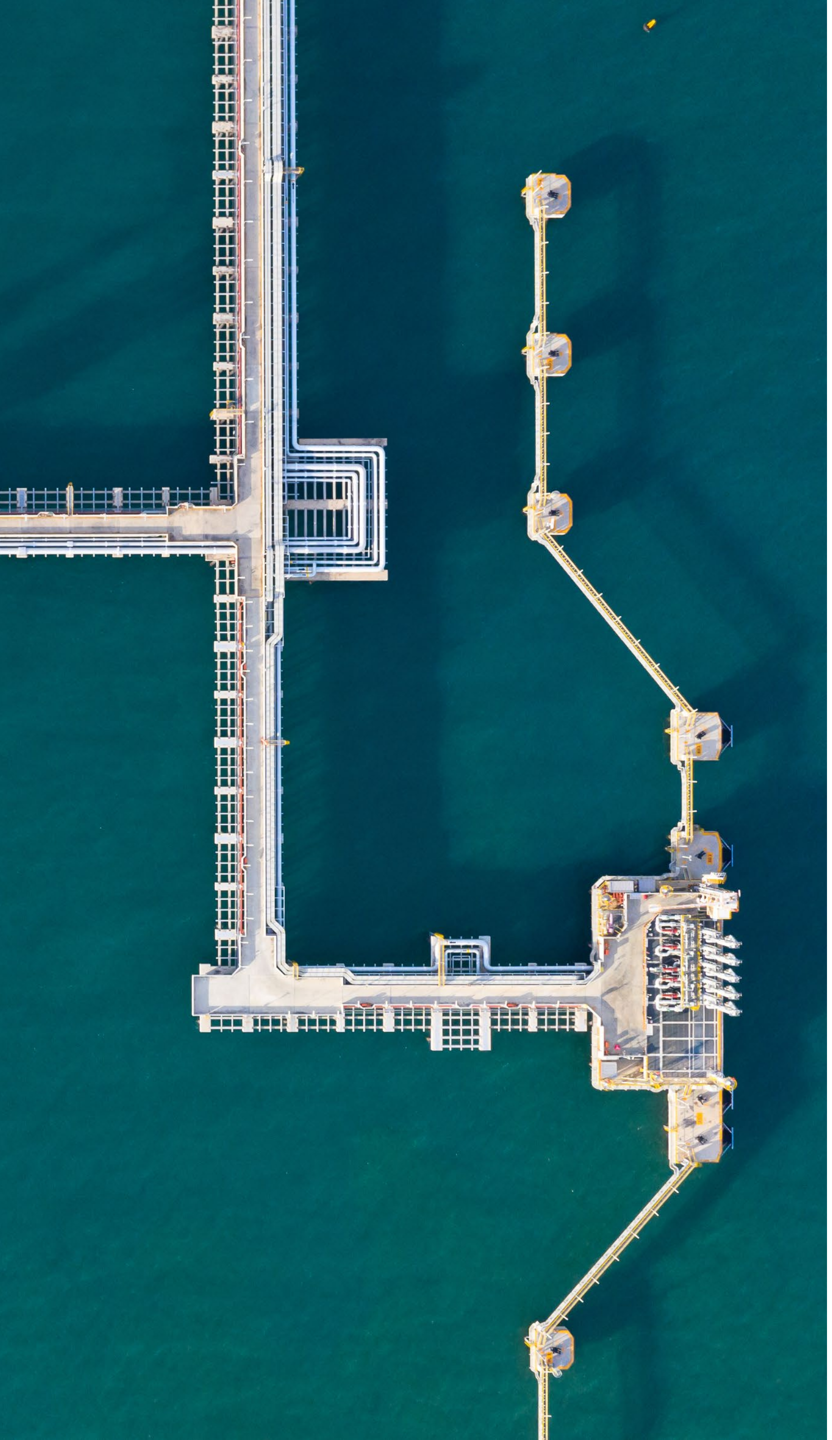
Calculating the cost gap

Western Australia–East Asia iron ore green shipping corridor

March 2024



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Introduction

Key challenge facing green shipping corridor projects

Green shipping corridors, defined as specific trade routes where the feasibility of zero-emission shipping is catalysed by public and private action, provide the opportunity to accelerate shipping's transition to zero emission fuels[1].

The initiatives working to establish green shipping corridors seek to convene participants from the full maritime value chain – such as fuel producers, ship owners and operators, cargo owners, ports, and regulatory authorities – that are active on the trade route, to support the necessary investments in, and deployment of, zero-emission vessels, fuel production and bunkering infrastructure.

As green shipping corridors move closer to implementation, however, several challenges have been identified as barriers to progress. One of the main barriers is **the significant cost gap** that exists between running vessels on conventional fuels versus zero-emission fuels, which, unless bridged, risk the materialisation of green shipping corridors as they become too expensive to operate.

This cost gap cannot be bridged by industry levers alone, but is dependent on financial support from policymakers at a national, regional and global level. The size of this cost gap – which may differ between different green shipping corridor initiatives – must be understood in order for governments to develop appropriate, effective and timely policy support.

1. Fuels with the potential to achieve zero or near-zero greenhouse gas emissions on a lifecycle basis.

Development of the Australia-East Asia Iron Ore Green Corridor

Identification of corridor and involvement of industry stakeholders

The effort to develop an Australia-East Asia Iron Ore Green Corridor was announced by the Global Maritime Forum in spring 2022 following the identification[1] of the corridor as a high-potential candidate for establishing zero or near-zero carbon ammonia-powered shipping of iron ore from the Pilbara region in Australia to importing countries in East Asia.

Since then, 15 industry members[2] working on the corridor under the Getting to Zero Coalition[3] have explored its implementation and undertaken various activities[4] to support its development.

Feasibility study to determine key enablers

In May 2023, four of the industry members completed a feasibility study[5], which found that the three main enablers – the availability of ammonia-powered ships, access to zero or near-zero carbon ammonia, and the availability of bunkering infrastructure – could be in place to kick off the corridor by 2028.

It was determined that this would achieve a 5% uptake of zero or near-zero carbon ammonia on the route by 2030, in line with the International Maritime Organization (IMO)'s 2030 fuel uptake target in its revised Greenhouse Gas (GHG) Strategy.

Estimating the cost gap in parallel to preparation for policy engagement

As the corridor's industry members have continued their work – preparing for policy engagement in Australia and East Asian countries and exploring what commercial arrangements on the route may look like – the cost gap for delivering the corridor has been **analysed independently** by the maritime advisory service UMAS on behalf of the Global Maritime Forum.

This report summarises the approach adopted in modelling the cost gap, the source of inputs and the basis for assumptions, and presents outputs from a few of the scenarios.

1. The Next Wave: Green Corridors
2. BHP, Bureau Veritas, Cargill, ClassNK, Fortescue Future Industries, Intercontinental Energy, K Line, Lloyd's Register, NYK Line, Oldendorff Carriers, Pilbara Ports Authority, Rio Tinto, Star Bulk, Woodside Energy, Yara Clean Ammonia.
3. Getting to Zero Coalition
4. Public activities include Joint Statement; Feasibility study (conducted by BHP; Oldendorff; Rio Tinto; Starbulk; Position paper to the Australian Government
5. Feasibility Study

Outputs calculated as the cost differential to IMO compliance

Building on feasibility study

Analysis performed during the feasibility study determined the following:

- An assessment of current shipping activity transporting iron ore from Australia to East Asia
- Forecast of the growth in demand for green iron ore exports (i.e. using low or zero emission shipping) on those routes
- Projection of the shipping capacity needed to deliver the green iron ore trade

This work builds on that analysis by estimating the cost of transporting projected green iron ore volumes on vessels fuelled by blue (low emission) and green (zero emission) ammonia produced in Australia and elsewhere.

Stages of analysis

Initial stages of the project involved sourcing information to estimate ammonia production costs in Australia and various other countries. Fixed fuel costs were used across the period of assessment (2028 – 2035) as it was assumed that fuel offtake agreements would be secured.

Following this analysis, costs associated with shipping, storing and bunkering the ammonia were estimated, producing the delivered cost of Australian ammonia to Port Hedland and ammonia from other countries to Singapore.

The cost gap was calculated as the differential between vessels running entirely on low/zero ammonia versus vessels using just enough to remain compliant (based on IMO's minimum trajectories). Multiple scenarios were formed using different types/sources of ammonia.

Note on outputs

The purpose of conducting and sharing this analysis is to shed light on the potential cost gap ranges for delivering this corridor; to provide a foundation for continued cost gap modelling in and/or outside this green corridor initiative; and to contribute to the global knowledge base of green shipping corridors by showcasing an example of how cost gap analyses can be modelled.

While this work benefited from input and review by industry participants in this corridor, key assumptions were necessarily derived from publicly available, unvalidated sources and the conclusions do not represent industry views on the level of the cost gap as signalled by current projects. Notably, several participants in the corridor indicated that they believe the **delivered unit cost of green ammonia will likely be higher** than indicated in this study.

Summary of model components and variables

Modelling components

- Individual cost components calculated:
    - Levelised cost of green ammonia production in Australia, Chile, India, Middle East, and the USA
    - Levelized cost of blue ammonia production in Australia, Middle East, and the USA
    - Cost of transportation – via pipeline and shipping to Pilbara and Singapore (as alternative bunkering hub)
    - Cost of storage and bunkering at port – on a project basis (at Pilbara) and a full utilisation basis (at Singapore)
- Model calculates cost differential between a green shipping corridor (GSC) using ammonia sourced from any of the five countries above and a business as usual (BAU) scenario which can use any source of ammonia to meet compliance levels
- Emissions intensity of voyages calculated on a well-to-wake (WTW) basis with well-to-tank (WTT) emissions incorporating upstream gas production, grid electricity generation, and ammonia shipping

Variables of analysis

- Key drivers of alternative scenarios is the type and source of green and blue ammonia
- Secondary variables include:
    - BAU/pilot fuel: select between VLSFO or HSFO; determines price, energetic content and WTW emissions
    - Bulkcarrier size: select between 180,000 dwt (Capesize) and 208,000 dwt (Newcastlemax); determines cargo capacity, engine specs/fuel consumption and onboard VLSFO/HSFO tank size; however, route and speed assumptions same across both types
    - Newbuild vs retrofit: determines cargo-carrying capacity of vessel
    - Gas carrier size for ammonia shipping: selection can determine cost of tank storage as well as cost of shipping; typically, 38,000 cbm is cost optimal for Australian cabotage and 84,000 cbm for international shipping

Linking the components of analysis

Ammonia costs

Green ammonia production in:

- Australia, India, Chile, Middle East and USA

Blue ammonia production (SMR retrofit and newbuild ATR) in:

- Australia, Middle East and USA

Other costs

Costs and impact of utilisation for:

- Storage
- Shipping
- Bunkering (at Port Hedland for Australian ammonia; at Singapore for RoW ammonia)

Fuel demand

Projection of energy demand based on forecast of green iron ore exports in feasibility study

BAU fuel demand split between HSFO/VLSFO and ammonia in line with trajectories based on MEPC80 minimum targets

Scenarios

Scenarios driven by variables:

- Type and source of ammonia
- BAU/pilot fuel (HFSO and VLSFO)
- Vessel size (180k vs 208k dwt)
- Retrofit vs newbuild
- Gas carrier size

Ammonia production

Sourcing country-specific data

One key focus of the project was to determine indicative ammonia production costs in Australia, and then to compare this with the delivered cost of ammonia produced elsewhere in the world. Therefore, where available, Australia-specific data was sourced on the individual steps within the blue and green ammonia production pathways. This included costs, capacity factors and upstream GHG emissions.

Fixed ammonia production costs

It was assumed that fixed-price fuel offtake agreements would be secured for the ammonia. Therefore, estimates of 2028 production costs (based on projected 2026 values for CAPEX items) were formed and utilised throughout the period of assessment (2028 – 2035).

Declining carbon intensity of inputs

While a fixed cost of ammonia estimated and subsequently used within the model, the fall in upstream GHG emissions related to grid electricity and gas production between 2028 and 2035 was incorporated to estimate WTT emissions.

Variance in levelised cost of ammonia

The sensitivity of the overall cost of production to variance of the individual components in the ammonia production pathways was tested. Material components in both blue and green ammonia production included CAPEX, input energy price (grid and gas – the latter only for blue ammonia), form of hydrogen storage (for green ammonia) and pipeline distance.

Modelling approach and sources of data

Approach to production cost estimation

- Research focused on Australian ammonia production; large-scale export-oriented projects with the capacity to meet demand from the green shipping corridor were interrogated
- Rest of world costs reflect large-scale, low-cost projects in locations with abundant renewable energy resources and/or access to geological H_2/CO_2 storage
- Project CAPEX costs were inflated to 2022-basis, and where a fall in costs due to learning curve/economies of scale was expected, CAPEX was priced at 2026 values (assuming costs locked in two years before 2028)
- SMR conversion costed for 90% CO_2 capture; ATR assumed to capture 96%; WTT CO_2e emissions associated with grid and upstream natural gas production also calculated
- Levelised costs of ammonia (LCOA) are based on delivered cost to exporting port

Data sources

- Estimates for renewable energy capacity factors, costs for solar PV and onshore wind, and cost of electrolysers sourced from CSIRO for Australian projects and from IEA for rest of world
- Costs for water treatment, H_2 storage, ammonia synthesis and ammonia transport by pipeline from literature
- Cost of grid electricity based on Australia's average wholesale futures price (Q3 2023 – Q1 2027), adjusted to reflect end of 2022 costs of connection, transmission, etc. in each country
- Cost of gas for Australia and USA, based on average of annual wholesale gas price from 2018-current; for Middle East, based on estimated cost of upstream (state-owned) gas production
- Cost of CO_2 transport and storage based on literature

Green and blue ammonia production locations

Green ammonia production

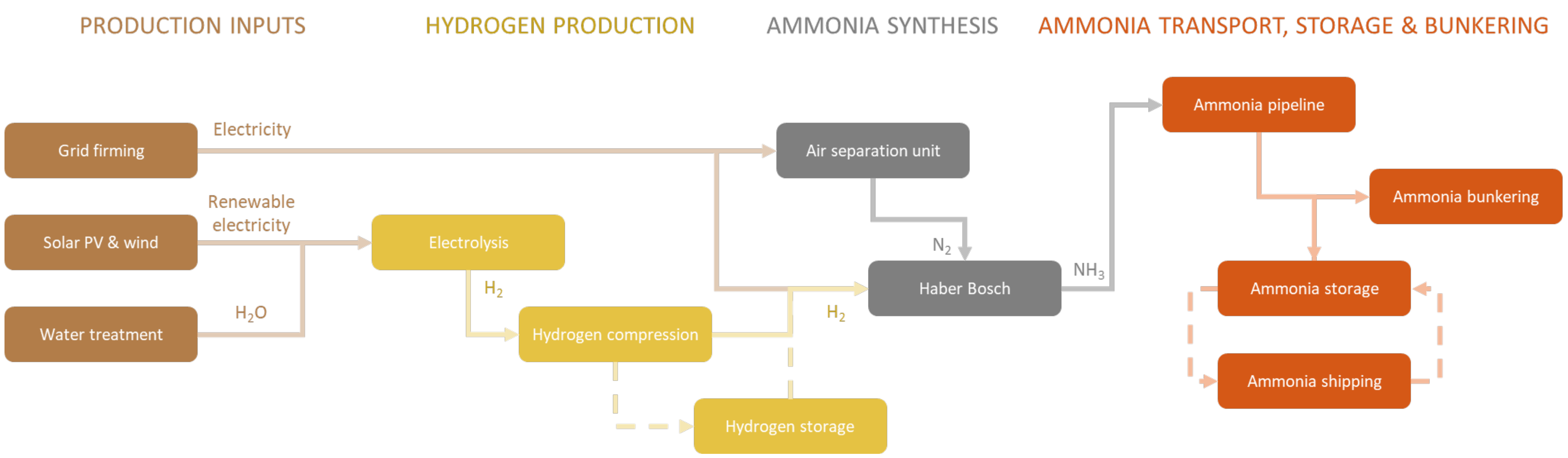
- Australia
- India
- Chile
- Middle East
- USA

Blue ammonia production

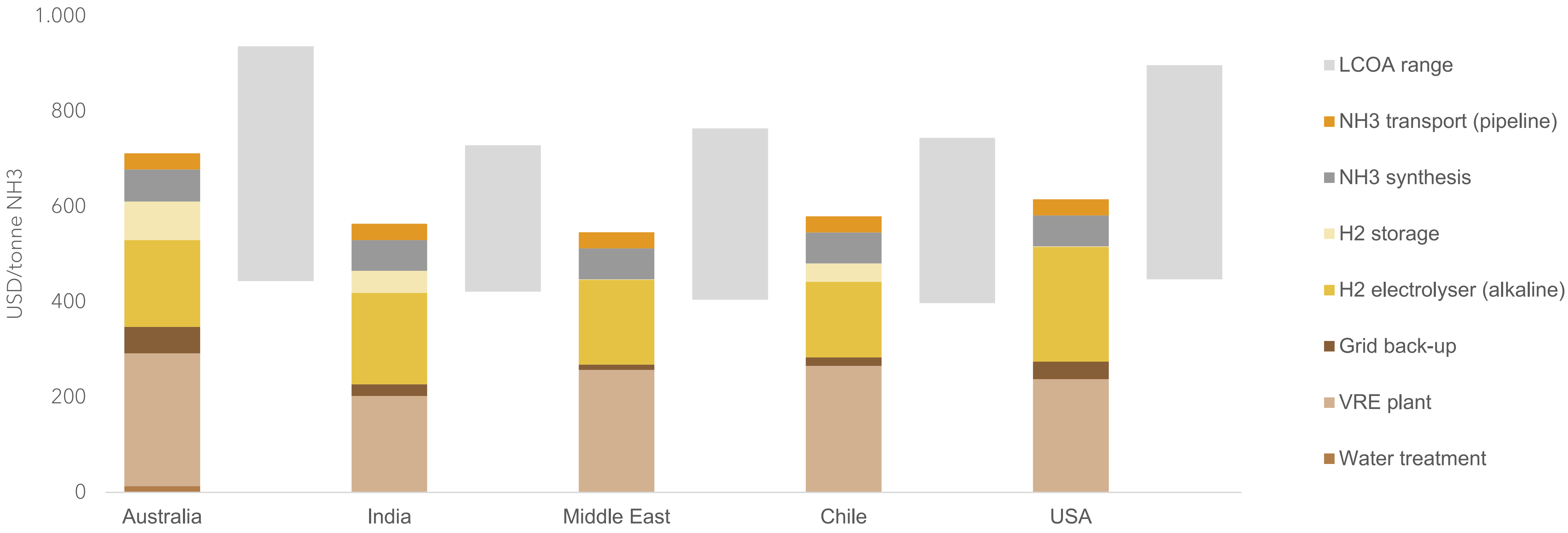
- Australia
- Middle East
- USA

Green ammonia production pathway

Each step costed to determine the levelised cost of green ammonia production and delivery



Green ammonia LCOA (delivered to exporting port)



LCOA range – variable sensitivity			
VRE/Electrolyser/ASU-HB CAPEX (+/- 25%)	Grid price (+/- 50%)	Plant to port distance (50 – 500km)	H2 storage type

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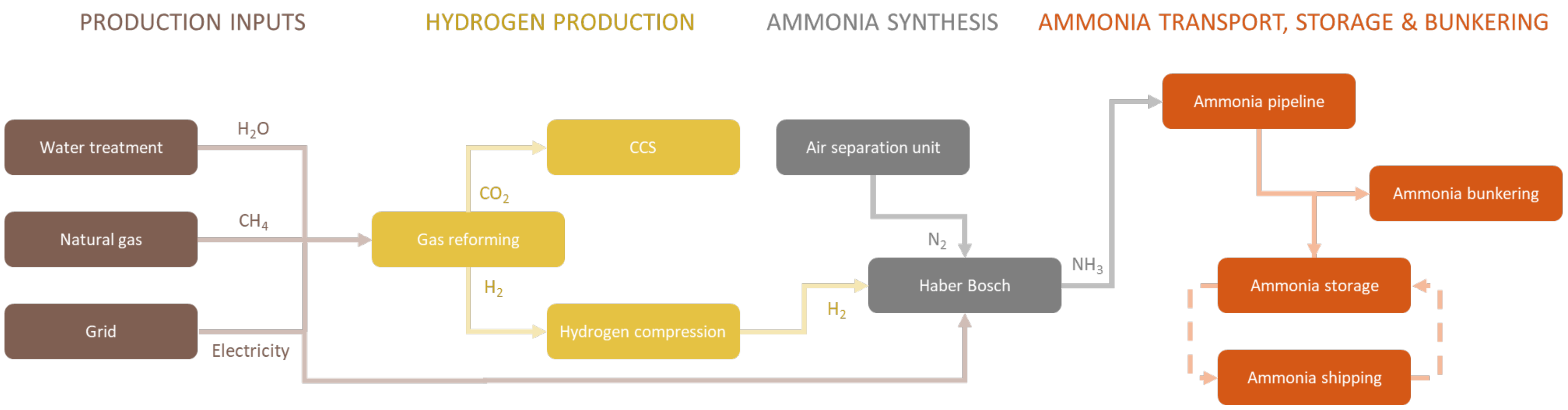
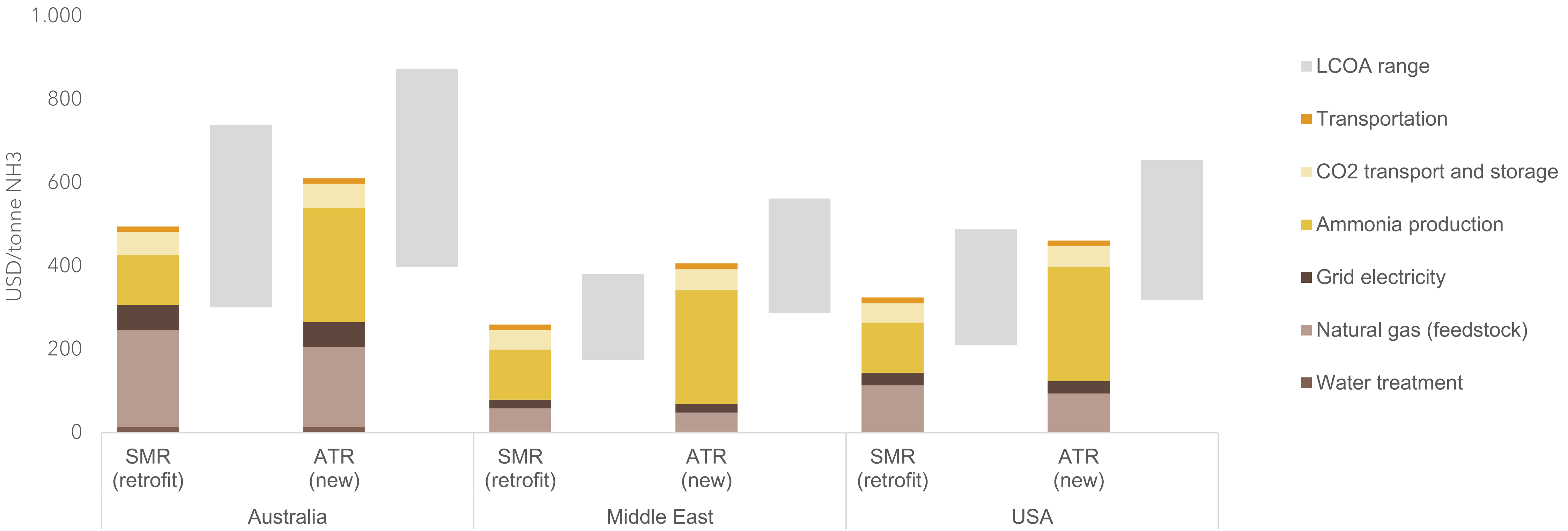
Blue ammonia production pathway

Each step costed to determine the levelised cost of blue ammonia production and delivery



Blue ammonia LCOA (delivered to exporting port)



LCOA range – variable sensitivity				
Gas price (+/- 50%)	Grid price (+/- 50%)	System CAPEX (+/- 25%)	Plant to port/CO2 offtake (50 – 500km)	CO_2 storage cost (+/- 50%)

Shipping & last mile

Ammonia shipping

It was assumed that ammonia produced in the Pilbara would be delivered to Port Hedland by pipeline. However, for ammonia produced elsewhere in Australia, the cost of shipping to Port Hedland from three locations (southern Western Australia, South Australia and Queensland) was calculated. For ammonia produced elsewhere in the world, the cost of shipping to Singapore was estimated.

In each case, the calculation was run across five different sizes of gas carrier. The size of vessel then determined the minimum volume of storage required at the importing port. The gas carrier size delivering the lowest combination of shipping and storage costs was then selected.

Bunkering and storage costs

Ammonia storage costs reflect the cost of tanks and port fees at Port Hedland and Singapore. Bunkering costs are based on the cost of the bunkering vessel and port fees. The costs associated with storage and bunkering are calculated in $/tonne of ammonia stored or bunkered.

For Singapore, as a large bunkering hub, 100% utilisation of storage and bunkering over the period (2028 – 2035) is assumed. However, for Port Hedland, utilisation is based on demand for ammonia in both comparative scenarios – for the green iron ore corridor where vessels are entirely running on ammonia – and the basis for the differential, where vessels are running on compliance-levels of ammonia.

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Shipping, storage and bunkering assumptions

Ammonia shipping

- Shipping costs calculated for five sizes of gas carrier (5,000 cbm – 84,000 cbm)
- Assumed ammonia produced in Australia is shipped to Port Hedland and vessels bunker there; ammonia production from RoW shipped to Singapore and vessels bunker there
- Shipping costs include port fees; for cabotage, Port Hedland fees applied to import and export port; for international shipping, Singapore fees applied to both ends
- Gas carriers assumed to burn the minimum amount of ammonia to ensure IMO compliance (based on the WTW carbon intensity of HFSO/VLSFO and onboard ammonia)
- Minimum size of ammonia storage at port linked to gas carrier volume

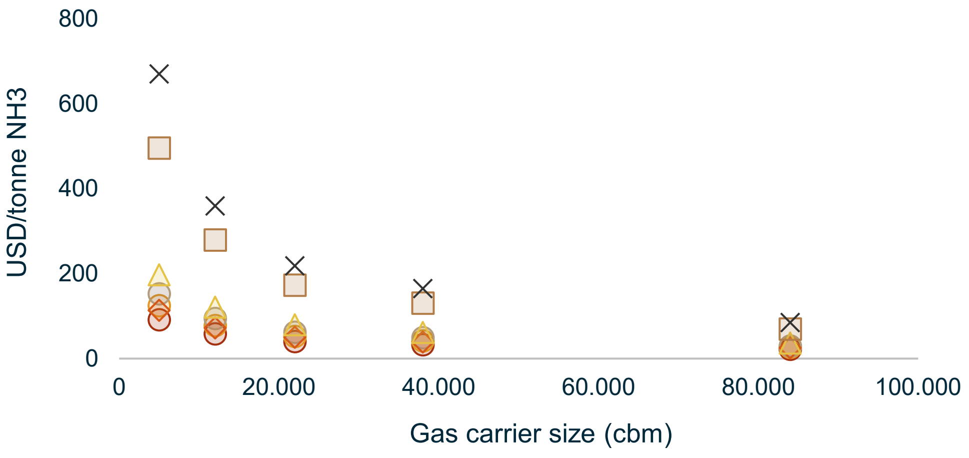
Storage and bunkering

- Storage costs based on no. of tanks required as determined by the larger of import volumes and bunkering demand; cost of tank estimated based on size to estimate CAPEX and footprint to estimate port lease cost
- Port fees for applied to the bunkering vessels based on Singapore port costs in all scenarios
- Singapore storage costs based on 100% utilisation; for the Australian ammonia production scenario, Port Hedland storage costs based on 2028-2035 ramp up in demand/ utilisation
- Singapore bunker vessel assumed to be 22,000 cbm and costs based on 100% utilisation; assumed 5,000 cbm bunker vessel for Port Hedland and costs based on 2028-2035 ramp up in demand/utilisation

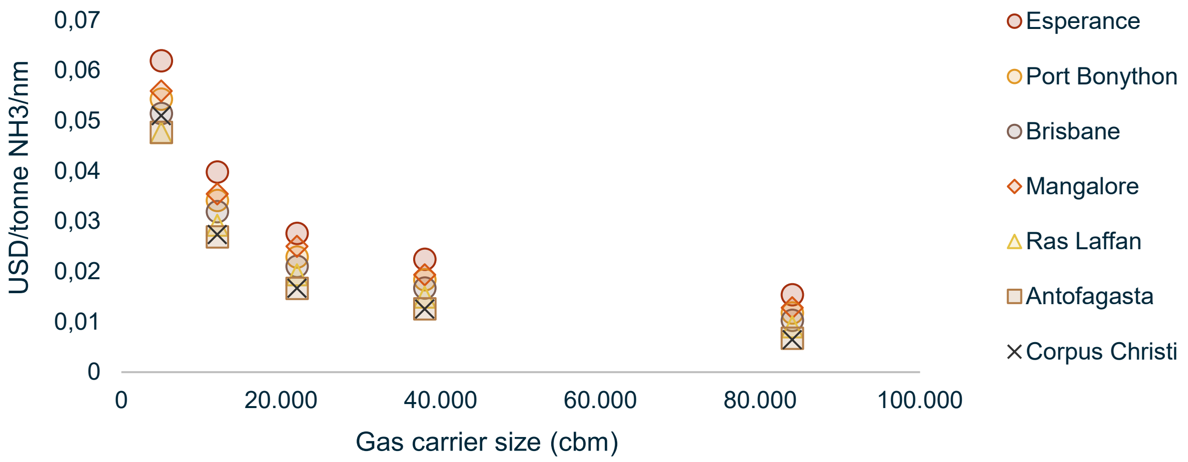
Sailing distance and average costs

Fuel producing region	Origin port	Destination/bunkering port	Nautical miles
Australia	Esperance	Port Hedland	1,484
Australia	Port Bonython	Port Hedland	2,309
Australia	Brisbane	Port Hedland	2,975
India	Mangalore	Singapore	2,045
Middle East	Ras Laffan	Singapore	4,151
Chile	Antofagasta	Singapore	10,407
USA	Corpus Christi	Singapore	13,131

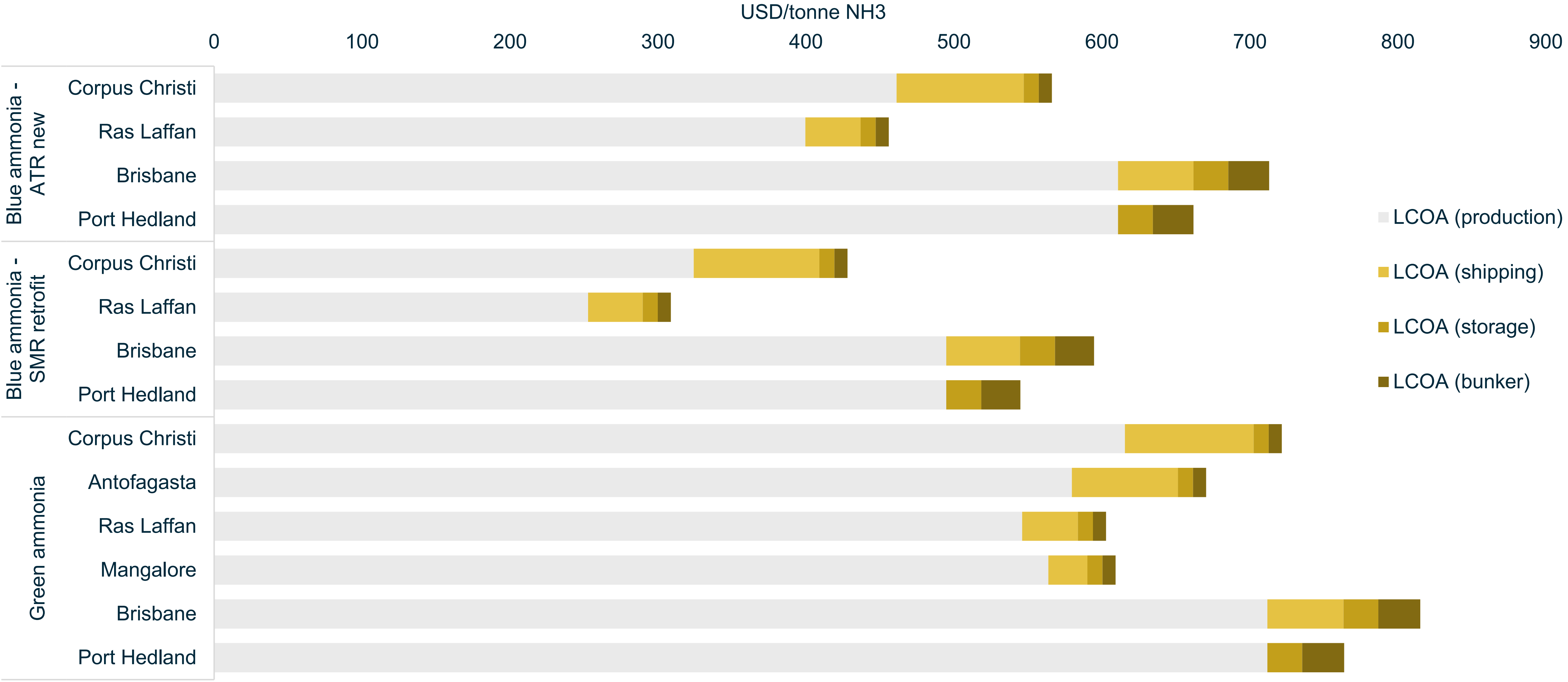
Shipping costs per delivered tonne of green ammonia



Shipping costs per tonne per nautical mile



Total cost of bunkered ammonia



Calculating fuel demand

Current shipping activity on the iron ore trade routes

The shipping activity associated with iron ore exports from Australia to China, South Korea, Japan and Taiwan was assessed as part of the feasibility study for the corridor. Analysis AIS (vessel tracking) data enabled each bulkcarrier transporting iron ore to be identified, and its port-to-port route and operational profile (speed and distance) to be determined.

Based on this information, and with input from corridor taskforce members, the growth of a fleet capable of running on low or zero emission fuels – and the resulting demand for those fuels - was extrapolated from projections of green iron ore demand.

Incorporating the adjustments that dual fuel ammonia vessels may face

Building on the work in the feasibility study, the average fuel consumption to each country was estimated. It was assumed that the vessels would be built with sufficient ammonia storage capacity to sail 15,000 nautical miles (more than four times the one-way sailing distance on the iron ore routes) to future proof the vessels when trading elsewhere.

Given the focus on determining the relative costs of bunkering these bulkcarriers in Port Hedland with ammonia produced in Australia versus in Singapore with ammonia sourced from elsewhere in the world, the outcomes of voyage deviations associated with the latter (time, distance and fuel consumption) was incorporated into the analysis.

Approach to estimating fuel demand

Fuel and vessel demand

- Route/vessel specifications and projected green iron ore volumes were drawn from the corridor feasibility study; these were translated into no. of trips/vessels based on:
  - Route characteristics: avg. distance to each importing country and incorporates no. of deviations for bunkering in Singapore per year
  - Vessel characteristics: bulkcarrier size and newbuild vs retrofit (cargo capacity of vessel is reduced for latter); fuel saving of 23% estimated from energy efficiency measures and EETs
- Fuel demand calculated on energetic basis (GJ) and for BAU apportioned between VLSFO/HSFO and NH3 to meet minimum MEPC 80 target trajectories; VLSFO/HSFO and NH3 split in GSC scenario based on pilot fuel demand
- Fuel apportioning accounts for ammonia WTT carbon intensity from production (including upstream) and shipping

Bunkering deviations

- Bulkcarrier fuel storage specifications:
  - 180k dwt: VLSFO/HSFO tank 5,000 cbm; NH3 tank 4,747 cbm
  - 208k dwt: VLSFO/HSFO tank 5,300 cbm; NH3 tank 4,747 cbm
- No. of bunkering stops per year determined by maximum of number triggered by VLSFO/HSFO vs NH3 refuelling requirement
- For vessels bunkering in Singapore, the additional sailing distance and voyage time is factored in to determine the average no. of trips per year each vessel can take; fuel consumption incurred by the deviation is also accounted for within the model
- Therefore, total fuel demand differs across alternative fuel scenarios and fleet projection in BAU and GSC calculations do not always match

Example of green ammonia demand in GSC and BAU scenarios

Year	Trade		GSC scenario Fuel type: Green ammonia Producer: Middle East Bulkcarrier size: 208,000 dwt Vessel type: Newbuild BAU/pilot fuel: VLSFO				BAU scenario Fuel type: Green ammonia Producer: Middle East Bulkcarrier size: 208,000 dwt Vessel type: Newbuild BAU/pilot fuel: VLSFO			
	Iron ore (mpta)	No. of trips	No. of vessels	Fuel demand (PJ)	VLSFO (tonnes)	NH3 (tonnes)	No. of vessels	Fuel demand (PJ)	VLSFO (tonnes)	NH3 (tonnes)
2028	13	64	8	2.2	7,946	99,249	7	2.1	39,371	27,762
2029	25	124	14	4.1	15,179	189,604	14	4.1	73,683	58,506
2030	36	181	21	6.0	22,042	275,323	20	6.0	101,950	97,176
2031	44	220	25	7.3	26,767	334,342	25	7.3	112,799	142,920
2032	57	289	33	9.6	35,069	438,049	32	9.6	136,325	213,248
2033	75	379	43	12.6	45,946	573,910	42	12.5	159,821	321,518
2034	99	501	57	16.6	60,577	756,669	56	16.5	191,199	467,538
2035	130	656	74	21.7	79,320	990,788	73	21.7	224,843	668,987

Example of blue ammonia demand in GSC and BAU scenarios

Year	Trade		GSC scenario Fuel type: Blue ammonia (ATR new) Producer: Middle East Bulkcarrier size: 208,000 dwt Vessel type: Newbuild BAU/pilot fuel: VLSFO				BAU scenario Fuel type: Blue ammonia (ATR new) Producer: Middle East Bulkcarrier size: 208,000 dwt Vessel type: Newbuild BAU/pilot fuel: VLSFO			
	Iron ore (mpta)	No. of trips	No. of vessels	Fuel demand (PJ)	VLSFO (tonnes)	NH3 (tonnes)	No. of vessels	Fuel demand (PJ)	VLSFO (tonnes)	NH3 (tonnes)
2028	13	64	8	2.2	7,946	99,249	8	2.1	34,451	38,950
2029	25	124	14	4.1	15,179	189,604	14	4.1	63,654	80,973
2030	36	181	21	6.0	22,042	275,323	20	6.0	85,745	133,295
2031	44	220	25	7.3	26,767	334,342	25	7.3	89,477	194,803
2032	57	289	33	9.6	35,069	438,049	32	9.6	102,286	288,812
2033	75	379	43	12.6	45,946	573,910	43	12.5	109,737	432,516
2034	99	501	57	16.6	60,577	756,669	56	16.5	120,164	624,769
2035	130	656	74	21.7	79,320	990,788	74	21.7	125,704	888,213

Scenarios & outputs

Determining compliance

The cost gap is presented as a differential between green shipping corridor (GSC) that entirely run on ammonia and business as usual (BAU) vessels that consume just enough to remain compliant with IMO trajectories.

In July 2023, the IMO updated its strategy on reducing GHG emissions. The level of ambition was lifted to reduce absolute emissions by at least 20% by 2030 and by 70% by 2040 when compared to 2008 levels.

These absolute targets were translated into emissions intensity trajectories based on estimates of future transport work (tonnes carried multiplied by distance shipped). This enabled compliance levels of emissions intensity for each vessel type and size to be extrapolated using the Energy Efficiency Operational Indicators (EEOI) metric.

Comparing scenario options

GSC and BAU scenarios have been modelled independently, i.e. different ammonia types and sources can be used in each. This means that numerous outputs can be produced depending on the focus of investigation.

As an example, in the slides below, two cost differentials have been modelled. The first compares GSC and BAU scenarios running on the same type/source of ammonia. The second example retains the above assumptions for the GSC scenario but models the BAU scenario using the cheapest source of ammonia.

The overall cost gap is driven by the relative GHG intensity (which determines the required volume in the BAU scenario) and cost of the fuels selected. But in both examples, the falling cost differential depicts the increasing role of compliance, and thus the falling role of 'voluntary' ammonia use over time.

Considerations when building appropriate scenarios

Business as usual vs green shipping corridor

- The cost gap is calculated as the differential between:
  - BAU scenario: fleet consumes minimum amount of ammonia to comply with MEPC 80 minimum target trajectories
  - GSC scenario: fleet consumes maximum amount of ammonia (less pilot fuel requirement) each year
- The model can compare BAU and GSC scenarios that utilise different types and sources of ammonia
- Two examples have been presented in the following slides:
  - Like-for-like: BAU meets compliance using the same ammonia type/source as GSC and bunkering in the same location
  - Cheapest compliance: GSC uses green ammonia produced in Australia and bunkers in Port Hedland; BAU uses the cheapest type/source of ammonia (blue ammonia via SMR retrofit from the Middle East) to meet compliance and bunkers in Singapore

Limitations of model

- As IMO targets signal that zero/low carbon fuels will need to be used to meet compliance by 2028, all vessels are assumed to be dual fuel and no vessel-related CAPEX/non-fuel OPEX has been applied, even where vessel numbers differ between the scenarios
- The analysis assumes that ammonia is used to reduce BAU vessel carbon intensity to reach compliance rather than any alternative low/zero emission fuels such as biofuel or methanol
- All LCOAs generated by analysis are based on estimated production cost, not market price: this may be a reasonable starting point in relation to an offtake agreement, but may not be a suitable proxy for bunker fuels purchased at spot market prices
- Fuel costs remain fixed between 2028 and 2035 in both scenarios; while this could be deemed to appropriately reflect ammonia offtake secured for the GSC scenario, for the BAU scenario, an argument could be made for using variable costs over that period stemming from learning curves/economies of scale for green ammonia or fluctuating gas costs for blue ammonia

Cost gap when GSC and BAU use same ammonia type/source

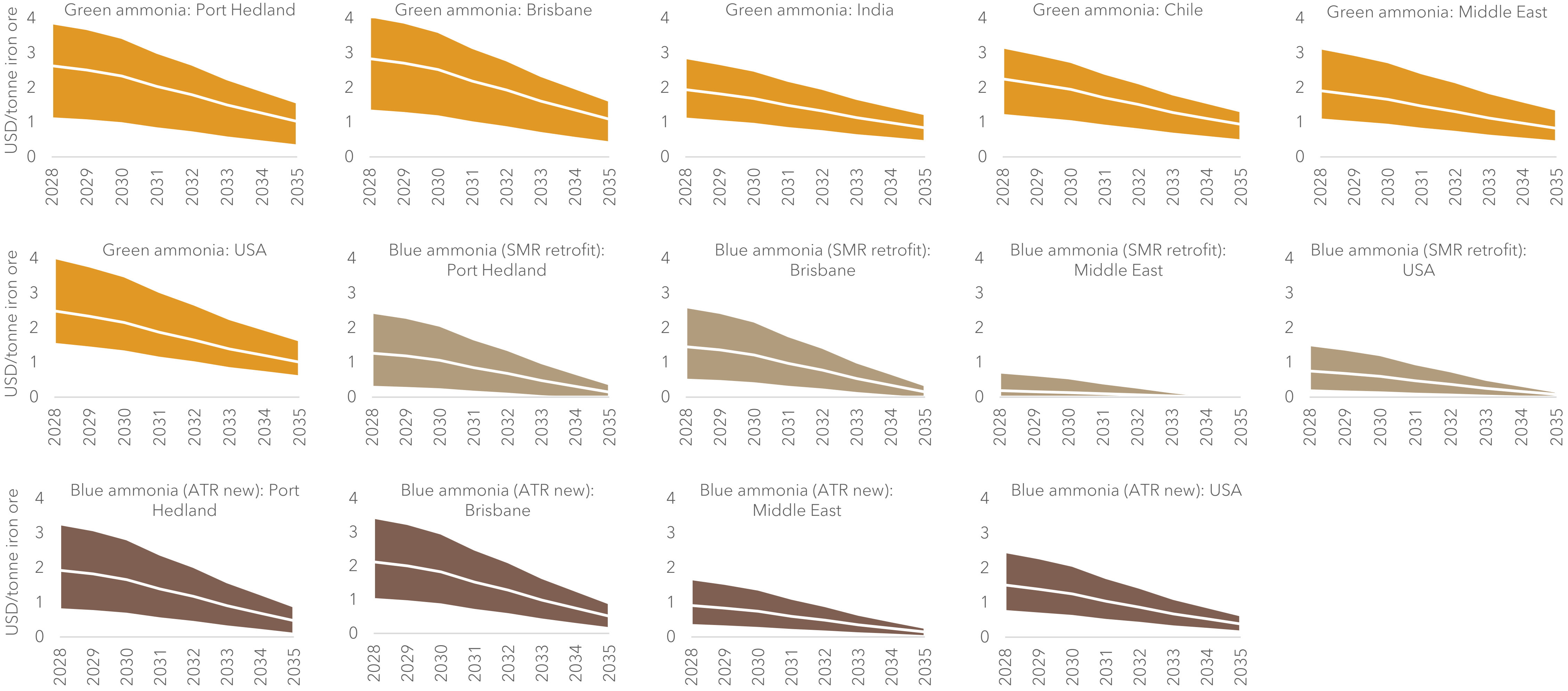
	GSC scenario Fuel type: Green ammonia Producer: Australia (Port Hedland) Bulkcarrier size: 208,000 dwt Vessel type: Newbuild BAU/pilot fuel: VLSFO **Bunkered LCOA: USD 763/tonne NH3**				**BAU scenario** Fuel type: Green ammonia Producer: Australia (Port Hedland) Bulkcarrier size: 208,000 dwt Vessel type: Newbuild BAU/pilot fuel: VLSFO **Bunkered LCOA: USD 763/tonne NH3**				**Cost differential**	
Year	VLSFO (USDm)	NH3 (incl. shipping) (USDm)	Last mile (USDm)	Total cost (USDm)	VLSFO (USDm)	NH3 (incl. shipping) (USDm)	Last mile (USDm)	Total cost (USDm)	Total cost (USDm)	USD per tonne iron ore
2028	5	69	5	78	24	19	2	45	33.4	2.63
2029	9	133	10	152	44	41	5	90	61.8	2.51
2030	13	194	14	221	61	68	9	138	83.7	2.33
2031	16	236	17	269	68	100	13	180	88.8	2.04
2032	21	310	22	353	82	149	19	250	102.9	1.80
2033	27	407	29	463	96	226	29	351	112.7	1.50
2034	36	537	39	612	115	330	42	486	125.3	1.26
2035	47	703	51	801	135	473	60	668	133.3	1.03

Cost gap from like-for-like ammonia type/source in GSC vs BAU

Year	Green ammonia						Blue ammonia - SMR retrofit				Blue ammonia - ATR			
	Port Hedland	Brisbane	India	Chile	Middle East	USA (USCG)	Port Hedland	Brisbane	Middle East	USA (USCG)	Port Hedland	Brisbane	Middle East	USA (USCG)
Total cost differential (USDm)														
2028	33	36	25	29	24	32	16	19	2	10	24	27	12	19
2029	62	67	45	52	44	57	29	33	4	17	45	49	20	34
2030	84	90	61	70	60	77	38	44	5	21	60	65	27	45
2031	89	96	65	74	64	82	37	42	4	20	61	66	26	45
2032	103	111	76	87	75	94	39	44	4	21	67	74	28	50
2033	113	121	85	96	84	104	36	40	3	19	68	74	26	51
2034	125	134	98	110	97	119	31	34	1	16	68	74	25	53
2035	133	142	109	122	108	131	19	20	0	10	62	66	19	50

Year	Port Hedland	Brisbane	India	Chile	Middle East	USA (USCG)	Port Hedland	Brisbane	Middle East	USA (USCG)	Port Hedland	Brisbane	Middle East	USA (USCG)
Additional cost of shipping (USD/tonne iron ore)														
2028	2.63	2.84	1.94	2.25	1.91	2.49	1.27	1.46	0.19	0.75	1.93	2.12	0.91	1.51
2029	2.51	2.71	1.82	2.11	1.79	2.33	1.19	1.36	0.16	0.68	1.82	2.01	0.83	1.39
2030	2.33	2.52	1.69	1.95	1.66	2.15	1.06	1.22	0.13	0.60	1.66	1.83	0.74	1.25
2031	2.04	2.19	1.49	1.71	1.47	1.87	0.85	0.97	0.09	0.47	1.39	1.52	0.60	1.04
2032	1.80	1.93	1.33	1.51	1.31	1.65	0.68	0.78	0.07	0.37	1.17	1.28	0.49	0.87
2033	1.50	1.61	1.14	1.28	1.12	1.39	0.47	0.53	0.03	0.25	0.90	0.98	0.35	0.67
2034	1.26	1.35	0.99	1.11	0.97	1.20	0.31	0.34	0.01	0.16	0.69	0.75	0.25	0.53
2035	1.03	1.09	0.84	0.94	0.83	1.01	0.14	0.15	0.00	0.08	0.47	0.51	0.15	0.39

Impact of variance in production costs for like-for-like ammonia



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Cost gap assuming BAU uses lowest cost fuel to meet compliance

	GSC scenario Fuel type: Green ammonia Producer: Australia (Port Hedland) Bulkcarrier size: 208,000 dwt Vessel type: Newbuild BAU/pilot fuel: VLSFO **Bunkered LCOA: USD 763/tonne NH3**				**BAU scenario** Fuel type: Blue ammonia (SMR retrofit) Producer: Middle East Bulkcarrier size: 208,000 dwt Vessel type: Newbuild BAU/pilot fuel: VLSFO **Bunkered LCOA: USD 307/tonne NH3**				**Cost differential**	
Year	VLSFO (USDm)	NH3 (incl. shipping) (USDm)	Last mile (USDm)	Total cost (USDm)	VLSFO (USDm)	NH3 (incl. shipping) (USDm)	Last mile (USDm)	Total cost (USDm)	Total cost (USDm)	USD per tonne iron ore
2028	5	69	5	78	19	13	1	33	45.6	3.59
2029	9	133	10	152	34	28	2	63	88.2	3.59
2030	13	194	14	221	45	45	3	93	128.2	3.57
2031	16	236	17	269	44	66	4	115	154.5	3.54
2032	21	310	22	353	48	98	6	152	201.5	3.52
2033	27	407	29	463	45	147	9	201	262.2	3.49
2034	36	537	39	612	43	212	13	268	343.9	3.47
2035	47	703	51	801	35	300	18	354	447.9	3.45

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