipping

Ms Caroline Yang

Chief Executive, Hong Lam Marine;
President, Singapore Shipping
Association

Mr Esben Poulsson

Chairman, International Chamber
of Shipping; Executive Chairman,
Enesel Pte Ltd

Mr Nick Shaw

Chief Executive Officer,
International Group of P&I Clubs

Mr Aziz Merchant

Executive Director,
Keppel Marine & Deepwater Technology Pte Ltd

Mr Yee Yang Chien

President and Group CEO, MISC Berhad

Mr Palle Brødsgaard Laursen

Chief Technical Officer, Senior Vice President, Maersk

Ms Quah Ley Hoon

Chief Executive,
Maritime and Port Authority of Singapore

Professor Lam Khin Yong

Senior Vice President (Research),
Nanyang Technological University

Mr Jeremy Nixon

Chief Executive Officer,
Ocean Network Express

Mr Tan Chong Meng

Group Chief Executive Officer,
PSA International

Mr Hor Weng Yew

Chief Executive Officer,
Pacific Carriers Limited

Mr Teo Choo Wee

Executive Director,
Pacific International Lines (Private) Limited

Professor Lynn Loo

Director, Andlinger Centre for Energy and the Environment, Princeton University

Mr Nick Potter

General Manager,
Shipping & Maritime,
APME Region,
Shell Eastern Trading Pte Ltd

Ms Tan Beng Tee

Executive Director,
Singapore Maritime Foundation;
Senior Advisor,
Maritime and Port Authority of Singapore

Mr Rasmus Bach Nielsen

Global Head of Fuel Decarbonisation,
Trafigura

Dr Tristan Smith

Reader in Energy and Shipping,
University College London,
Energy Institute

Mr Andrea Morgante

Vice-President Strategy,
Wärtsilä Marine Power

Dr German Weisser

Senior Advisor Research & Development,
Winterthur Gas & Diesel Ltd

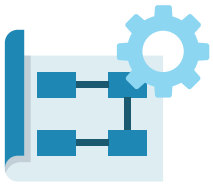
IAP's Vision

The IAP's vision *(Figure 1)* is for Maritime Singapore to support decarbonisation of the industry to meet or exceed the IMO goals for 2030 and 2050 by:

- **shaping Greenhouse Gas (GHG) measures** to ensure that actions have a real and lasting positive impact
- **setting standards** for operational, technical and safety factors
- **piloting innovations** in the technical, operational and digital sphere
- **building selective infrastructure** to support these innovations
- **deploying incentives** at national, regional or global level, combined with private capital initiatives, to implement solutions for vessel efficiency and new fuels
- **connecting global stakeholders** to share knowledge and implement actions

HARMONISE
Standards

1. Shape common metrics for carbon accounting
2. Set standards for new technologies and solutions



IMPLEMENT
New Solutions

3. Pilot trials and deploy solutions
4. Build flexible ship capabilities and relevant infrastructure

FINANCE
Projects

5. Develop green financing mechanisms
6. Develop mechanisms that could support carbon pricing
7. Act as custodian for and deploy R&D funds and grants

COLLABORATE
with Partners

8. Multiply local, regional and global collaboration across stakeholders
9. Set up a decarbonisation centre

Figure 1:

The IAP's four strategic objectives & nine pathways towards decarbonisation in the maritime sector

Note:

The reduction of GHGs constitutes the ultimate objective for climate change mitigation. As CO2 is estimated to comprise about 80% of GHGs, and "decarbonisation" is a well-understood concept, we have used the terms – "reduction of GHGs" and "decarbonisation" interchangeably in this paper.

Pathway 1

Shape common metrics for carbon accounting

Aspiration:
Effective and harmonised measurement systems that capture the right metrics and result in positive impact

Pathway 1

There is currently no standardised way of measuring emissions in a comprehensive manner. Measurements currently in place include the IMO's Energy Efficiency Design Index (EEDI), the IMO's Energy Efficiency Operational Index (EEOI) which is also used by Sea Cargo Charter, the Annual Efficiency Ratio (AER) used by the Poseidon Principles, and other standards of measurement used by companies and institutions to map sustainability. The newly promulgated Carbon Intensity Indicator (CII) and Energy Efficiency Existing Ship Index (EEXI) will further add to these measures.

Banks, investors, regulators, and customers increasingly expect shipping companies to measure their carbon footprint. A harmonised and easily understood carbon measurement system would help the industry to ensure progress based on a common set of standards, and prevent the unintended consequence of reducing GHGs in one area while increasing them in another.

While it will be challenging to define such a standard involving the entire ecosystem, steps can be taken to develop more universal and consistent guidelines for measuring emissions. A consolidated mapping of the available metrics may help as a first step towards a globally harmonised approach.

Appropriate measurements would need to account for various factors. For instance, they may need to consider the emissions related to production, processing and consumption, not only one of these. One approach could be through a framework that accounts for the differences between fuels, such as including a carbon factor. Whilst the IMO does not regulate fuel production, the IMO or others could work with the International Organization for Standardization to explore the expansion of an existing interface such as the Bunker Delivery Note into a "fuel passport" that would include more information on how the bunker fuel was produced. Other factors to consider include the actual cargo carried during the ship's journey, as this affects the fuel consumption of the vessel, and measures work done.

A core question relates to lifecycle analysis: how much of the supply chain to include in the calculation. Carbon accounting may need to take into account the embedded carbon in materials (for example, when choosing to build new vessels with better fuel efficiency but where significant emissions may be involved in their construction). The industry could consider how to reduce emissions by quantifying the carbon cost of vessels, and looking for lower-emission building techniques and materials, or retrofitting existing vessels to avoid increasing total carbon footprint. While the theory of lifecycle analysis has been examined extensively, a gap exists in its practical implementation.

Examples of unintended consequences

As new rules and measures are designed, it is important that appropriate effort is made to guard against unintended and undesired consequences. As examples:

A one-sided focus on efficiency for existing ships may lead to the simplest solution being to build new, more efficient ships. However, this may not take into account the carbon cost of building a ship (estimated at 70,000 tonnes of CO2 for a standard large gas carrier). As the building process requires steel and energy, with related emissions, this should be considered when calculating the total impact of old versus new assets. While the intention is not to inhibit investments in new solutions, the total carbon cost must be taken into account so that the net effect is positive for the climate.

To meet new standards, for ships that reach the limit of what they can achieve from design retrofits, the only remaining solution is to slow down. This may be suitable in many cases, but for certain trades such as liquefied natural gas (LNG), slowing down may result in a higher climate cost due to the nature of the cargo. LNG boils off during the voyage and is normally used for propulsion; but with a cap on speed, boil-off gas will need to be burned away, resulting in emissions without the benefit of propulsion. The impact on safety, climate impact, and industry structure (for example, existing contract obligations) all need to be taken into account in order to avoid unintended consequences.

In developing a carbon accounting policy, the industry would need to consider the issues of monitoring, reporting, verification and transparency. For instance, it would be important to conduct measurements in a fair and neutral way through the presence of a third party. Independent bodies such as classification societies could play a role in the verification of data. To allow speed of information discovery and enhance industry compliance, several certified bodies who are already aligned on common standards for data collection, instead of just one single organisation, could be involved. The data collected could go towards the development of benchmarks, which could also help individual companies to improve energy efficiency and define their pathways to decarbonisation.

The reporting of existing measurements, such as those defined by the IMO and the United Nations Framework Convention on Climate Change, may have a time lag from implementation to effective reporting. It would be helpful to have timely measurements which are more immediately available for businesses to report on and respond to. For example, it could be useful to have information technology platforms to measure and benchmark the carbon impact of different operating or navigational parameters such as different routes, speed, and operational adjustments. Correlating input factors like engine measurements and in situ weather data to outputs like fuel consumption are essential for performance improvement.

The calculated carbon footprint could also be a component of shipping indices (for example, the indices published by the Baltic Exchange). On a related note, it could be useful to have a global registry for maritime-related GHG emissions to inform stakeholders of the GHG emissions resulting from a voyage. The regular publishing of such data could help shape behaviour, in part driven by customer response.

A set of properly established and verified measurements will become increasingly important as a system of incentives and penalties emerge around emissions. Whether this is in the form of grants, financing, levies, or emissions trading, commonly-accepted metrics will be critical.

The IAP recommends that Singapore could bring together like-minded parties to discuss carbon accounting and measurements, including the IMO, IMO member states, NGOs, as well as industry associations and maritime-related organisations such as the International Chamber of Shipping (ICS), the International Bunker Industry Association (IBIA), the Baltic Exchange and the Global Maritime Forum (GMF). The IMO has had many discussions regarding measurements. The ICS, as a voice for the shipping community, could help to bring an industry perspective. The IBIA represents stakeholders across the bunkering value chain, and could help bring insights from further upstream. The Baltic Exchange is a critical source of market-wide information and has deep knowledge of shipping indices which it publishes daily. The GMF is the driver for initiatives such as the Poseidon Principles and the Sea Cargo Charter, which form part of the maritime carbon accounting landscape.

To coordinate the harmonisation, standardisation and verification process, a centre or institute for maritime GHG accounting could be established in Singapore, possibly under a broader decarbonisation centre.

The International Maritime Organization (IMO)'s Data Collection System (DCS)

The 70th session of the IMO's Marine Environment Protection Committee (MEPC 70) adopted Resolution MEPC.278(70), whereby ships of 5,000 gross tonnage and above must collect and report their fuel oil consumption data from 1 January 2019 onwards. The aggregated data is reported to the flag state, which will issue a Statement of Compliance to the ship once it has ascertained that the data has been reported according to the requirements. Flag states are then required to transfer the data to an anonymised IMO Ship Fuel Oil Consumption Database.

References:

The International Maritime Organization, *Data collection system for fuel oil consumption of ships.*

Action Plan

- Map out GHG metrics currently used with a view to shaping a globally-harmonised approach.
- Evaluate lifecycle carbon cost, including embedded carbon (materials) and emissions not only from the vessel but also from production and processing.
- Improve monitoring, reporting, verification and transparency through appropriate collaborations with industry stakeholders such as shipowners/operators and classification societies.
- Develop information technology platforms to measure and benchmark the carbon impact of different operating or navigational parameters, working with service providers, classification societies and industry associations.
- Build upon the IMO's Data Collection System (DCS) to create a registry for maritime-related GHG emissions.
- Establish a centre to work with relevant bodies such as the IMO, and coordinate the harmonisation of carbon footprint measurements.

Pathway 2

Aspiration:
Clear standards and systems that frame the actions to reduce carbon footprint

Set standards for new technologies and solutions

Pathway 2

Efficiency improvements can contribute significantly to the reduction of carbon emissions by 2030. Such improvements can be achieved through technical, technological and operational measures.

Technical measures can include retrofitting engines/propulsion systems, and making changes to ship and hull design to reduce emissions through lower fuel consumption or a lower-carbon build process. The IMO's EEDI has been a tool in this regard, and there is room to expand on its application, for instance as a potential benchmark when designing potential carbon pricing mechanisms.

Technological measures include the deployment of technologies such as sensors combined with big data and machine-learning to help measure emissions and drive actions to lower them.

Operational measures include process changes to mitigate the climate impact of the global fleet, for instance, speed adjustments along the supply chain which can reduce fuel consumption.

These areas will need design thinking to ensure they can be implemented in an efficient manner. This is partly because they overlap. For instance, speed adjustments can be enabled either by technological or technical improvements. However, it is important to consider the consequences of adopting these measures, for example, the impact on safety resulting from new fuels, operational changes or new technologies.

One area with particular promise for improving efficiency is Just-in-Time (JIT) arrivals. The concept has been challenging to implement on account of split incentives between stakeholders, for instance where customers take the risk of delays while shipowners benefit from lower fuel cost (spot market), or vice versa where shipowners are required to invest in JIT systems while the fuel benefits accrue to customers. Support for investments and alignment of incentives may be needed, by taking a systems-level overview and ensuring collaboration between stakeholders so that all parties can benefit while not compromising cargo scheduling or safety requirements.

Given variances in JIT capabilities across different types of ports (for example, between container and oil/chemical terminals), selected port and terminal operators could take the lead to mandate the use of a common platform for vessels entering their waters/terminals. This is in view of the port's central role in this process.

As different systems proliferate, it is important to ensure that different port community systems are interoperable. Common and shared international standards would facilitate the exchange of data amongst different stakeholders and platforms. In addition, consideration should be given to integrating systems onboard vessels with the systems of port and terminal operators. This might require using open-source application programming interface (API) or establishing a global neutral data platform for parties to share their data in a secure manner. This harmonisation of systems would enable different stakeholders, such as ship operators and their customers, to connect seamlessly with various ports.

Other than developing common standards for exchange of data, stakeholders should also come together to develop the safety standards and regulatory framework for the handling of alternative fuels. This could include operating parameters related to drop-in fuels like methanol or future fuels such as ammonia and hydrogen which have challenges relating to toxicity, density and volatility. Classification societies and the IMO could help establish safety standards for vessels, while port authorities and the industry could work together to develop bunkering standards. For instance, in the development of Singapore's LNG bunkering standard, the Technical Reference 56 (TR56), stakeholders across industry, government, research institutes and other relevant organisations were consulted.

Examples of standards developed for LNG infrastructure

The Technical Reference (TR56) was first launched in 2017 as the world's first national standard to prepare Singapore's bunkering industry for MARPOL Annex VI Global Sulphur limit of 0.50%, which was introduced on 1 January 2020. TR56 covers LNG delivery from LNG bunkering facilities to receiving ships through four modes of transfer (truck-to-ship, shore-to-ship, ship-to-ship and cassette bunkering).

References:

Maritime and Port Authority of Singapore (MPA), *Fact sheet on Technical Reference 56 for Liquefied Natural Gas (LNG) bunkering.*

Given that there is a need for standards in relation to new technologies, and new operational and technical solutions, it would be worthwhile to see how Singapore could contribute to the setting of standards in view of its longstanding relationship with the IMO and its stature as a comprehensive maritime hub made up of key stakeholders from diverse sectors. As an IMO member state, Singapore could also initiate proposals with other member states, and work together with them to advance the decarbonisation efforts of the maritime sector.

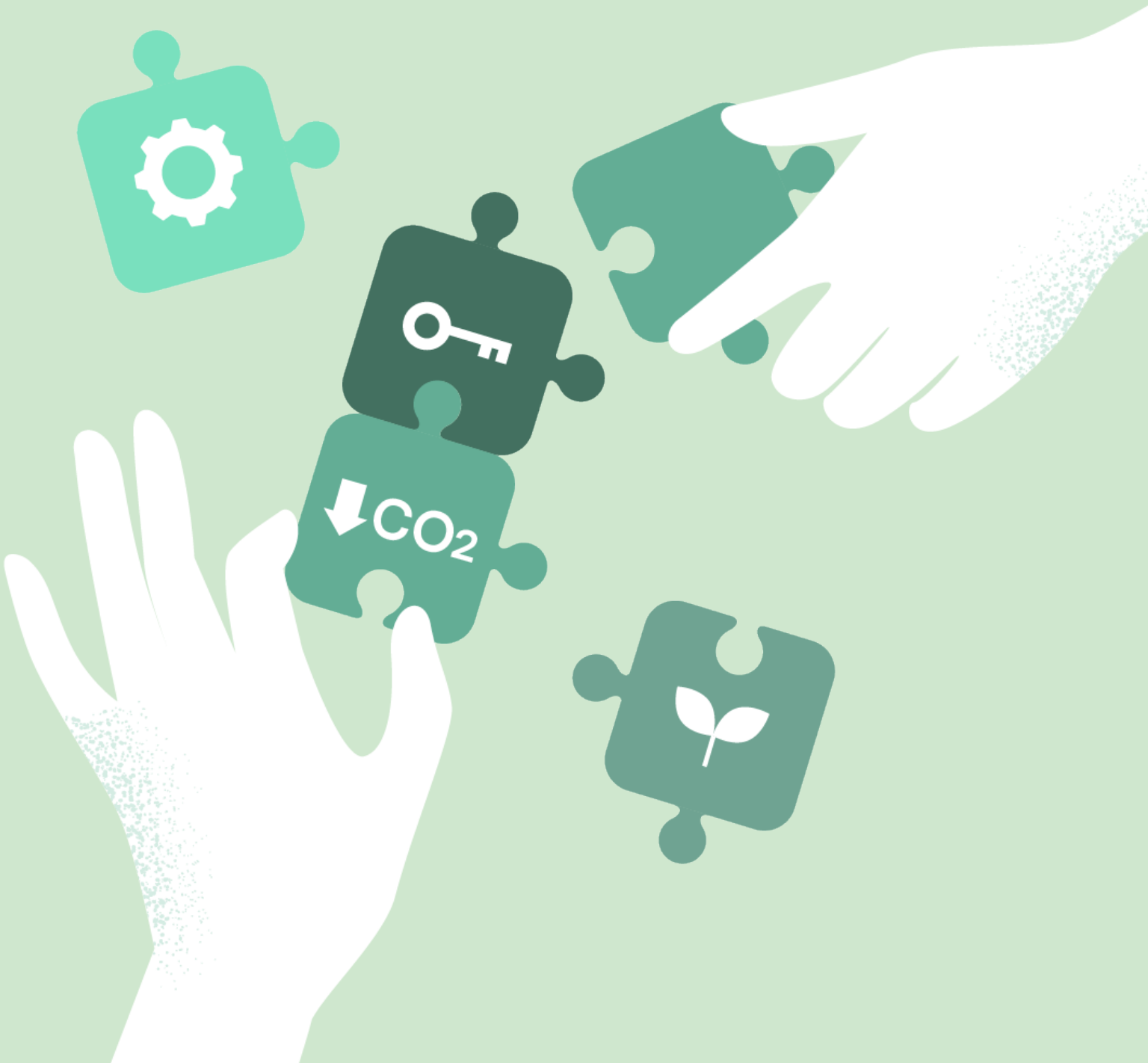
Action Plan

- **Develop a global common standard for improved efficiency through Just-in-Time (JIT) arrivals: support investments and collaborations to align incentives, and involve ports. The agreed framework could be incorporated as a standard charter-party clause.**
- **Harmonise data standards to ensure interoperability across port community systems, with the creation of a platform for the secure sharing of data. Stakeholders such as the International Association of Ports and Harbors (IAPH) could be engaged.**
- **Develop safety standards for bunkering and regulatory frameworks for the handling of alternative fuels, with the involvement of IMO and stakeholders such as port authorities, bunker suppliers and classification societies.**
- **Gather and disseminate knowledge on the potential impact of technical and operational solutions and interventions on carbon emission reductions, for instance, under the work of a decarbonisation centre.**

Pathway 3

Aspiration:
Effective trials that accelerate new solutions

Pilot trials and deploy solutions



Pathway 3

Pilot projects and the deployment of concrete applications are integral to the success of maritime decarbonisation. As a start, small-scale pilot projects are recommended in order to test the feasibility of alternative fuels and supporting infrastructure, and for capability building.

For instance, while electric and hydrogen-powered vessels might not yet be feasible for deep-sea shipping, it is already possible to power smaller vessels (such as tugboats and crew transfer vessels) with hydrogen; and harbour craft, short-sea ferries and cruise ships with batteries. Such small-scale pilot projects will allow the industry to learn more about these alternative fuels and provide pathways to eventually power larger vessels on deep-sea routes.

Leveraging Singapore's position as a leading container transhipment hub, some suggested pilots include:

a. Launching a GHG-free regional container service between Singapore and other ASEAN countries such as Indonesia or Malaysia. This would provide project participants with the opportunity to trial and learn about the possible technologies, bunkering requirements, and the need for multi-stakeholder involvement. Such projects with a regional focus – involving regional shipping services and the use of new fuel – could tap on Singapore's position as a major container port with extensive regional feedering activities and bunkering capabilities.

b. Developing a next generation GHG-free container feeder vessel. This could be a collaboration between Singapore and industry stakeholders, with the aim of pioneering new ship designs with potential deployment in a few years. Such collaboration would enable co-sharing of risks of new investments and sharing of knowledge on common issues.

c. On the operational front, implementing JIT arrivals with a coalition of willing parties, including ports and shipping lines, to create momentum for more widespread implementation of JIT arrivals.

A consistent observation is that different fuels may be required for different circumstances. To ensure the most effective development and adoption of new fuels, collaborations will be needed. A holistic approach is also required to ensure that fuelling infrastructure can cater to the energy needs of domestic consumers in addition to the wider maritime industry.

A value chain or consortium approach could be taken when identifying pilots to be carried out. A consortium could be formed in Singapore where participants undertake different pilots around the supply and operation of alternative fuels, such as pilots for refuelling, engine testing and applicability in tugboats. Consortiums could be formed along different fuel lines within the next 5 to 10 years.

A key stakeholder group to be involved in such a consortium would be the users of the fuel (shipowners and charterers), as they would underpin the commercial uptake of these fuels. Other potential stakeholders could be engine makers, port authorities, terminal operators, shipyards, and research institutes. The maritime industry would also need to collaborate with stakeholders from other industries, for example in the development and supply of new fuels, given overlapping infrastructure needs and the shared challenge of decarbonisation. Aggregating fuel needs between shipping and other sectors could create a stronger case for the fuel in question, and help to accelerate development.

To avoid efforts being duplicated, there should be platforms through which lessons learnt from pilot projects are shared with a wider audience. A decarbonisation centre could play such a role, ensuring that initiatives build on the work done by others. To facilitate the sharing of information, best practices should be adopted on reporting, verification, and terminology used.

Funding support would be important to help get pilot projects started, but such funding should be time-bound and channelled towards commercially-viable outcomes. An effective scheme is Norway's PILOT-E funding scheme, which seeks to promote the rapid development and deployment of new and environmentally-friendly energy technology products and services. PILOT-E projects must demonstrate commercial viability and include a consortium of participants.

Examples of schemes and initiatives for supporting piloting and deploying solutions

Norway's PILOT-E scheme is a funding scheme for the Norwegian business sector to accelerate the development and deployment of new, environmentally-friendly energy technology products and services that can reduce emissions both in Norway and internationally. PILOT-E adopts a full life-cycle approach, following up with participants from "concept to market".

The FLAGSHIPS project was awarded 5 million euros by the European Union (EU) to deploy two commercially-operated hydrogen fuel cell vessels. The project brought together stakeholders across the value chain, such as shipowners, OEM and design companies, and technology providers. On top of the project funding, the consortium partners also made substantial additional investments to build the ships.

References:

Enova SF, About PILOT-E (Information in English).

FLAGSHIPS, FLAGSHIPS project to deploy two hydrogen vessels.

In view of the early stage of development for many alternative fuels, the IAP recommends that it could be beneficial to provide initial seed funding for a wider range of innovative projects before identifying a few projects deserving greater funding. Such a programme could also match projects with available funding sources.

Action Plan

- **Promote a consortium approach towards the design of pilot projects, and involve stakeholders within and beyond the maritime industry (for example, cargo interests and energy suppliers).**
- **Create a platform such as a digital library (for example, within a decarbonisation centre), for the sharing of findings from pilot projects.**
- **Launch a programme that can provide funding for a larger number of feasibility studies and demonstration/pilot projects. Such a programme would include seed funding and additional funding for strategic projects.**

Pathway 4

Aspiration:
Ships with lower-carbon propulsion, and infrastructure to support them

Build flexible ship capabilities and relevant infrastructure

Pathway 4

To avoid the risk of stranded assets, it will be important to work on transition solutions where a fuel choice today can be shifted to an alternative fuel in the future. Transition solutions are all the more important given that the industry will have to meet IMO's goals for 2030. As a result, while we examine more complete long-term solutions, there is a need to implement near-term approaches that offer pathways to zero-carbon fuels later.

Near-term solutions include the use of shaft generators, where traditional power is supplemented by batteries or fuel cells that can power auxiliary loads. Where fossil fuel infrastructure is being installed – whether on board ships or at ports – ways to minimise the cost of a future switch to lower-carbon fuels should be incorporated at the design and planning phases. As an example, liquefied petroleum gas (LPG) propulsion can be converted in future to ammonia without significant additional investment. Another example is liquefied natural gas (LNG) propulsion that can be adapted for biogas or synthetic methane by using existing LNG equipment, and blended with or converted to ammonia or hydrogen by upgrading the fuel supply and fuel injection systems. A third example is methanol, which runs well in existing engines with few modifications and low additional investment.

An example of transition fuel solution

LPG has been suggested as a potential transition fuel which could eventually lead to the adoption of ammonia in the long run. In terms of storage conditions such as temperature and pressure, the two fuels share similarities. LPG installations onboard a vessel could also be suitable for ammonia as well. The materials used in the manufacture of LPG tanks and systems, as well as their safety features, are also suitable for ammonia. Given their relative compatibility, only minor modifications and investment may be needed to convert an existing LPG propulsion system to an ammonia-ready system in future.

References:

DNV GL, Making LPG fuel an option for the shipping industry.

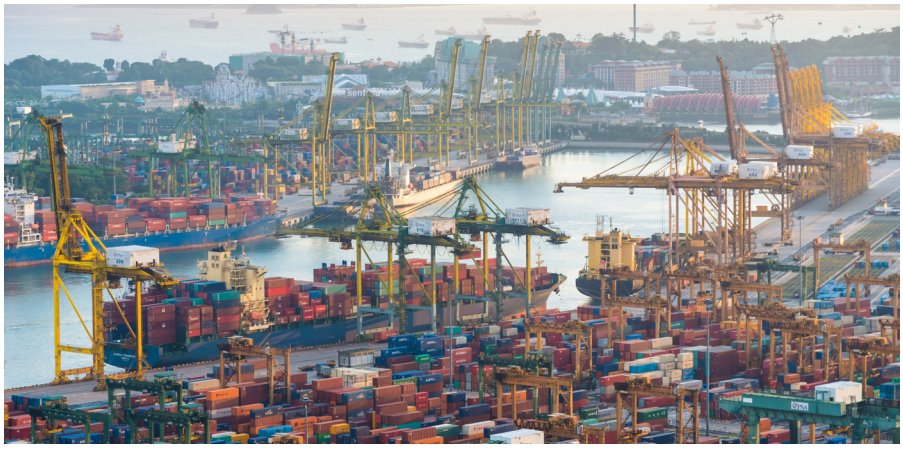
Alfa Laval et al., Ammonfuel: An industrial view of ammonia as a marine fuel.

Longer-term solutions include the use of hybrid systems, where a vessel could be primarily powered by fuel cell but also have flexibility in terms of primary fuel used. However, it should be noted that transition-ready solutions may be more costly than single-fuelled systems.

Given the diversity of options, shipping companies are best placed to decide which fuels suit their needs. It is not within the IAP's mandate to recommend which singular fuel is best, but to recommend ways in which the transition can be supported. To match the many pathways, the IAP recommends to provide flexible fuelling infrastructure which allows multiple fuels to be used, including the option of electrification. Such infrastructure could, for instance, allow for the supply of a transition fuel in the near term before switching to another fuel later. It would reduce the cost burden on the maritime industry if such infrastructure could be shared with other onshore sectors such as rail/road transport and industrial sectors.

At the country level, some ports might have a better chance of providing future fuels and charging stations. While the ideal solution would be for a new fuel to be widely available on a global basis, it might not be a necessary precondition, especially for fixed trades which count on just a few major bunker ports for refuelling.

As decarbonisation solutions are developed, it would be helpful to have a central repository of information that tracks the progress and readiness of these solutions, and indicates when certain technologies are ready for adoption.



Action Plan

- **Support projects which allow for future transition to zero-carbon fuels.**
- **Create flexible ship capabilities and port infrastructure which allows multiple fuels to be supplied, and ensure safety standards in the development of such infrastructure.**
- **Track the progress of fuel solutions to assist the industry to assess readiness for adoption.**

Pathway 5

Aspiration:
Ample funding to support green initiatives

Develop green financing mechanisms

Pathway 5

To support decarbonisation across the sector, the IAP recommends that it would be useful to adopt an ecosystem perspective and develop financing schemes.

Green financing schemes, such as green bonds and loan guarantees, could help to support required capital expenditure. Examples include the construction of vessels using new fuels, including electrification, or the development of infrastructure (for example, charging points for vessels). Cargo interests will have a significant role to play in the design and feasibility of these schemes, as they underwrite the commercial outcomes that underpin the financing.

Additional mechanisms such as leasing schemes could help to defray the upfront cost of new investments into decarbonisation while allowing the capital provider to recoup the investment with a return over time. Traditional banks and leasing companies might prefer larger-scale projects, so in the case of lower-cost items (such as small equipment additions as opposed to entire vessels), there might be an opportunity to aggregate smaller transactions. Leasing would also be particularly helpful for smaller companies with less access to capital for decarbonisation. The right provider(s) of such a leasing vehicle would need to be found, as a balance between hard economics and sustainability motivations would need to be achieved.

In the case of retrofitting vessels, any green financing mechanism would need to consider the issue of collateral on the retrofitted vessel, as the equipment would likely become an integrated part of the vessel in question.

Some of these financing schemes have already been introduced. In cases where such providers are not available in the market, it may be worthwhile to establish a financing vehicle which could engage in such activities. The vehicle could start small, and subsequently scale up after gaining traction.

Another approach could be to generate a quid pro quo for national governments providing such incentives. For instance, if Singapore were to offer incentives for retrofitting vessels, the accompanying conditions could be for the retrofitting to be done at a Singapore-based shipyard. Other examples could be requirements for companies receiving incentives to base their decarbonisation efforts, including R&D, in locations providing funding.

In addition to 'financing green' (supporting green investment), 'greening finance' should also be encouraged. The latter refers to capital providers changing their metrics for financing to include climate risk and asset-value resilience, in order to factor carbon footprint into the cost of capital. An example of this is the work of the Task Force on Climate-related Financial Disclosures (TCFD). In this regard, labelling or other forms of disclosure for financial products and portfolios would help to increase transparency and promote change.

Beyond capital expenditure, the industry could explore schemes to help close the price gap between existing fuels and alternative carbon-neutral fuels, and encourage early adopters to trial these fuels. Incentives such as rebates on port fees should be considered in conjunction with larger incentives, to reward investment in cleaner vessels. Adopting a combination of different incentives would help to distribute the cost burden among different parties.

It will be important to involve multiple stakeholders within and beyond the maritime industry. In the case of closing the fuel price gap, governments and international bodies can help to put in place the necessary regulatory, legal and funding mechanisms. At the same time, fuel producers and charterers also have a role to play in reducing the cost of such new fuels, and should be included in the process. The proposed decarbonisation centre could provide a centripetal force drawing the various stakeholders together.

Examples of initiatives related to green financing or rebate mechanisms

The European Investment Bank's Green Shipping Guarantee (GSG) is designed to help finance shipbuilding projects which promote sustainable transport and environmental protection. Such projects include newbuilds, conversions and retrofitting of vessels. The GSG will be developed in the form of a guarantee framework with financial institutions involved in ship financing.

The Maritime Singapore Green initiative (MSGI) seeks to reduce the environmental impact of shipping and related activities and promote clean and green shipping in Singapore. The MSGI's Green Port Programme encourages ocean-going vessels calling at the Port of Singapore to adopt solutions to reduce the emission of pollutants. Qualifying vessels enjoy 25% concessions in port dues.

References:

European Investment Bank, Green Shipping Guarantee Programme.

Maritime and Port Authority of Singapore (MPA), Maritime Singapore Green Initiative.

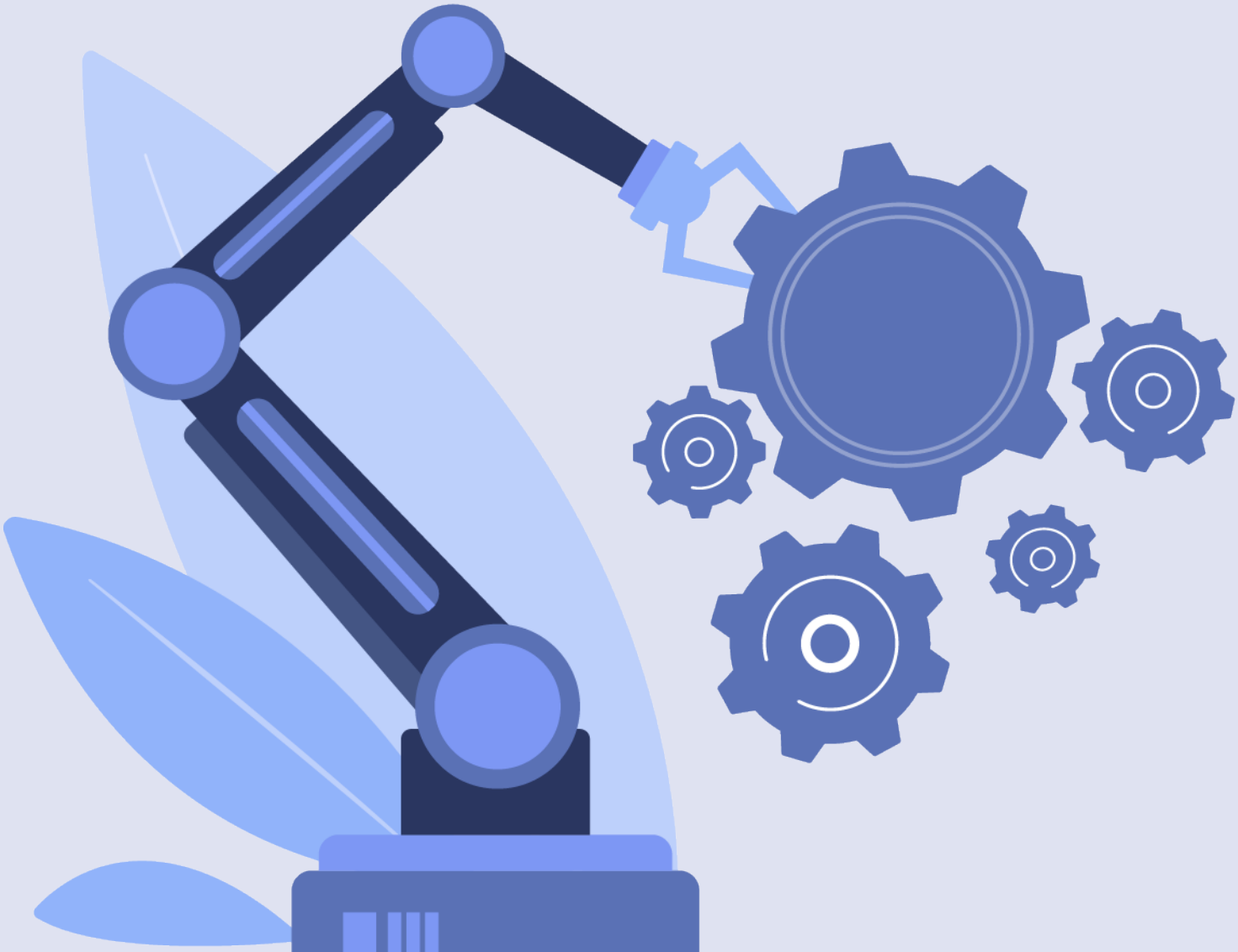
Action Plan

- **Develop green financing schemes to support investments.**
- **Co-create leasing schemes or financing vehicles to defray the upfront cost of new investments into decarbonisation.**
- **Explore schemes to close the price gap between existing and new fuels.**
- **Offer smaller incentives, such as rebates on port fees, to distribute the cost burden among different parties.**
- **Explore schemes to increase disclosure of carbon footprint in relation to maritime financial products and portfolios.**

Pathway 6

Develop mechanisms that could support carbon pricing

Aspiration:
A carbon pricing mechanism that reflects the social cost of carbon, and channels funding back to the industry to support further progress on decarbonisation



Pathway 6

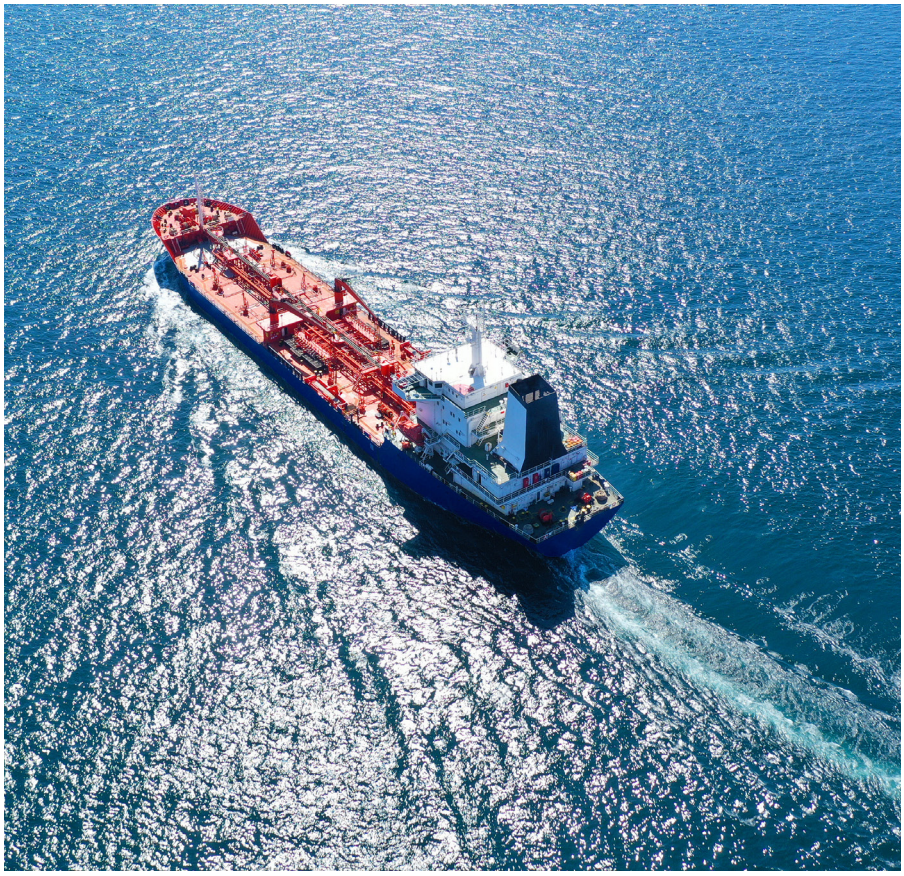
The current production cost of low-carbon or zero-carbon fuels is significantly higher than the cost of fossil fuels. Therefore the pricing of carbon will be an important factor in determining the feasibility of alternative fuels.

A carbon levy would provide price signals to encourage a reduction in carbon-based fuels and related emissions. Even if the levy is easily affordable, the pressure to stay competitive is likely to spur action to save fuel. With a levy that rises over time, businesses would gain the visibility needed to make investments in emissions-reducing technologies.

While some countries are adopting trading schemes as an alternative approach, a carbon levy would provide a clear and simple mechanism to mitigate carbon emissions, as there would be predictability and uniformity. The initial levy could be set low to increase the acceptance level and promote better reporting. The industry could then take time to familiarise itself with the mechanism, while exploring how the revenue from the levies could best be deployed, building trust in the system.

The IAP recommends that the industry and like-minded states continue to press for a form of carbon pricing, working together with regulatory bodies and the IMO. Such a scheme would need to overcome the objections of a number of nations towards market-based measures and mandatory levies.

Numerous mechanisms will be required to administer such contributions, from verification to collection and deployment of proceeds. Singapore can play a role as a trusted intermediary for developing and applying such mechanisms.



Offsets have been presented as a partial solution. These could disincentivise decarbonisation if undertaken in isolation, may not achieve the intended GHG emission reductions, and are still uncertain in terms of availability and legal viability. They may just provide a means of buying oneself out of the obligation to address the underlying issue within one's business, and may introduce further uncertainty into investment decisions.

While offsets carry risks, there may be cases where these risks could be mitigated, for instance by linking them to carbon markets and in-sector use of offsets ("in-setting", where the practice of offsetting is not outsourced to others but linked to a company's own strategy for decarbonisation). Their role can be explored further in this context.

Examples of market-based carbon mechanisms

With its implementation on 1 January 2019, Singapore's carbon tax set is the first carbon pricing scheme in Southeast Asia. Set at a rate of S$5/t CO2e for 2019 – 2023, the carbon tax applies to direct emissions from facilities emitting 25ktCO2e or more in a year, and sends a signal to companies to start reducing their emissions.

The European Union Emissions Trading System (EU ETS) aims to restrict emissions from more than 11,000 energy-intensive installations and airlines operating between countries. Established in 2005 and covering about 40% of the EU's greenhouse gas emissions, the EU ETS is the first international emissions trading system in the world and works on the "cap-and-trade" principle.

References:

National Climate Change Secretariat, Carbon Tax.

European Commission, EU Emissions Trading System (EU ETS).

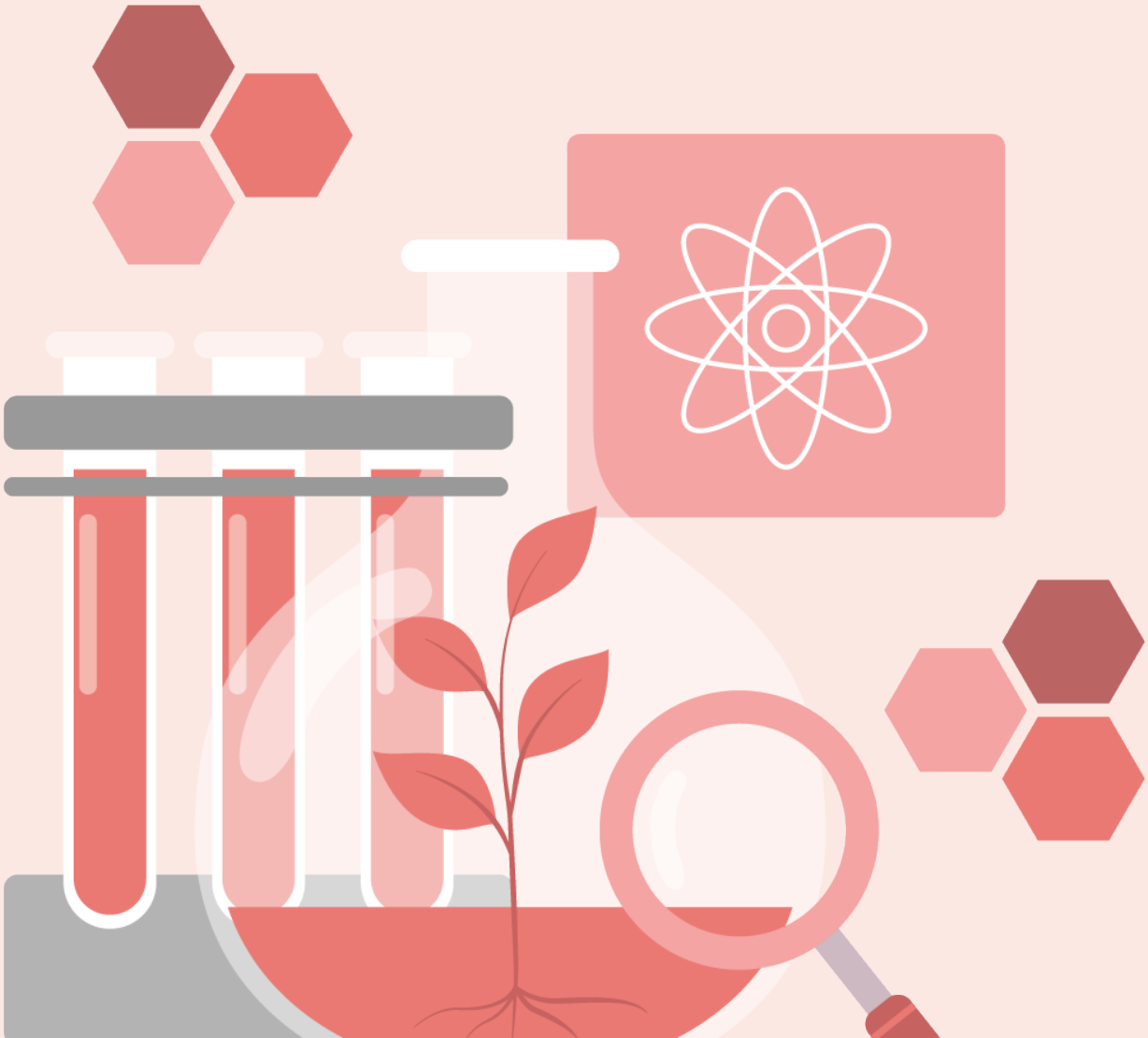
Action Plan

- **Continue to press for the cost of carbon to be included in the price of fuel, starting at a low level and growing over time.**
- **Develop and apply mechanisms for the verification and collection of funds that maximise acceptability and practicality.**
- **Explore offsets or in-setting as a complementary path to carbon reduction for the industry.**

Pathway 7

Aspiration:
A trusted framework for deploying funds for research, development and deployment of decarbonisation solutions

Act as custodian for and deploy research and development funds and grants



Pathway 7

R&D for decarbonisation requires significant funding. For state/public funding, countries might prioritise national interests and prefer domestic companies to commercialise the technology. The maritime industry might therefore need access to a global scheme to fund R&D. It is also critical that the custodian of such a global funding scheme is able to deploy the funds effectively to benefit the global maritime community.

The IAP recommends that it will be necessary to design policies to assure policymakers and industry players that the funds are being channelled appropriately. Singapore could assist in such a role, modelling on successful research funding schemes around the world, and building on the ideas promulgated by the ICS regarding an International Maritime Research and Development Board.

Examples of funding schemes

The Maritime GreenFuture Fund was initiated by MPA to accelerate efforts in research and test-bedding, and promote the adoption of low-carbon technologies to position Singapore for long-term maritime sustainability. A sum of S$40 million has been set aside by MPA and its partners to create ecosystems of trials and test-bedding of low-carbon technologies.

The United States government agency, Advanced Research Projects Agency-Energy (ARPA-E), aims to fund research on high-potential energy technologies that are typically too early for private-sector investments. ARPA-E supports transformational energy projects that develop new ways to generate, store and use energy with small amounts of funding over a defined period of time.

Horizon Europe is the EU's funding programme for research and innovation. Nearly 80 billion euros of funding was available over the 7-year period from 2014 to 2020, in addition to the private investment that the funding attracts. The new Horizon Europe programme covering 2021 – 2027 has been allocated a budget of approximately 95.5 billion euros.

The Singapore Research, Innovation and Enterprise (RIE) 2025 plan allocates S$25 billion for the period 2021 – 2025 towards four domains: health, sustainability, the digital economy, and manufacturing.

References:
Ministry of Transport, Speech by Senior Minister of State for Transport and Health Lam Pin Min at The Ministry of Transport's Committee of Supply Debate 2020.
Advanced Research Projects Agency-Energy (ARPA-E), About ARPA-E.
European Commission, Horizon Europe.

As a global carbon pricing mechanism has not yet been established, it could also be useful to pilot a framework that channels other funding sources into decarbonisation. This framework would need to provide transparency on spending and outcomes, using facts and continuous assessment to improve decision-making. Once efficacy and good governance are proven, this could be scaled up to include additional future funds.

When the funding sources grow, the ambition would be to expand fund deployment beyond R&D and into a wider spectrum of actions that could advance the maritime industry's progress on decarbonisation. These could include the scaling of infrastructure, deployment of solutions, compensation to small states, and addressing operating cost considerations (for example, making the price of alternative fuels competitive with traditional fossil fuels). This would create a virtuous cycle of investment back into the industry's decarbonisation journey.

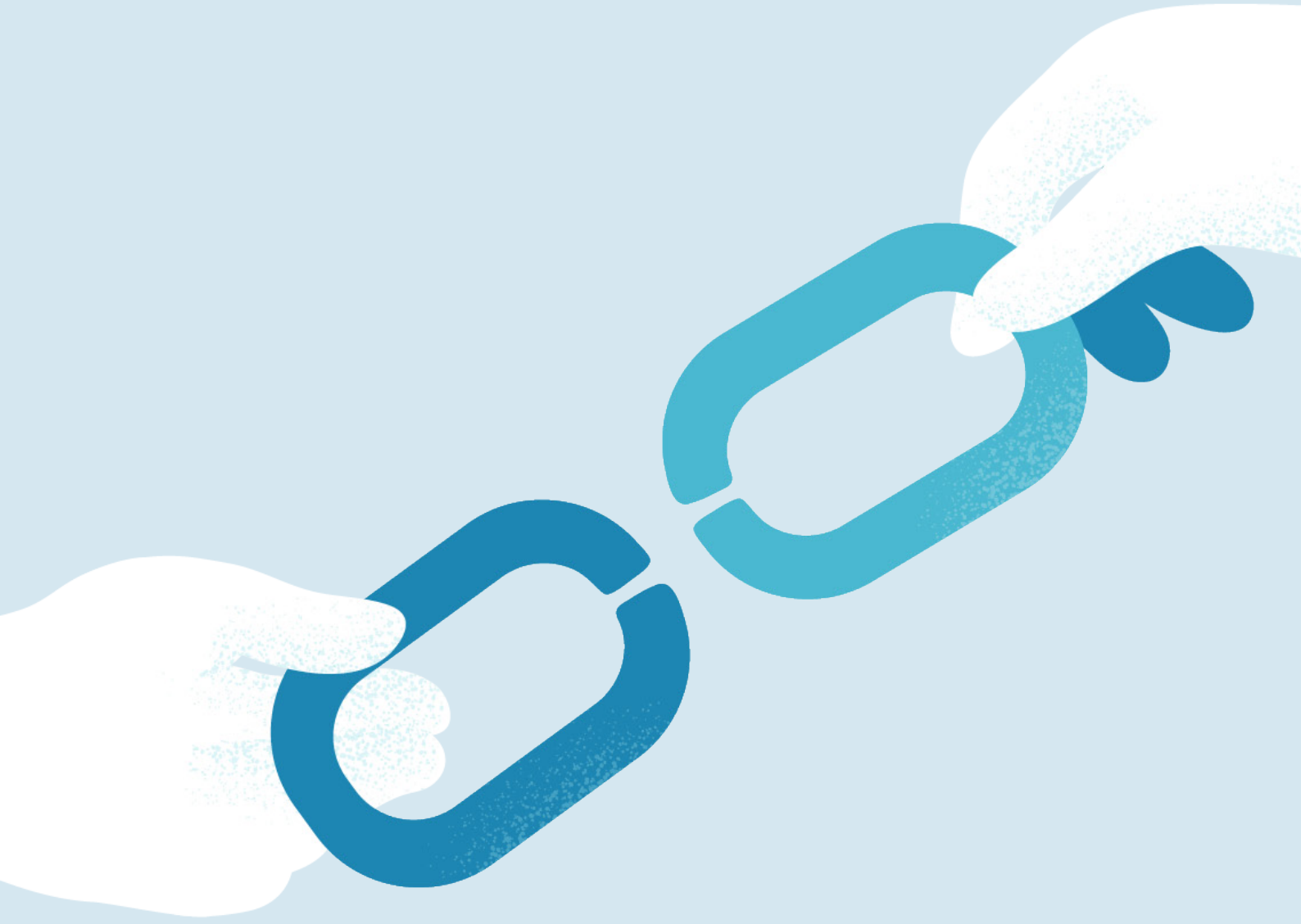
Action Plan

- **Establish a global funding scheme that collects contributions related to bunker consumption (or other suitable metrics for emissions), to be deployed within the industry for acceleration of decarbonisation.**

Pathway 8

Aspiration:
Extensive collaboration between like-minded stakeholders on decarbonisation programmes

Multiply local, regional and global collaboration across stakeholders



Pathway 8

It may be easier for some decarbonisation initiatives to progress at a regional rather than a global level. The IAP recommends having like-minded jurisdictions come together to develop certain projects to accelerate progress, although this has to be balanced against the risk of global regulatory fragmentation.

An example of such collaboration would be a coalition of ports. Having such a coalition could prevent ports from having to take unilateral action that results either in fragmentation of standards, or reduced competitiveness for first movers (for instance if it involves cost to themselves or their users).

Such a coalition could, for example, look at the development of bunkering standards and trialling of new fuels such as ammonia and hydrogen. The coalition could tap into a common fund to provide subsidies to vessels piloting the use of new fuels. As part of such a coalition, Singapore could collaborate with other leading bunkering ports to drive initiatives such as bunker contributions. The coalition could also develop a funding mechanism, such as a hybrid model of carbon trading tied to performance standards, again keeping in mind the risks of regulatory fragmentation at a global level.

A coalition of willing parties could also take the lead to invest in other areas, such as JIT systems. JIT arrivals give rise to benefits such as fuels and emissions savings, as well as increased efficiency and productivity. The coalition could work together to develop standards for the implementation of JIT arrivals, thus progressing a pathway to decarbonisation. One objective would be to gather the right stakeholders to design solutions that cater to differing requirements, for example container shipments versus bulk cargo shipments. For the trial phase, stakeholders might need to begin from a position of trust and willingness to trial, instead of being unduly preoccupied with splitting benefits. Singapore could take the lead and examine the key shipping lanes, identify suitable ports along those shipping lanes to pilot new schemes, and subsequently scale up to include more ports.

The port ecosystem comprises a wide variety of stakeholders, such as terminal operators, subcontractors, service providers and regulatory authorities. There is a need to strengthen communication and information flow among these different stakeholders in the port ecosystem, as well as between the port ecosystem and vessels entering and leaving the port. A common platform such as a Port Community System (PCS) could be explored to ensure information flows could be shared end-to-end with minimal lapses in communication. Examples of similar projects in Singapore include digitalPORT@SG™, which aims to provide a one-stop platform streamlining regulatory transactions for Singapore's port users; and digitalOCEANS™, which aims to promote the development of common data standards and common exchange APIs among different ports. Critical to such efforts would be collaborating with like-minded ports in pilot trials to demonstrate the feasibility and benefits, which would in turn encourage other ports to come onboard.

At the global level, the establishment of a global funding scheme may be useful in supporting cross-country collaborations on decarbonisation efforts around the world. The fund could, for example, incentivise collaborations between ports, scaling of infrastructure by project partners, joint development of new solutions, among other possibilities.

For collaborations at any level to be successful, it is important that best practices are shared in an open and transparent manner. For example, it would be helpful to align reporting, verification and terminology. Such transparency in the innovation process will facilitate progress in solution discovery, and minimise wastage of resources. The proposed decarbonisation centre could be a platform to drive such sharing of best practices.

Action Plan

- **Establish a coalition of ports to develop solutions on a level playing field. Initiatives could include development of bunkering standards, trialling new fuels, developing funding mechanisms, or building JIT systems.**
- **Strengthen communication and information flow stakeholders in the port ecosystem including common platforms, common data standards and common exchange APIs.**
- **Ensure collaborations include all stakeholder types, and enable interconnection and efficiency with other like-minded organisations.**

Pathway 9

Set up a decarbonisation centre

Aspiration:
A global centre for decarbonisation in Singapore which acts as a catalyst for progress in the maritime industry and beyond

Pathway 9

Given the numerous decarbonisation initiatives in the maritime industry, it will be important to ensure communication between stakeholders and coordination of initiatives through a central coordinating institution. This could take the form of a decarbonisation centre.

Centres for decarbonisation can act as nodes in a global network. These nodes may be most effective if they cover different regions and are coordinated with each other. If they are properly organised and funded, they are likely to have more lasting impact than singular, short-term initiatives. They can act as a signal of intent, and as a magnet for initiatives.

The IAP recommends that a decarbonisation centre be established in Singapore to help coordinate, drive and sustain decarbonisation efforts. This could include developing carbon accounting and carbon measurements, piloting trials and projects, conducting R&D, and connecting financiers and solution providers. Such a centre could develop challenge statements and facilitate calls for solutions. It could help bring together different stakeholders such as engine-makers, shipyards, shipowners, cargo interests, academia, start-ups, banks, public interest groups, and other industry participants, and formulate solutions to meet the needs of international shipping.

The decarbonisation centre could also serve as a place for thought leadership, by providing relevant information and proposals to help industry stakeholders make informed decisions. For instance, it could work with shipbuilders to provide the industry with information on operating and capital costs, and on lifecycle emissions for different vessel designs.

The decarbonisation centre could build on Singapore's strengths in R&D, technology and digitalisation, and its status as a major container transhipment port, leading bunkering hub and vibrant international maritime centre. This would allow the Singapore centre to provide a value proposition that is differentiated while complementing other centres.

The proposed centre should have a global perspective, although not all the actions taken by the centre need to be global in nature. As an example, one possible project given Singapore's geographical location could be to pilot regional carbon-free shipping services.

Global decarbonisation centres could share appropriate information with one another to reduce duplication of effort. Like-minded parties can share learning points, and this creates opportunities for collaboration. The proposed Singapore-based decarbonisation centre can serve as an Asian bridge to other centres and like-minded initiatives around the world, such as the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping, Getting to Zero Coalition, and NCE Maritime CleanTech. Different centres with different niches could partner and complement one another, thus minimising duplication of effort.

Examples of decarbonisation centres and related initiatives

The Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping, which was set up in 2020, is a Copenhagen-based independent, non-profit research centre, made possible by an initial start-up donation by the A.P. Møller Foundation. The centre will collaborate globally with industry, academia and authorities to create overviews of decarbonisation pathways, facilitate the development of new energy technologies, and support the establishment of financial and commercial means to enable transformation.

The Getting to Zero Coalition was launched in 2019 as a partnership by the Global Maritime Forum, the Friends of Ocean action, and the World Economic Forum. Today it comprises more than 140 companies within the maritime, energy, infrastructure and finance sectors, supported by key governments and IGOs. The Coalition's ambition is to have commercially viable zero-emission vessels operating along deep sea trade routes by 2030, supported by the necessary infrastructure for scalable zero-carbon energy sources including production, distribution, storage and bunkering.

The Norwegian Centre of Expertise (NCE) Maritime CleanTech is a Norwegian-based industry cluster that comprises more than 130 partners representing various stages of the maritime value chain. The cluster leverages the Norwegian maritime expertise to develop new energy-efficient and environmentally-friendly technologies.

References:

A.P. Møller-Mærsk, New research center will lead the way for decarbonizing shipping.

Getting to Zero Coalition, Getting to Zero 2030 Coalition Ambition Statement.

NCE Maritime CleanTech, About NCE Maritime CleanTech.

For decarbonisation centres to be effective, they would need to address the questions of: 1) physical location; 2) organisational set-up; and 3) content/ activity. In addition, they need to staffed by a team with the requisite expertise and global perspective to put ideas into motion. Experts from a wide range of backgrounds could be brought in, while keeping the centre open to different collaborations. The centre would need to include experts with operational experience and technical insights, academics, start-ups, and other relevant stakeholders. The centre's role could also be expanded to include policy-related issues such as regulations and incentives.

The centre should attract investment for decarbonisation projects. Both public and private funding would be important for establishment and operation of the decarbonisation centre. Contributions to the centre could be monetary or in-kind. It would be important to explore innovative ways to partner with potential sponsors.

Action Plan

- **Establish a global decarbonisation centre in Singapore that serves as a regional node in a global network of similar centres, with experts from different countries and sectors to ensure maximum breadth and effectiveness.**
- **Leverage the centre to coordinate, drive and sustain decarbonisation efforts such as developing carbon accounting, piloting trials, and conducting R&D. The centre could serve as a repository for knowledge gleaned from pilot trials and R&D projects.**

The way forward:

Collaborating for concrete change

The way forward: Collaborating for concrete change

Decarbonisation will be a challenge for the industry in the years to come. The IAP believes that Singapore, with its position as a leading global hub port, international maritime centre, and international financial hub, is well positioned to confront these challenges and turn them into opportunities.

The strategies outlined in this report represent the IAP's collective vision for how Singapore can contribute to the global effort to reduce GHG emissions from international shipping. There is no silver bullet to decarbonisation, and the way ahead needs to incorporate multiple pathways. The IAP has identified 4 strategic objectives and 9 pathways to leverage different resources, stakeholders and solutions. We hope that it will serve as a useful guide to a range of stakeholders, both public and private, in the decarbonisation journey.

Two recurring themes are the importance of taking action, and the importance of collaboration. Given the short runway and increasing pressure to meet decarbonisation goals, the IAP believes it is important to take concrete steps to pilot, trial and implement solutions. We also believe that collaboration will be essential to address the multi-dimensional, multi-stakeholder nature of decarbonisation. These collaborations may be between shipping companies, across different maritime sectors, with other industries and across geographic boundaries.

With a view to action and collaboration, we have identified joint projects to embark on, and the list on the next few pages illustrates projects currently in progress. We hope such initiatives serve as ways to carry forward the ideas and recommendations in this report, and ensure that solutions continue to evolve. We welcome everyone who is keen to work with us on this journey towards a more sustainable future for international shipping.

ESTABLISH A DECARBONISATION CENTRE

MPA will set up a maritime decarbonisation centre, with joint contribution from the industry. This will serve as a focal point for Singapore's efforts to help the global maritime industry transform and meet IMO's decarbonisation goals. BW Group, Eastern Pacific Shipping (EPS), Ocean Network Express (ONE), Sembcorp Marine, Foundation Det Norske Veritas and BHP are amongst those who have committed towards funding for the establishment of the centre.

COLLABORATE WITH GLOBAL DECARBONISATION CENTRES

The decarbonisation centre and the Maritime Energy and Sustainable Development (MESD) Centre of Excellence located at the Nanyang Technological University of Singapore will collaborate with other global centres such as the Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping. Collaboration could be in the form of joint R&D projects, joint workshops, or an exchange of researchers.

EXPLORE FUTURE FUEL TRIALS FOR REGIONAL CONTAINER FEEDER VESSELS

MPA and ONE are exploring a coalition with other liner companies and feeder operators to advance decarbonisation solutions for regional container services. Relevant stakeholders, such as classification societies, fuel suppliers and cargo interests, will be involved too. This could begin with trials on a dedicated container feeder service powered by more mature solutions such as biofuel or other hybrid solutions, with a view to setting up a fully functional feeder service based off Singapore and moving towards solutions such as ammonia and hydrogen in the longer term.

EXPLORE BIOFUEL TRIAL FOR TRAMP SERVICES

MPA and Eastern Pacific Shipping are considering trialling biofuel bunkering at the Port of Singapore in collaboration with other relevant partners such as a biofuel supplier. This builds on the company's results from its recent biofuel trial, and could be tested on other ship classes.

ELECTRIFICATION OF PULAU BUKOM FERRIES

Shell Eastern Trading is exploring the electrification of its ferries calling at Pulau Bukom, which is used to ferry workers between Pulau Bukom and the main island of Singapore.

RETROFIT AND CONSTRUCT NEWBUILD VESSELS TO USE METHANOL AND AMMONIA AS MARINE FUEL

EPS, OCI N.V. (OCI) and MAN Energy Solutions (MAN) have signed a Memorandum of Understanding (MoU) to develop methanol and ammonia as marine fuels. Conventional vessels from EPS's existing fleet that uses MAN engines will be retrofitted to run on methanol and ammonia supplied by OCI. OCI intends to charter the first retrofitted vessel from EPS. EPS will also construct newbuild vessels using MAN engines powered by methanol and ammonia.

UNDERTAKE JOINT DEVELOPMENT PROJECT FOR AMMONIA-FUELLED TANKER

MISC Berhad will collaborate with MPA, Yara International, Samsung Heavy Industries, Lloyd's Register and MAN Energy Solutions on a joint development project for an ammonia-fuelled tanker to support shipping's drive towards a decarbonised future. The experience and expertise of each partner provide a complete representation from all areas of the maritime ecosystem.

EXPLORE GREEN AMMONIA BUNKERING IN SINGAPORE

A.P. Møller-Mærsk A/S, Fleet Management Limited, Keppel Offshore & Marine, Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping, Sumitomo Corporation and Yara International have signed a Memorandum of Understanding (MoU) to conduct a feasibility study. This aims to establish an end-to-end supply chain for the provision of green ammonia ship-to-ship bunkering at the Port of Singapore. It will cover the development of a cost-effective green ammonia supply chain, design of ammonia bunkering vessels and related supply chain infrastructure.

CONDUCT JOINT WORKSHOPS ON AMMONIA AS A MARINE FUEL

DNV and MPA are looking to engage selected shipowners that have shown interest in exploring the use of ammonia as zero-emission shipping fuel. This could be in the form of workshops to address concerns around the production and utilisation of ammonia, as well as the availability and future pricing which will impact the operational and commercial viability of ammonia as a marine fuel.

STUDY SUBSEA STORAGE OF GREEN AMMONIA

ABS will partner with NOV on "Subsea Ammonia Energy Storage System" which is a disruptive technological solution to address existing challenges with green ammonia as a route towards the hydrogen economy. The research project will study a novel method of storing, recovering and transporting green ammonia in the most optimal way. The end goal is to increase the ease and safety of storing green ammonia and the efficient fuelling of shipping vessels, thus reducing the overall environmental impact based on current benchmarks.

EXPLORE CROSS INDUSTRY COLLABORATION FOR HYDROGEN AND SOLID OXIDE FUEL CELL TRIAL

MPA is looking at collaborating with interested parties such as Shell Eastern Trading and Corvus Energy on the testing of hydrogen and solid oxide fuel cells in Singapore. This could begin with piloting on either port vessels or auxiliary engines of deep-sea vessels, with the possibility of scaling up in the longer term. Shipyards with the necessary expertise, such as Sembcorp Marine, could be involved. Collaboration with front-runners using hydrogen as a marine fuel, such as CMB, is also being considered.

EXPLORE CARBON CAPTURE TECHNOLOGY ONBOARD VESSELS

MPA is looking at working with parties such as Pacific Carriers Limited and Sembcorp Marine to investigate the technical and economic feasibility of installing carbon capture technology on board vessels.

DEVELOP JUST-IN-TIME OPERATIONS

The IAP recommends that Just-in-Time (JIT) operations should be developed as a near-term solution and noted that MPA has embarked on digitalPORT@SG™ which will facilitate just-in-time operations for optimal vessel passage planning at the Port of Singapore. It would be important for Singapore to continue collaborating with other ports and stakeholders to harmonise efforts through its digitalOCEANS™ initiative. The Singapore Shipping Association has been working with MPA on this front, and liner companies such as Pacific International Lines may participate through sharing of data and information.

PUBLISH CARBON FOOTPRINT FOR COMMONLY-PLIED MARITIME TRADE ROUTES

Leveraging on its position as an independent provider of shipping information and indices, the Baltic Exchange could explore publishing carbon footprint measurements tagged to the Baltic routes. This could be in consultation with academic experts at University College London as well as dovetailing with existing efforts such as the Sea Cargo Charter. MPA could support this effort by soliciting industry feedback on the computation methodology and trial numbers.

EXAMINE POSSIBILITY OF DEVELOPING VOLUNTARY TRADING OF MARITIME OFFSETS

The Baltic Exchange and the Singapore Exchange are exploring the trading of maritime offset credits to create a voluntary carbon market, taking into account the challenges highlighted in this report. In its concept development phase, MPA could facilitate industry consultation for feedback on the idea and sizing of demand from the industry.

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Mr Christopher Chatterton
Chief Operating Officer, Methanol Institute

Dr Chai Kah Hin
Associate Professor, Industrial Systems Engineering and Management Department, National University of Singapore

Mr Aki Kachi
Senior Climate Policy Analyst, New Climate Institute

Ms Grace Cheah
Managing Director, Sustinere

Dr Oliver Fetzer
Chief Executive Officer, Synthetic Genomics

Mr Galen Hon
Principal, The PoliSea Group

Dr Jakob Buus Petersen
Director, Vessel Performance Solutions

Mr Dmitry Rostopshin
Head of Ship Traffic Safety & Port Operations Solutions, Wärtsilä

Contact Us

120 Cantonment Road
#02-01 Maritime House Singapore 089760

T: (65) 6325 0225 | F: (65) 6325 4050

SMF Singapore Maritime Foundation