Global Centre for
MARITIME DECARBONISATION

Accelerating maritime decarbonisation through pilots and trials

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Ammonia transfers between the Green Pioneer and the Navigator Global in the anchorage of Port of Dampier

4000 cbm (2700 tonnes) of liquid ammonia was transferred at 700-800 cbm/h from the Green Pioneer to the Navigator Global and back

Mission statement

Our mission is to help the maritime industry eliminate GHG emissions by **shaping** standards, **deploying** solutions, **financing** projects, and **fostering** collaboration across sectors.

Founders/ strategic partners

BHP · Rio Tinto · DNV · Eastern Pacific Shipping · MPA Singapore · ONE Ocean Network Express · Seatrium · bp · Hapag-Lloyd · Hanwha Ocean · NYK Line

Coalition partners

IBIA · International Chamber of Shipping (Established 1921) · IWSA International Windship Association · OGCI Oil and Gas Climate Initiative · sgmf the society for gas as a marine fuel · SSA Singapore Shipping Association

Knowledge partners

Global Maritime Forum · GSBN · Kpler · Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

Impact partners

BCG · the human energy company (Chevron) · gard · MOL Mitsui O.S.K. Lines · msc · Olympic Shipping and Management S.A.

Enabling partners

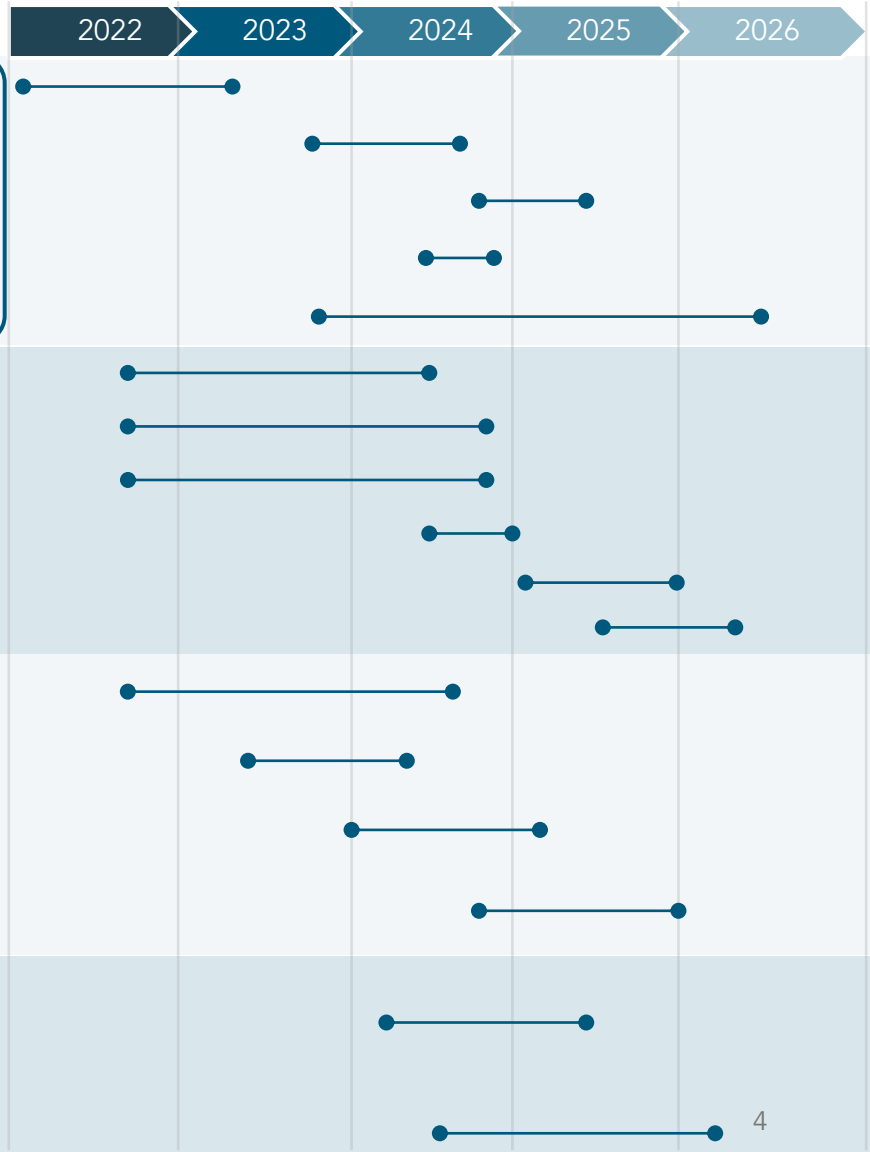
KIRI Capital

And > 100 project partners

Our initiatives roadmap

(as of 3 Oct 2024)

● Completed ◐ In Progress ◌ Planning



Enabling ammonia as a marine fuel

- ● Phase 1: Ammonia bunkering pilot safety study
- ◐ Phase 2A (Singapore): Detailed operational risk assessment for ship-to-ship (STS) cargo transfer of ammonia
- ◐ Phase 2B (Singapore): Plan and execute STS ammonia transfer pilot
- ● Detailed operational risk assessment and execution of STS ammonia transfer pilot in Pilbara
- ◐ Enabling a network of ports for ammonia bunkering

Assuring the quality, quantity and emissions abatement of drop-in green fuels

- ● Biofuels end-to-end supply chain pilots
- ◐ Assurance framework for biofuels end-to-end supply chain
- ◐ Crude algae oil as a drop-in green marine fuel
- ◐ Project LOTUS: Long term impact of continuous use of biofuels on vessel operations
- ◌ E/ bio-methanol quality, quantity and abatement assurance (QQAA)
- ◌ BioLNG QQAA

Unlocking the carbon value chain

- ● Project REMARCCABLE: Realising maritime carbon capture to demonstrate the ability to lower emissions
- ● Concept study to offload onboard captured CO_2
- ◐ Project COLOSSUS: Carbon capture, offloading, onshore storage, utilisation and sequestration
- ◌ Project CAPTURED: Demonstrate the offloading, handling, utilisation and/ or sequestration of onboard captured CO_2

Scaling adoption of energy efficiency technologies

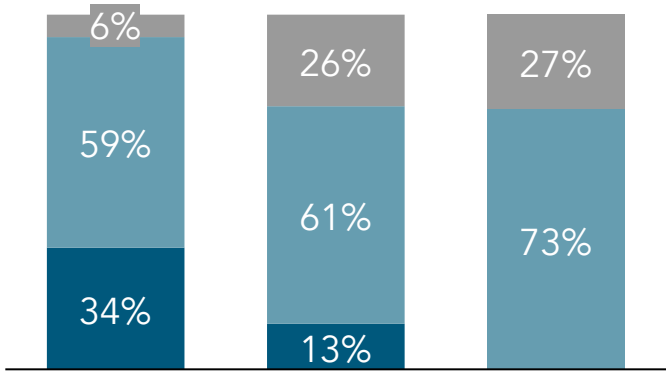
- ◐ Pay-As-You-Save (PAYS) 1: Establish binding commercial, data and technical agreements for retrofit installation + execution, data collection, validation and activation of contracts
- ◌ PAYS 2: Establish agreements for PAYS retrofit installations for a fleet of vessels + execute installation, data collection, validation and activation of contracts

Respondents plan to adopt ammonia as early as **2029**

Current and planned adoption of future fuels

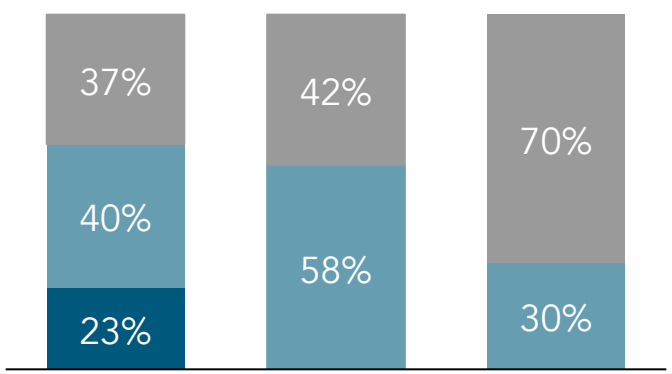
Frontrunners

% of respondents



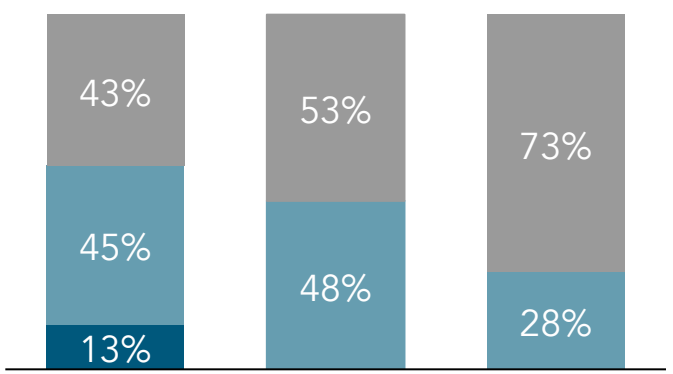
Followers

% of respondents



Conservatives

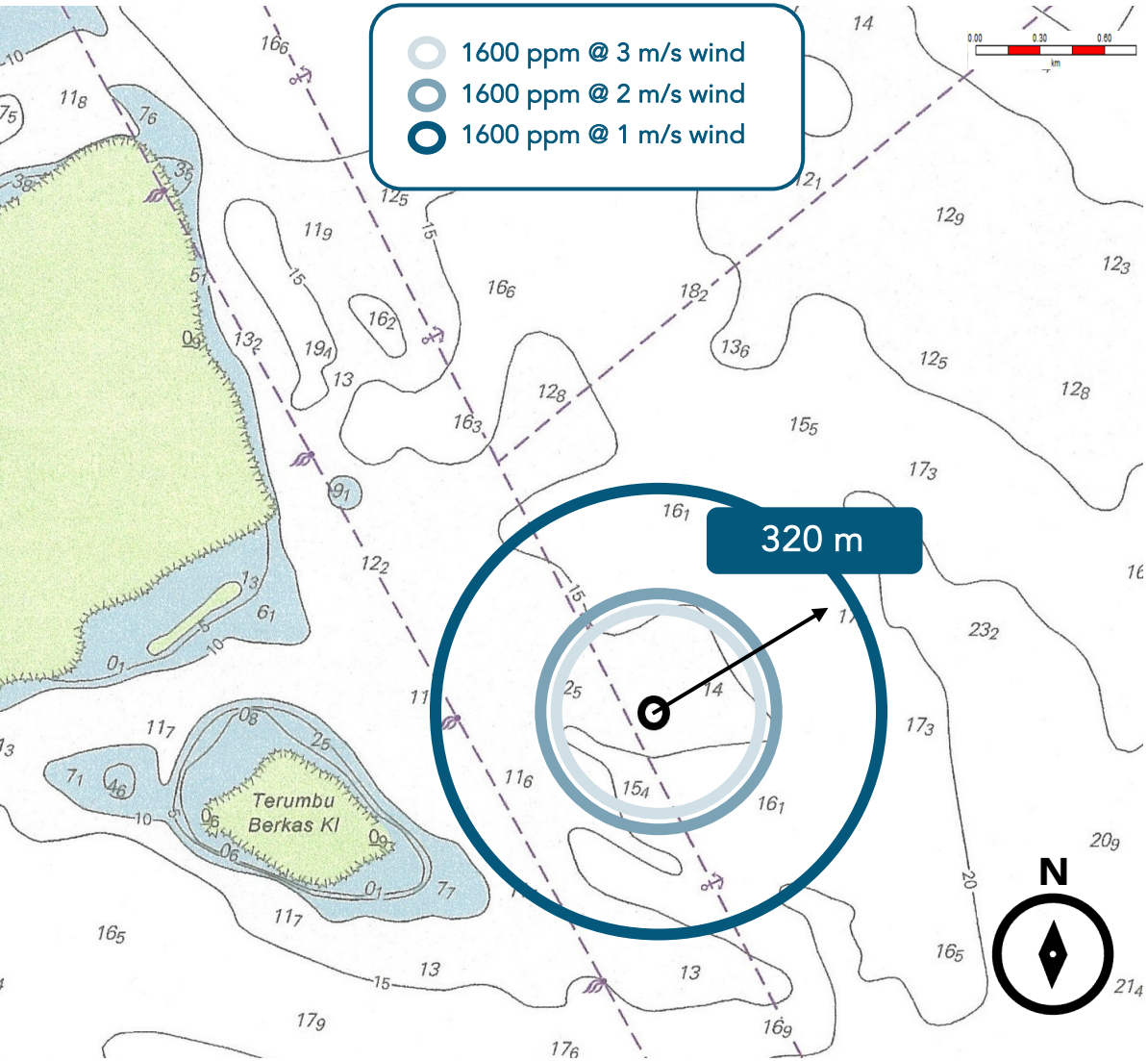
% of respondents



Already adopted | Plans to adopt | Not sure/no plans

Source: GCMD-BCG Industry Survey on Maritime Decarbonisation (N = 128), BCG analysis

Ammonia bunkering pilot safety study released Apr 2023



Singapore ammonia bunker demand

- Projected to take off in mid-2030's; estimated to be around 2 MTPA by 2035
- Can be supported by one 15,000 cbm bunker vessel

Operational and location risks

- 400 operational and locational risks identified across 4 concept designs and 3 locations
- All considered **low** or **mitigable**

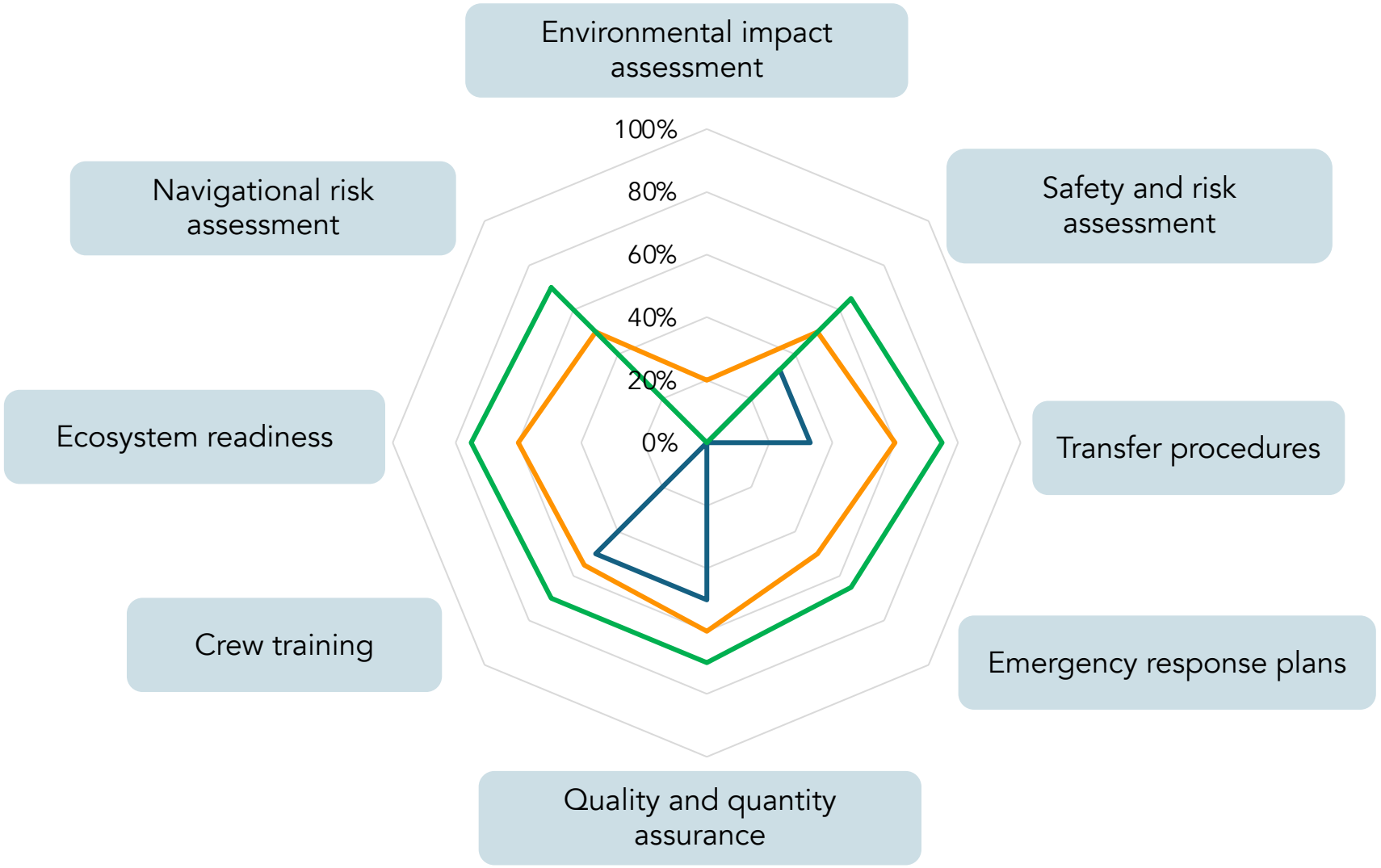
Industry development and training

- Guidebook incorporated into curriculum at SMA; first course offered in March 2023
- Learnings incorporated in SGMF interim bunkering guidelines
- Collaborating with OSRL to develop emergency response plans

Readying for STS transfers as proxy to bunkering

- In Singapore anchorage and ports elsewhere
- To build confidence and competence

Closing knowledge gaps progressively with each pilot



- Phase 1 safety study
- Singapore (safety study only)
- Dampier (safety study and trials)

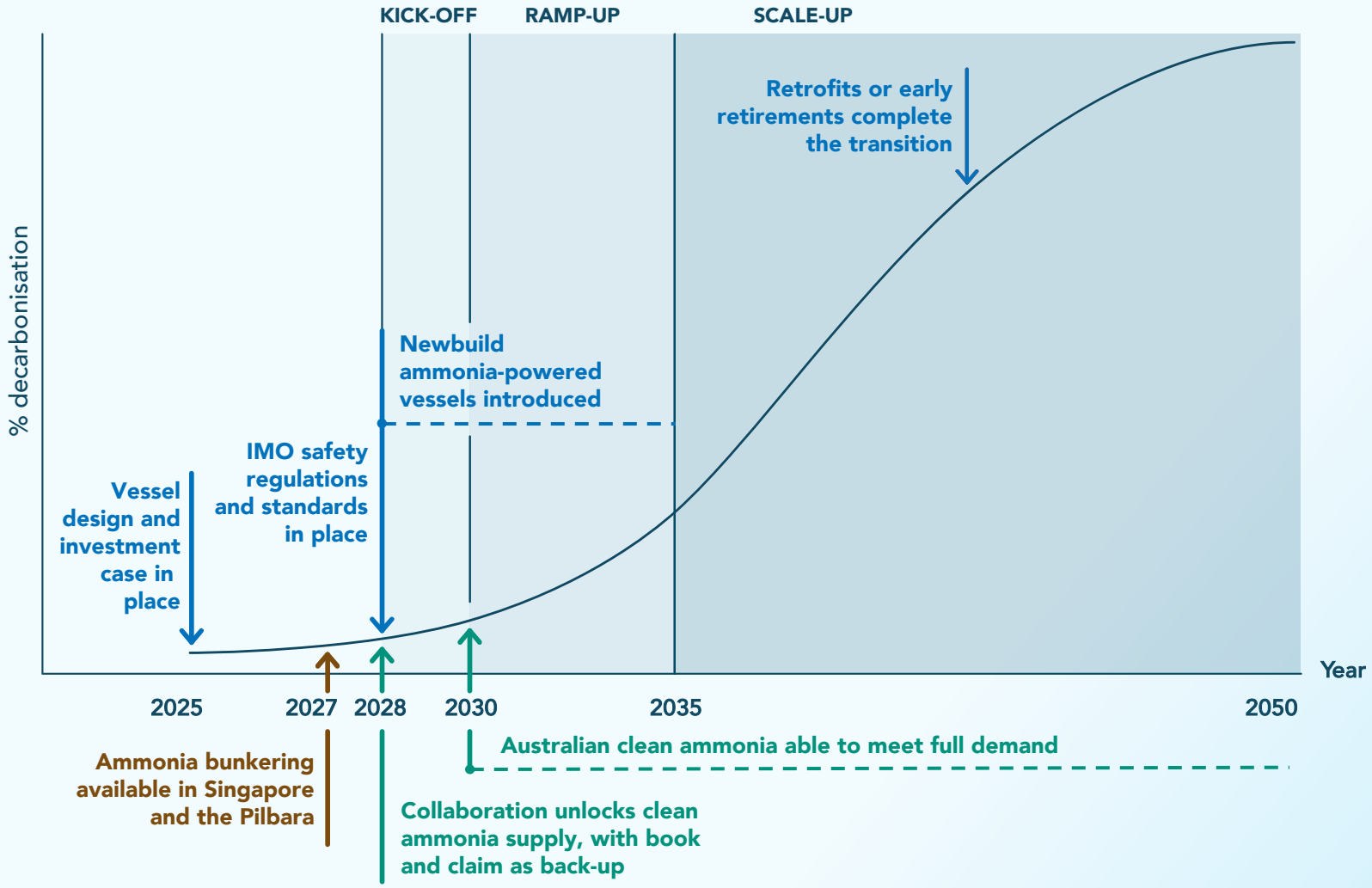
Pilbara – A potential ammonia bunkering hub?

A Potential Port for Ammonia

- **5%** of all tradeable ammonia are currently supplied through Dampier
- Start of the busiest iron ore route
- About **7,700** vessel calls in the Pilbara Ports for 2023
- Potential demand of **1-1.5** million tonnes of bunker by 2035

Source: Kpler, 11 Oct 2024
Vessel traffic for iron-ore carrying capesize and newcastle max bulk carriers

Implementing an ammonia-fueled iron ore route



"Fuelling the decarbonisation of iron ore shipping between Western Australia and East Asia with clean ammonia"
Source: Global Maritime Forum, 2023

Feasible pathway to implement the "Western Australia-East Asia Iron Ore Corridor" if:

By 2027
Ammonia bunkering available in Singapore and / or Pilbara

By 2028
Ammonia-powered bulk carriers on the water

By 2030
Enough clean ammonia production in Australia to meet the corridor's long-term fuel demand

Goal of our pilot

To **showcase breakbulk** and **mimic bunkering operations** before ammonia-fueled vessels are available

Four areas of focus:

01 | Safety + risk assessments

02 | Operational procedures

03 | Safety protocols

04 | Emergency response protocols

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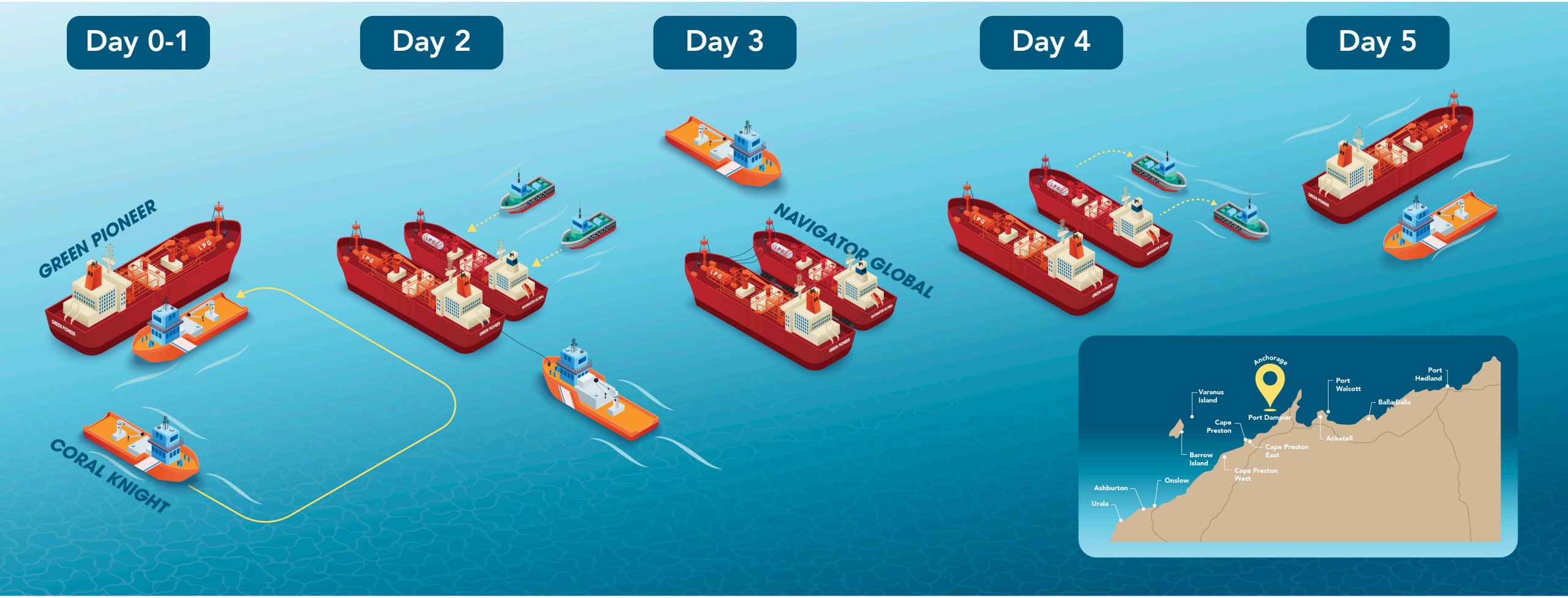
Five-day operations in the anchorage of Port Dampier

4000 cbm (2700 tonnes) of liquid ammonia was transferred at 700-800 cbm/h from the Green Pioneer to the Navigator Global and back



PILBARA PORTS · Yara Clean Ammonia · MOL Mitsui O.S.K. Lines · NAVIGATOR GAS · BHP · bp · DNV · EASTERN PACIFIC SHIPPING · gard · James Fisher Fendercare · OSRL · RioTinto · FCOMS

Risk assessments were conducted for the operations

No high-risk items across risk nodes identified

Risk nodes

+ **Hazard Identification (HAZID)** was conducted from approach of vessel to mooring, transfer and unmooring
+ **Hazard and Operability (HAZOP)** study was carried out for the transfer process from pressure testing to post-transfer purging

Risk summary

Risk ranking	Risks identified (HAZID)	Risks identified (HAZOP)
High	0	0
Medium	15	8
Low	8	3

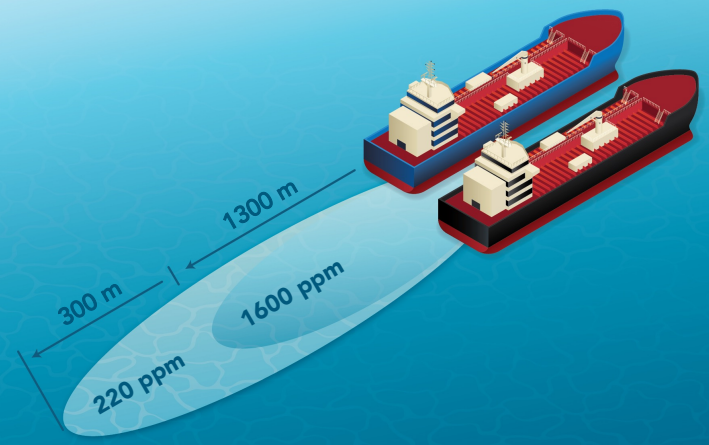
Key recommendations

+ No simultaneous operations (SIMOPS)
+ Tugs for mooring / unmooring
+ Standby Anchor Handling Tug Supply (AHTS)
  - To assist with equipment transfer
  - To assist with perimeter patrol
  - To standby with fire fighting capability
+ Conduct drills closer to operation date

Maximum plume length is less than 1 NM

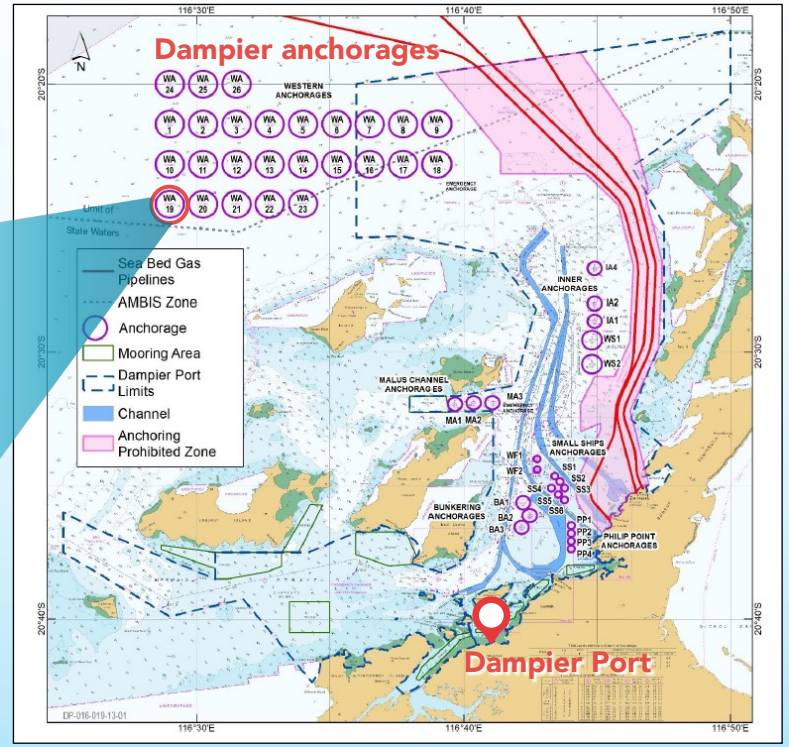
Under a credible worst-case scenario (AEGL 3), the maximum plume length is approximately 1,300 m or 0.7 NM.

This maximum plume length is within the WA19 anchorage.

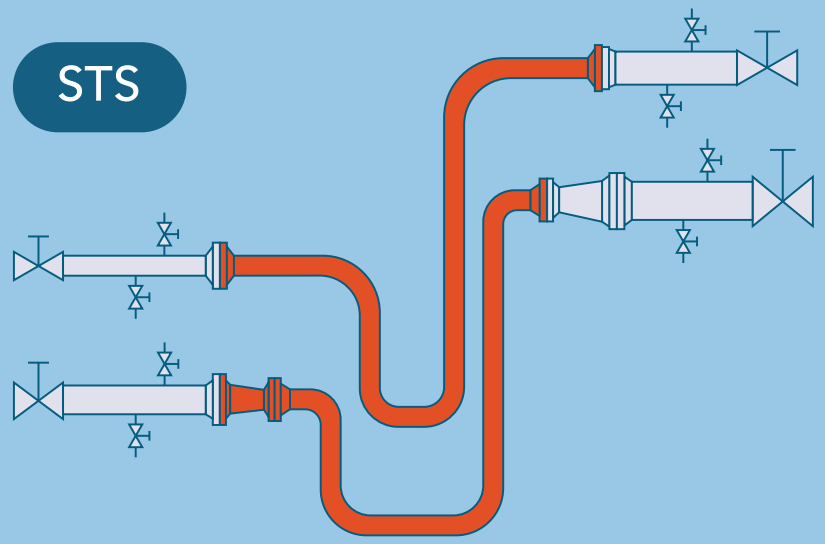


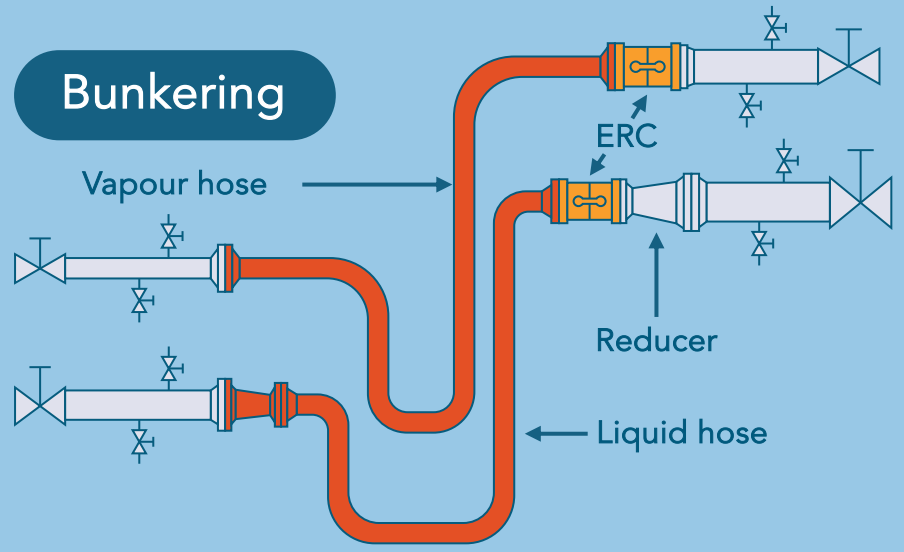
AEGL scenarios

ppm	Health risks	10 min	30 min
AEGL 1	Transient	30 ppm	30 ppm
AEGL 2	Irreversible	220 ppm	220 ppm
AEGL 3	Potentially fatal	2,700 ppm	**1,600 ppm**



Building on STS procedures to mimic bunkering operations





Procedures	STS	Bunkering
Manifold connection	Flange to flange connection	Emergency release coupling either on the receiving vessel or the supply vessel manifold
Vapour line	May involve a vapour return line	Vapour return line connected
Lines connection	Multiple liquid lines connected	Only one liquid line connected
Transfer rate	Typical transfer rate > 2000 m^3/hr	Transfer rate < 1000 m^3/hr
Disconnection	Disconnection after hot gassing	Disconnection after hot gassing and nitrogen purging

Personal Protection Equipment (PPE): balancing safety with practicality

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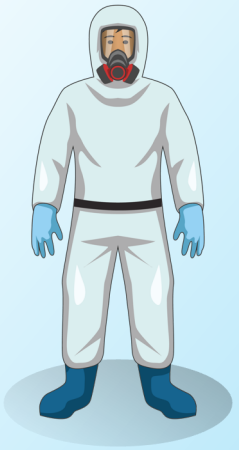
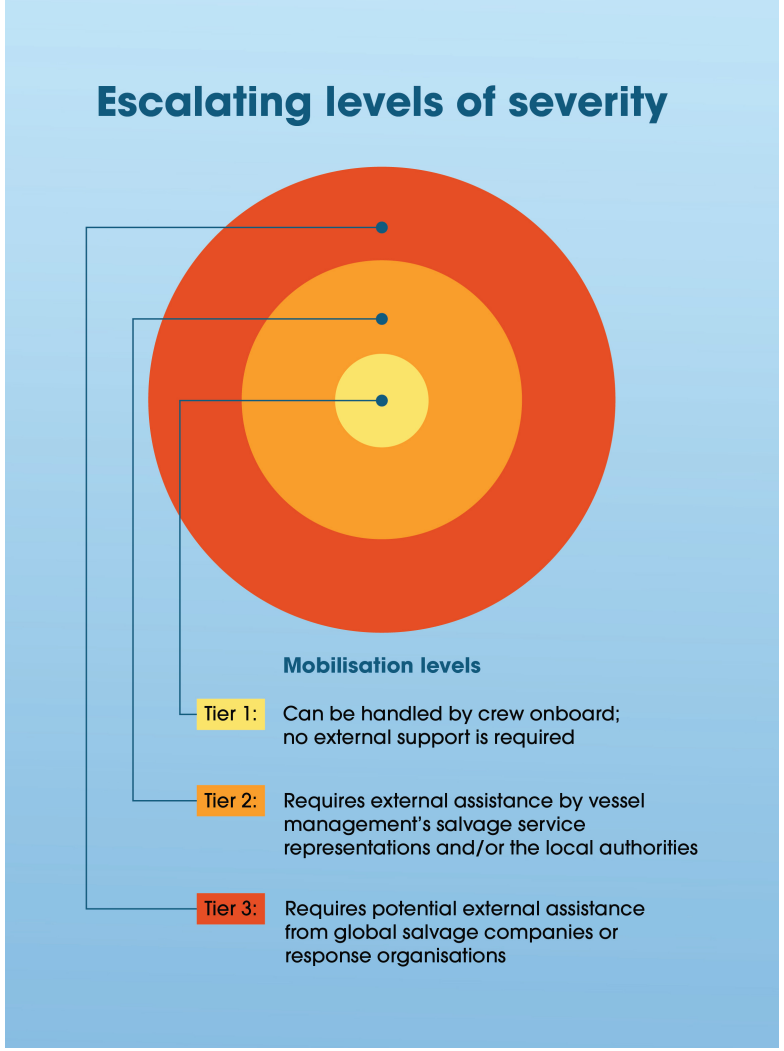
	Hose disconnection		
Watchkeeping	STS (Hot gassing)	Bunkering (Hot gassing + nitrogen purging + gas measurement)	Emergency response
Regular PPE set with personal gas detector	Light duty chemical suit with breathing apparatus	Light duty chemical suit with gas mask	HAZMAT suit with Self Contained Breathing Apparatus (SCBA)
			
✓ **5 ppm:** All crew members equipped with personal ammonia monitors, set to detect levels as low as 5 ppm. ✓ **25 ppm:** Alarm goes off; crew would don gas masks and evacuate to the accommodation block.	**<300 ppm:** Gas measurement taken to ensure < 300 ppm before disconnection. **Pilbara trial: 7 ppm after hot-gassing and purging, well within safety limits.*		Emergency shutdown devices halt transfer and isolate manifold when ammonia concentrations exceed 250 ppm

IMO draft interim guidelines for ammonia detection thresholds
25 ppm for enclosed spaces, 110 ppm for secondary containments, 220 ppm for alarms and shutdowns.

Emergency response procedures were developed

Tailored to ammonia's physical characteristics



Ammonia's physical characteristics

- Harder to vapourise (needs 2.5 times more heat than LNG)
- Harder to ignite in open environments
- Can be recondensed using shields and covers (Required by IMO interim guidelines for bunker stations)

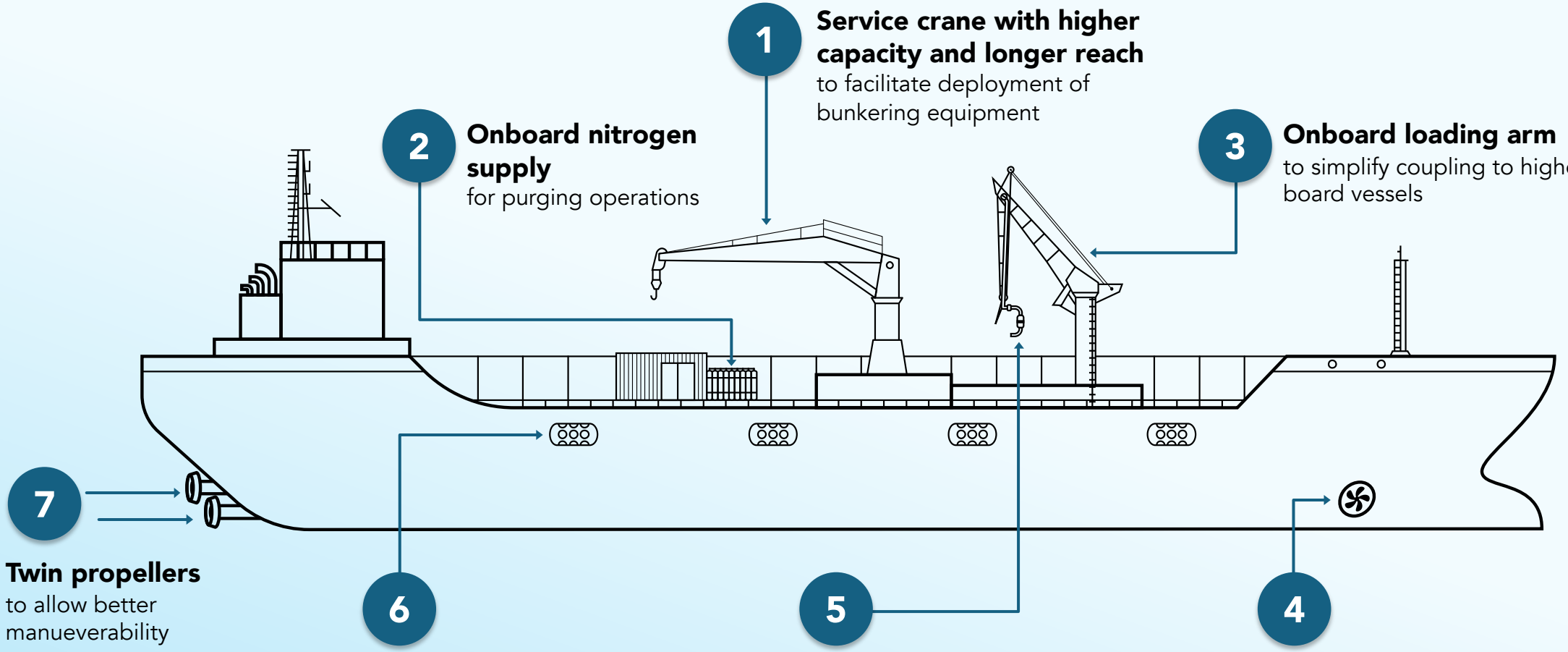
ERP Primary objectives (SGMF's recommendations)

- Minimise liquid and vapour ammonia release
- Contain any released liquid
- Minimise further vapour generation from any liquid release
- Further reduce human exposure to the release

Resources required according to severity release

Tier 1	Tier 2	Tier 3
Required by IMO • Shipboard monitoring • Emergency shutdown devices • Relevant PPEs • FiFi systems • Shipboard Marine Pollution Emergency Plan (SMPEP) kits	• Stability support • Lightering support • Towing and recovery • Salvage and emergency response Additions incorporated in this trial • Optical Gas Imaging camera onboard • Standby vessel capable of firefighting and towing • Standby certified incident handler for guidance on local resources	

Elements to facilitate ammonia bunkering



1 **Service crane with higher capacity and longer reach**
to facilitate deployment of bunkering equipment

2 **Onboard nitrogen supply**
for purging operations

3 **Onboard loading arm**
to simplify coupling to higher free-board vessels

4 **Bow thruster**
for better manueverability

5 **Emergency Release Couplings (ERC) at end of liquid and vapour hoses**
that auto-shut during an emergency to limit release quantity

6 **Onboard fender**
to reduce deployment time for fendering

7 **Twin propellers**
to allow better manueverability

All images used are for illustrative purposes only. Individual features, as well as sizes and fittings, are not drawn to scale and will vary.

Macro drivers of ammonia adoption

A multi-fuel future

The shipping industry is evolving towards multiple fuel types, driven by vessel types and trade routes.

Ammonia adoption by segments

Ammonia-fuelled gas carriers

+ Likely front runners due to their ability to use cargo as fuel
+ Bunkering and associated infrastructure less of a concern

Bulk carriers

+ Potential early adopters
+ Bulk cargo routes are typically plied by dedicated large bulkers with only one loading and one unloading port.
+ Ports typically located in remote areas, minimising risks to populated areas.
+ Opportunity increases with nearby ammonia production (e.g., Australia's Pilbara region and China's Zhoushan and Rizhao region)

Container ships

+ Faces additional safety challenges as container ports are typically located in closer proximity to populated areas

Building up a network of ammonia ready ports

Thank you!

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