Global Centre for
MARITIME DECARBONISATION

Translating 2D study recommendations to 3D solutions

Ammonia ship-to-ship transfer trials in Pilbara

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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 that require bunkering
+ 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

Project overview

~ 6 - 9 months

Phase 1

General study

+ Demand forecast
+ Operating concepts
+ Site selection
+ HAZID and Coarse QRA
+ Capital expenditures

~ 6 – 9 months

Phase 2

Detailed study

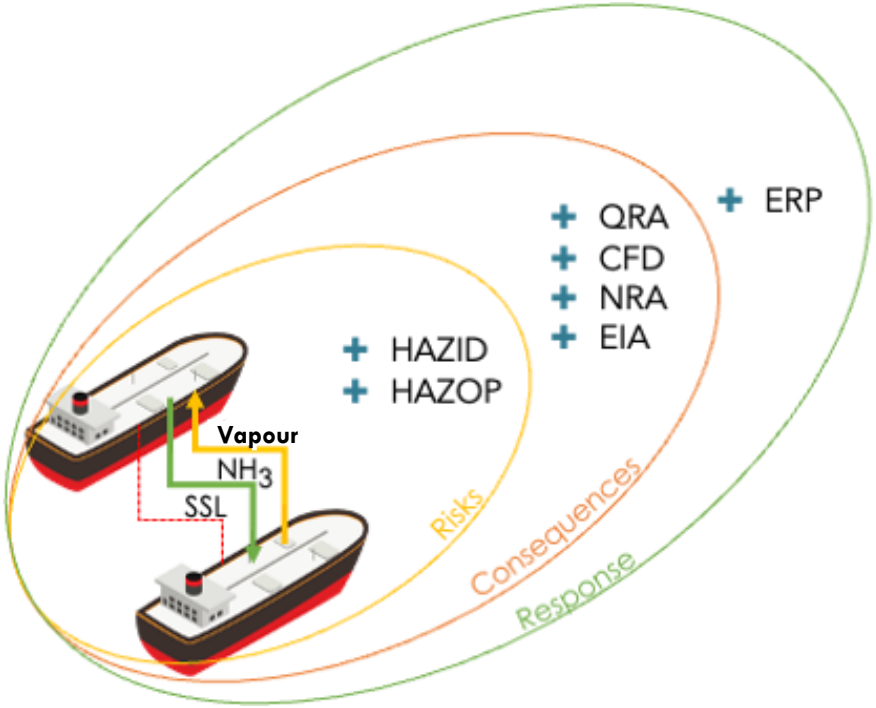
Safety study: Vessel and site specific

~ 3 to 6 months

Phase 3

Actual transfer

Approvals & trials



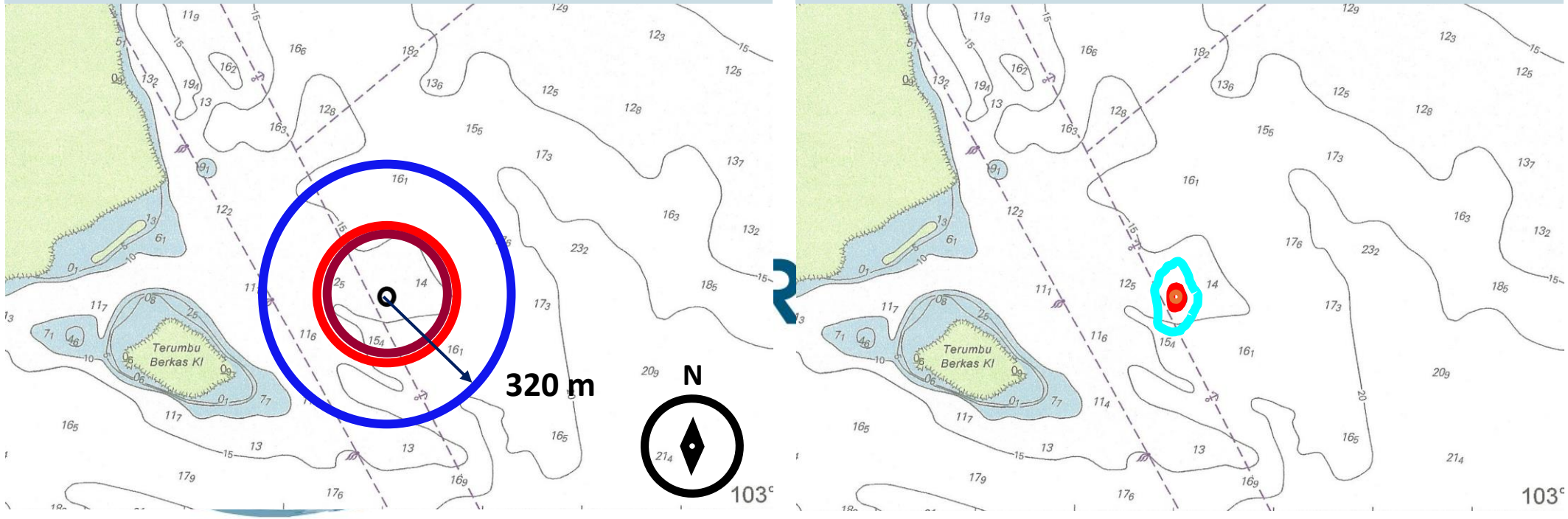
HAZID: Hazard Identification
HAZOP: Hazard Operability
QRA: Quantitative Risk Assessment
CFD: Computational Fluid Dynamics
NRA: Navigational Risk Assessment
EIA: Environmental Impact Analysis
ERP: Emergency Response Plan
SSL: Ship-to-ship Link

Using deterministic approach to assess risk for pilot

Deterministic approach
Dispersion at 1600 ppm per AEGL3

Probabilistic approach
Individual injury/ fatality risk:

1 in 100,000 : <5 m
1 in 1,000,000 : 50 m



Risk assessment and safety zone considerations

Safety zones should be designed from the perspective of laypersons who are not involved in pilots.

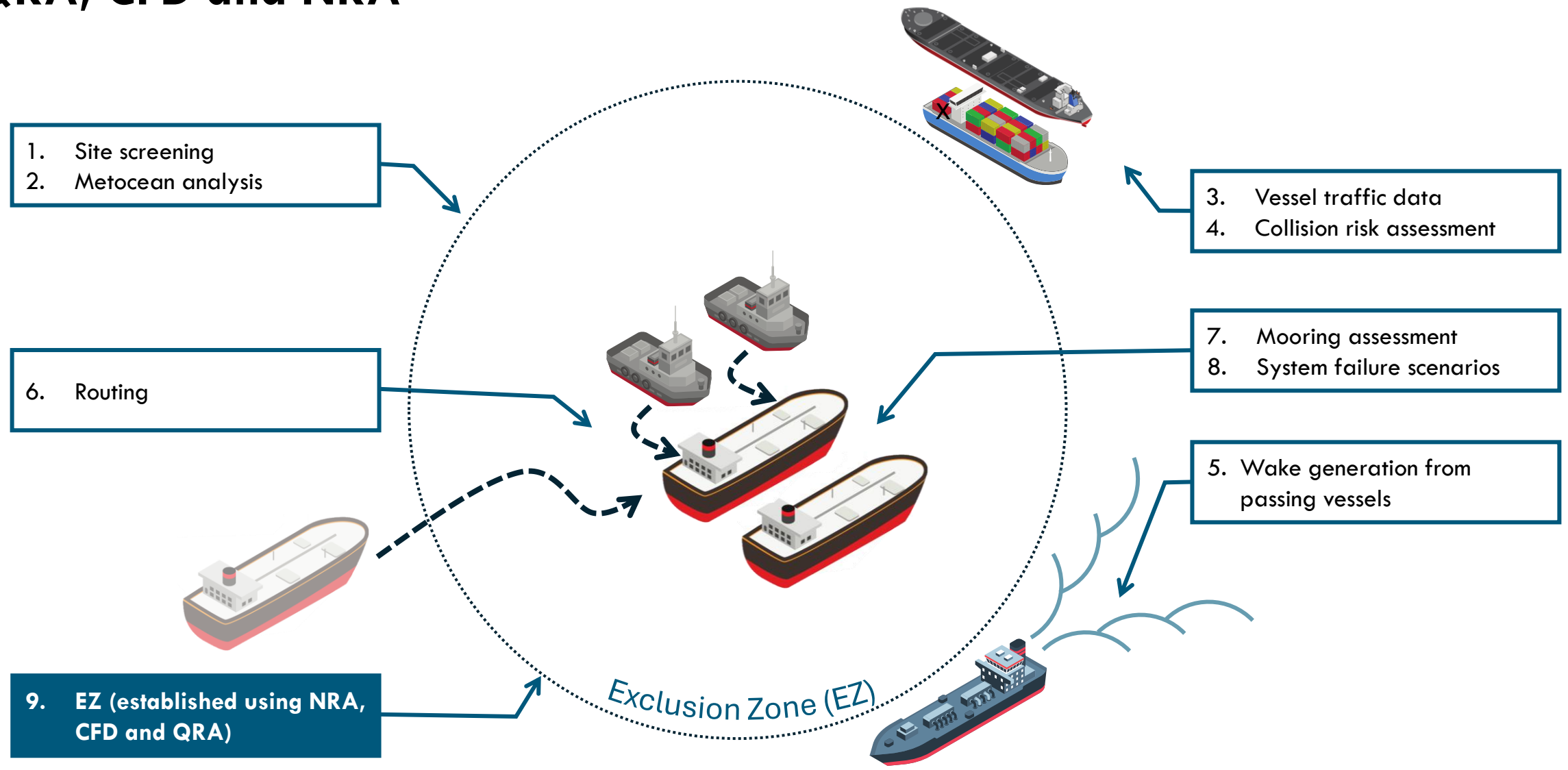
Injury and fatality risks

Average risks were assessed to be low due to limited transfer frequency and volume, which did not reflect the actual risk per operation.

Safety zone specifications

The safety zone is set at approximately 300 m, following the ALARP principle, similar to the initial 500 m estimate for LNG bunkering.

QRA, CFD and NRA

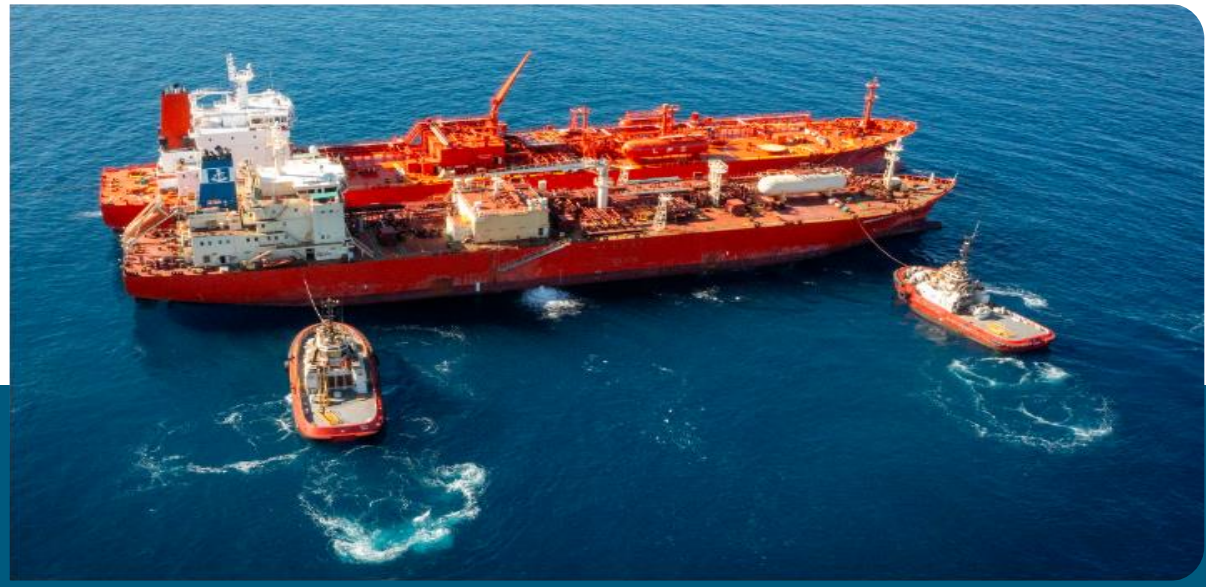


Goal of our pilot in Pilbara

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



Five-day operations in the anchorage of Port Dampier

Day 0-1

Day 2

Day 3

Day 4

Day 5

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 · TCOMS

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

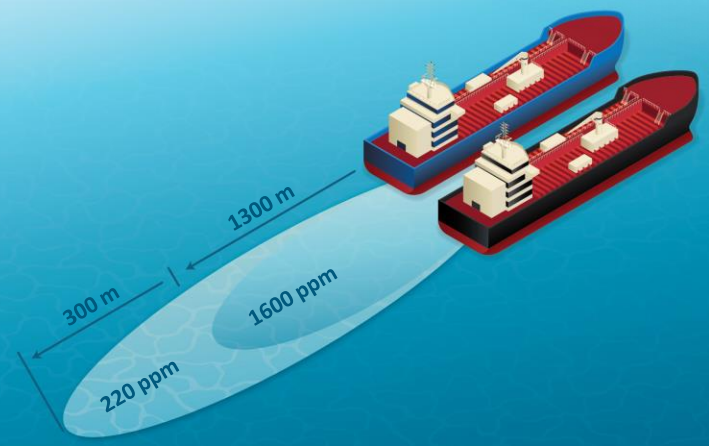
Key recommendations

+ 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

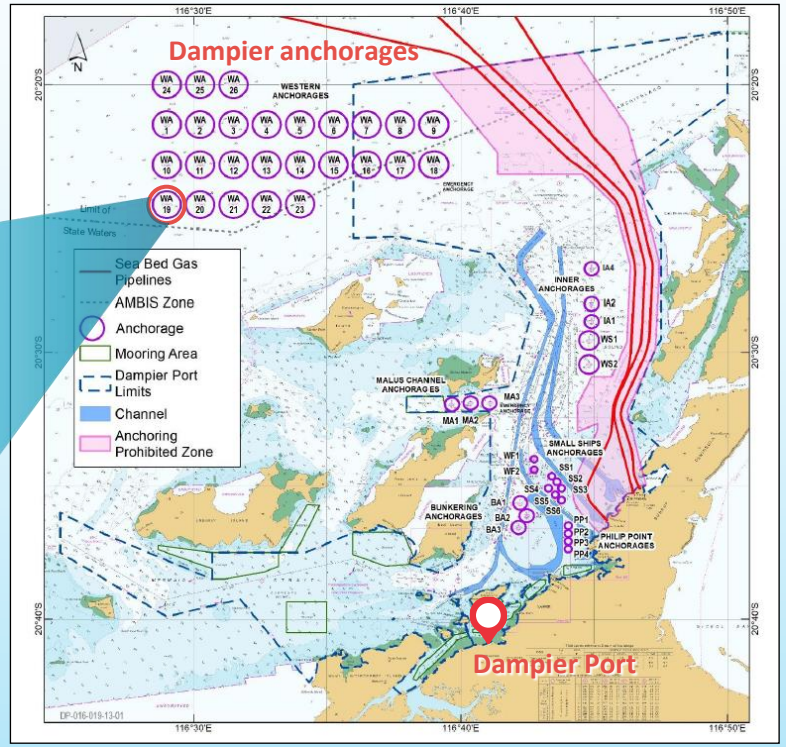
At four times the risk of that estimated for the most credible worst case scenario of a hose rupture (AEGL-3), the plume length is 1.3 km, or 0.7 nautical miles.

This maximum plume length is within the WA19 anchorage.



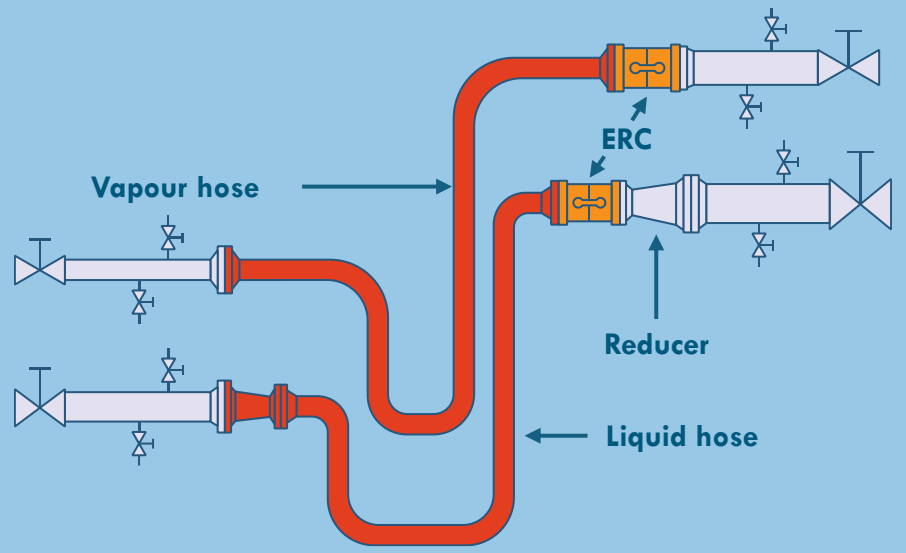
AEGL scenarios

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

Bunkering



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 volume	> 10,000 m^3	3,000m^3 ~ 8,000 m^3
Transfer rate	Typical transfer rate > 2000 m^3/ hr	Transfer rate < 1000m^3/ hr
Disconnection	Disconnection after hot gassing	Disconnection after hot gassing and nitrogen purging

Personal Protection Equipment (PPE): balancing safety with practicality

Hose disconnection

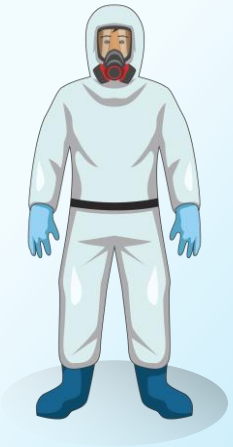
Watchkeeping

Regular PPE set with personal gas detector

- ✓ **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.

Bunkering (Hot gassing + nitrogen purging + gas measurement)

Light duty chemical suit with gas mask



<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 response

HAZMAT suit with Self Contained Breathing Apparatus (SCBA)

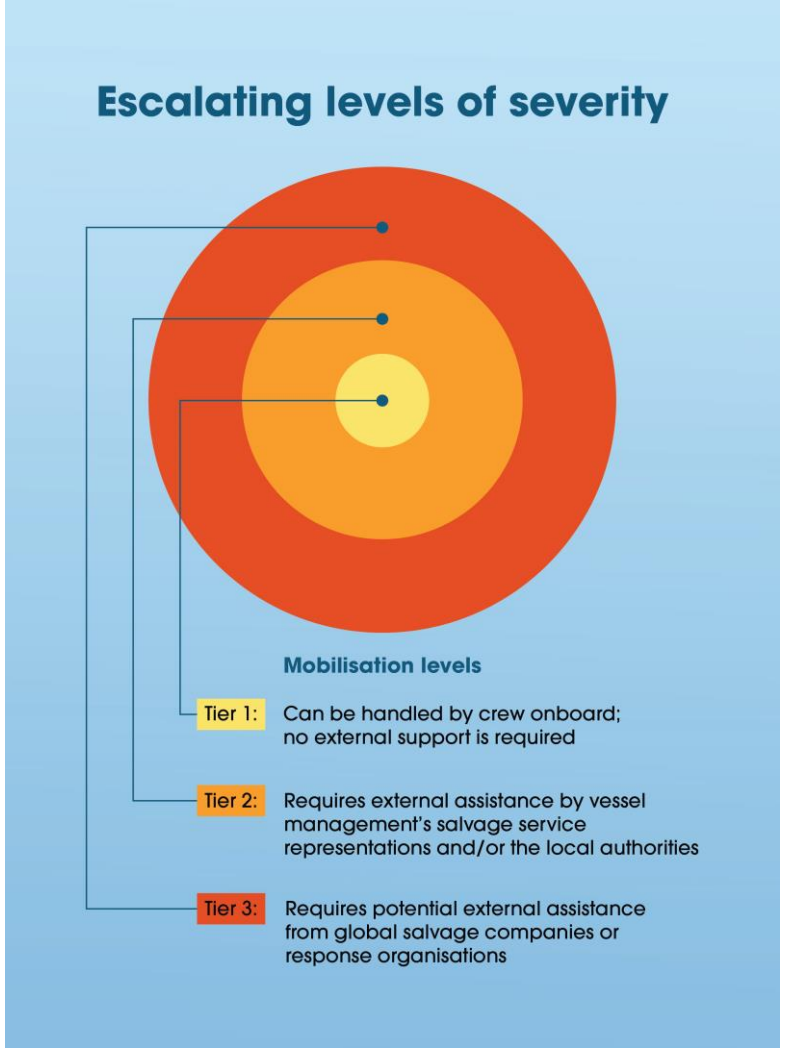
Emergency shutdown devices automatically halt transfer and isolate manifold when ammonia concentrations exceed 250 ppm.

IMO draft interim guidelines and SGMF bunkering 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)

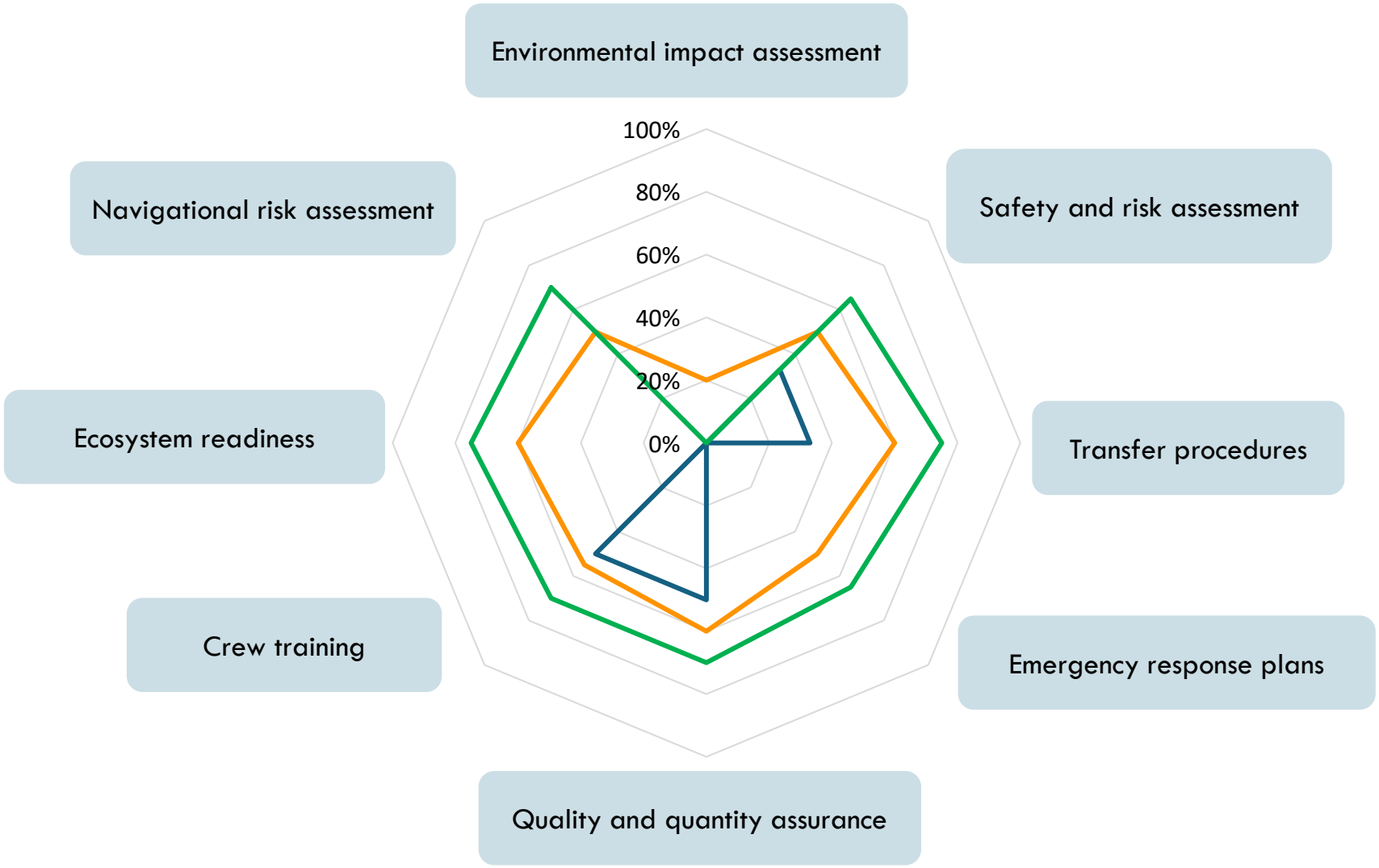
ERP primary objectives (SGMF's recommendations)

- Minimise liquid and vapour ammonia release
- Contain any released liquid
- Minimise vaporisation of released liquid
- Minimise crew exposure to released ammonia

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 Additional elements incorporated in our trial • Optical Gas Imaging camera onboard • Standby vessel capable of firefighting and towing • Standby certified incident handler for guidance on local resources	

Closing knowledge gaps progressively with each pilot



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

Thank you!

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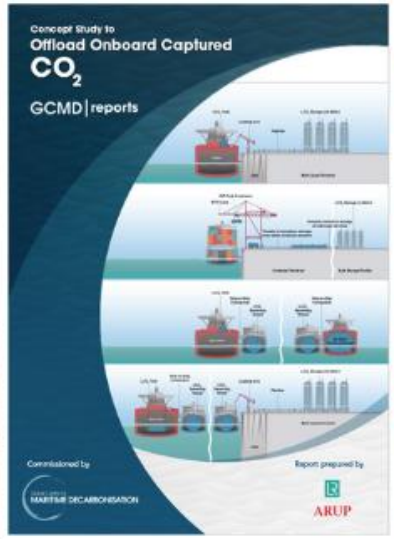

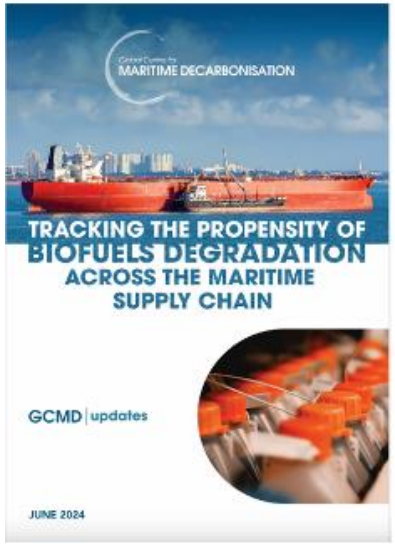

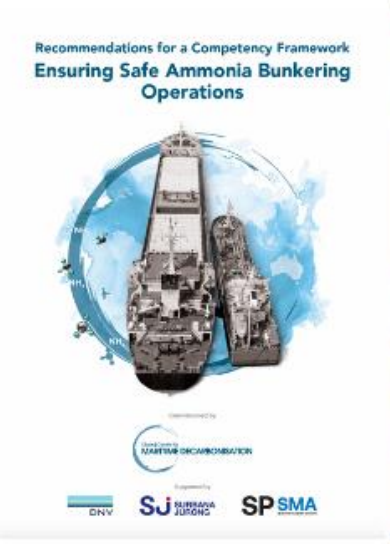

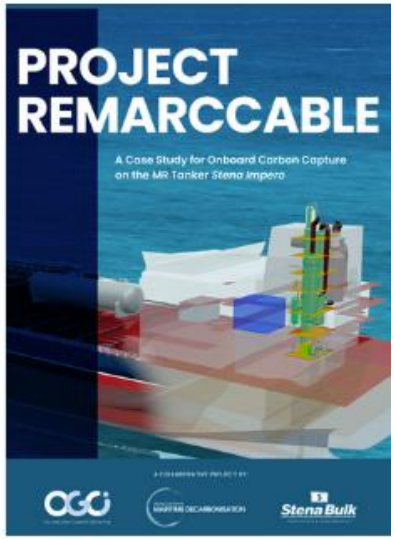

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