Pathways to the decarbonisation of shipping using green ammonia

22nd of February 2024

www.agile-initiative.ox.ac.uk/sprints/

The Agile Initiative

at the Oxford Martin School

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SPRINT TEAM

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Structure of the webinar

Introduction Rene Banares-Alcantara

Presentation of project results

- Context (Jasper)
- Overall model (Carlo)
- Green ammonia production (Carlo)
- Maritime fuel demand (Jasper)
- Supply-demand network (Jasper)
- Sensitivity analyses (Carlo)
- Policy instruments (Anupama)
- Contracts for Difference (Anupama)

Q&A Jim Hall

Pathways to the decarbonisation of shipping using green ammonia

Results

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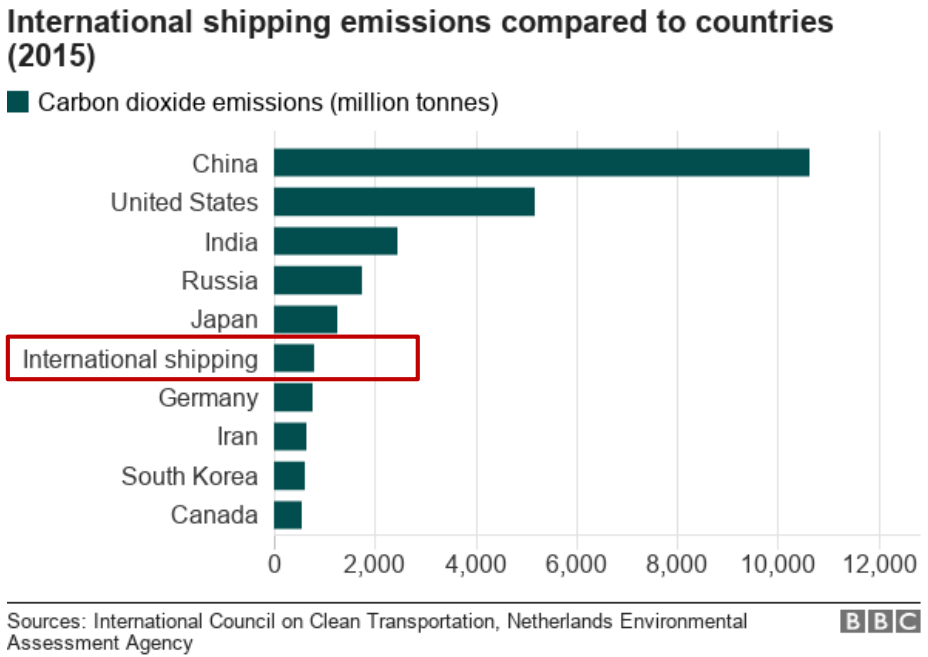
Shipping major GHG emitter

3% **of global CO2 emissions**



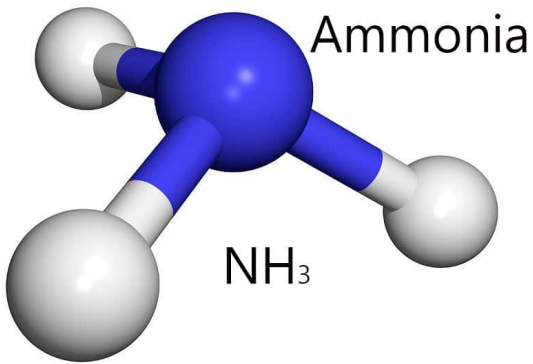
Policy push to decarbonize

Net-Zero emissions by around **2050**

IMO Revised GHG Strategy 2023

Green ammonia as a fuel

International Energy Agency: Dominant alternative maritime fuel by 2050

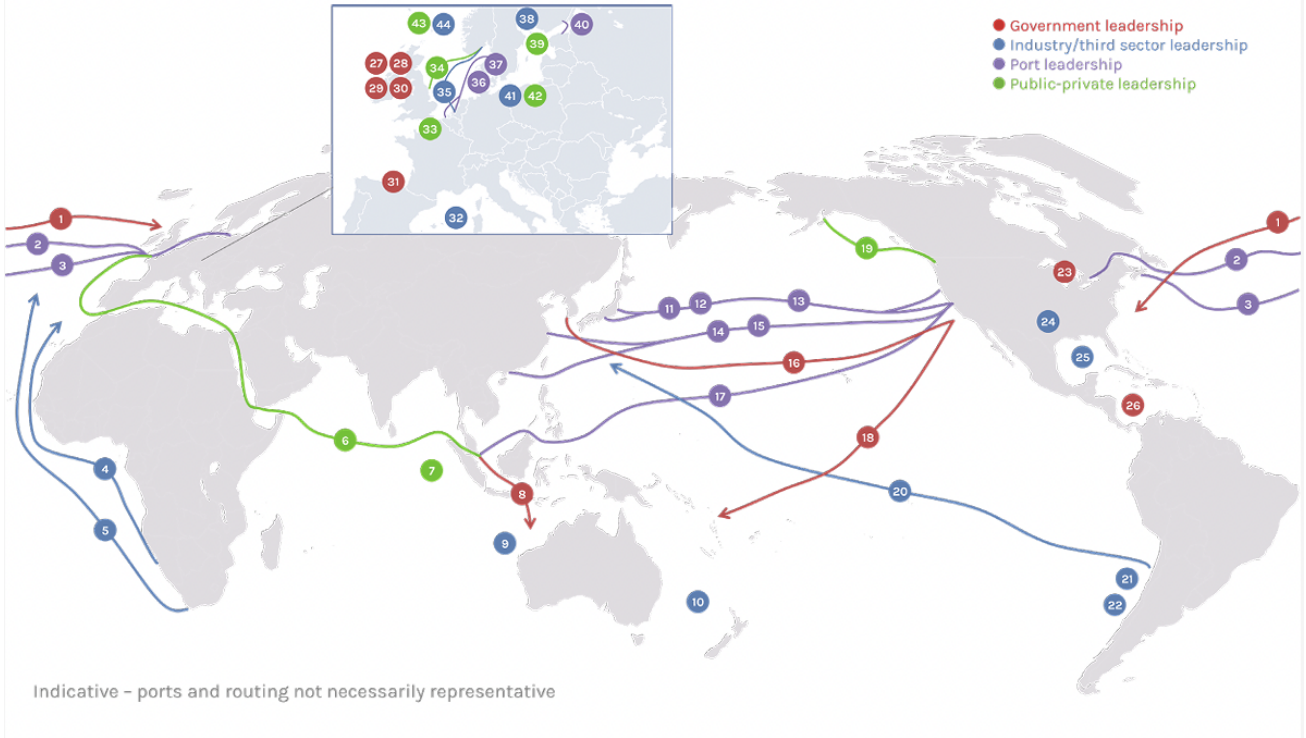


~180 million tonnes NH3, mainly for fertilizer

Green ammonia using **renewables, air and water**

Green Shipping Corridors

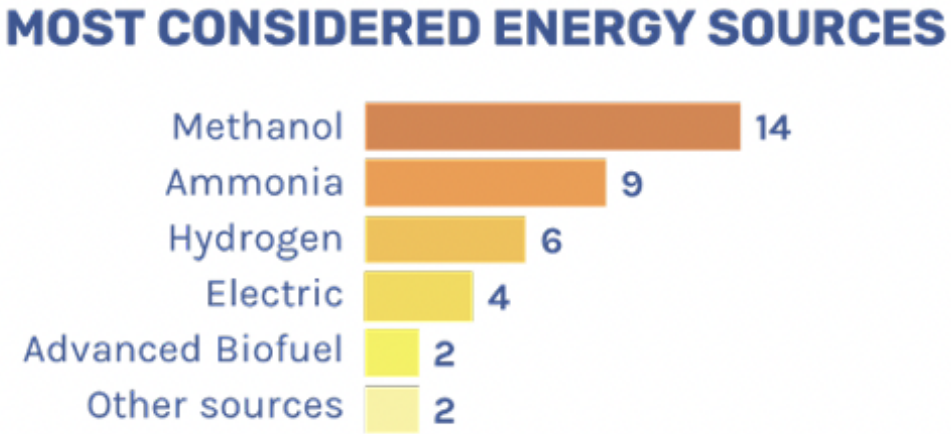
Green corridors map

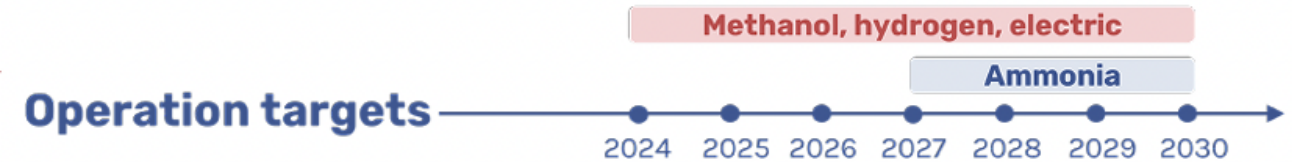


Ongoing initiatives to set up **green shipping corridors**

Global Maritime Forum, 2023

Green Shipping Corridors



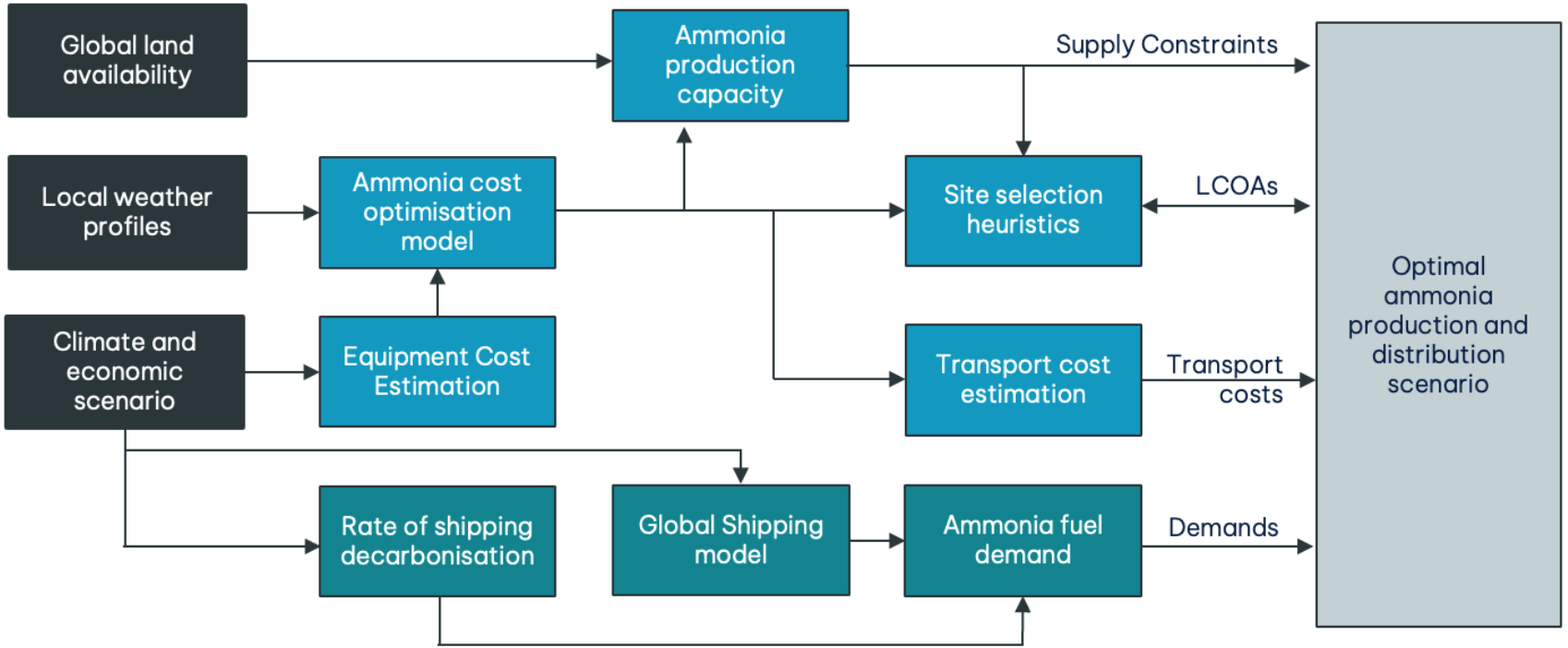


Ammonia considered feasible from **second half of this decade**

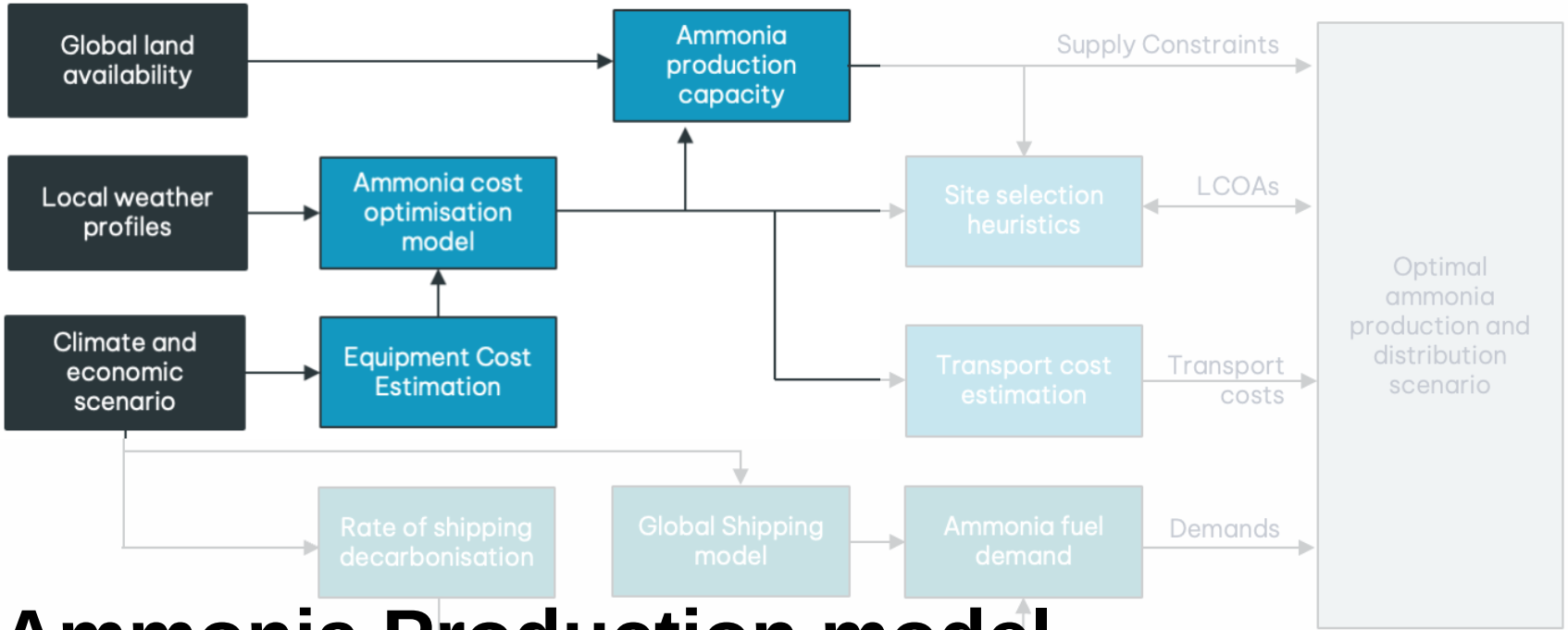
Global Maritime Forum, 2023

How could a future green ammonia supply network look like in 2050?

Model Summary

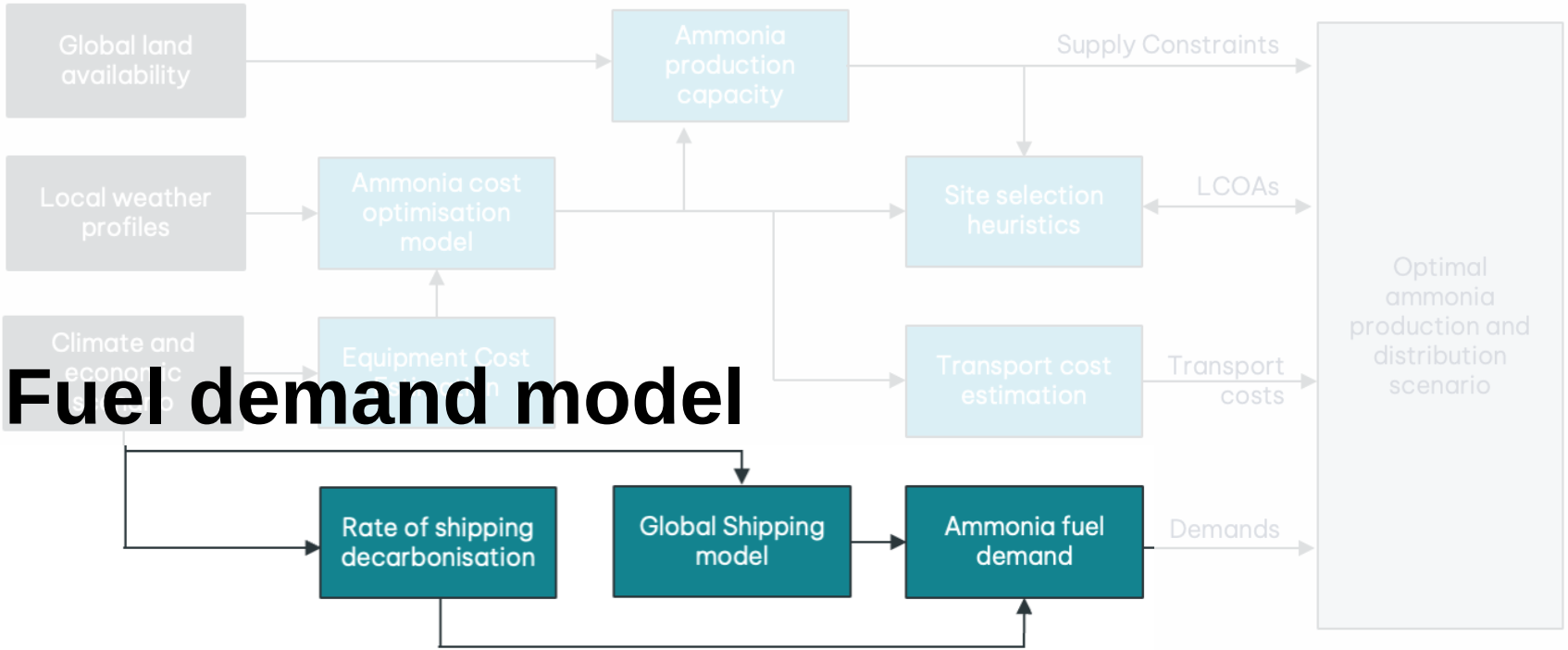


Model Summary

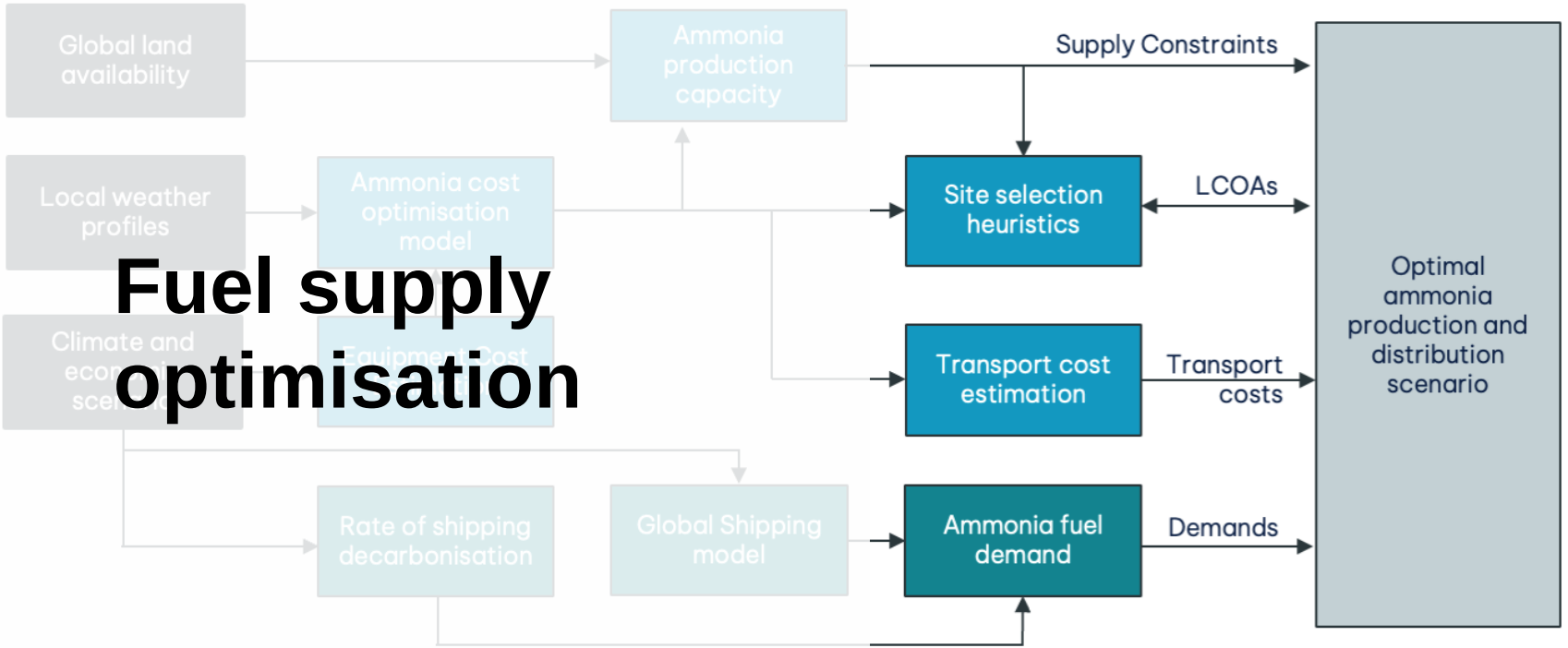


Ammonia Production model

Model Summary



Model Summary



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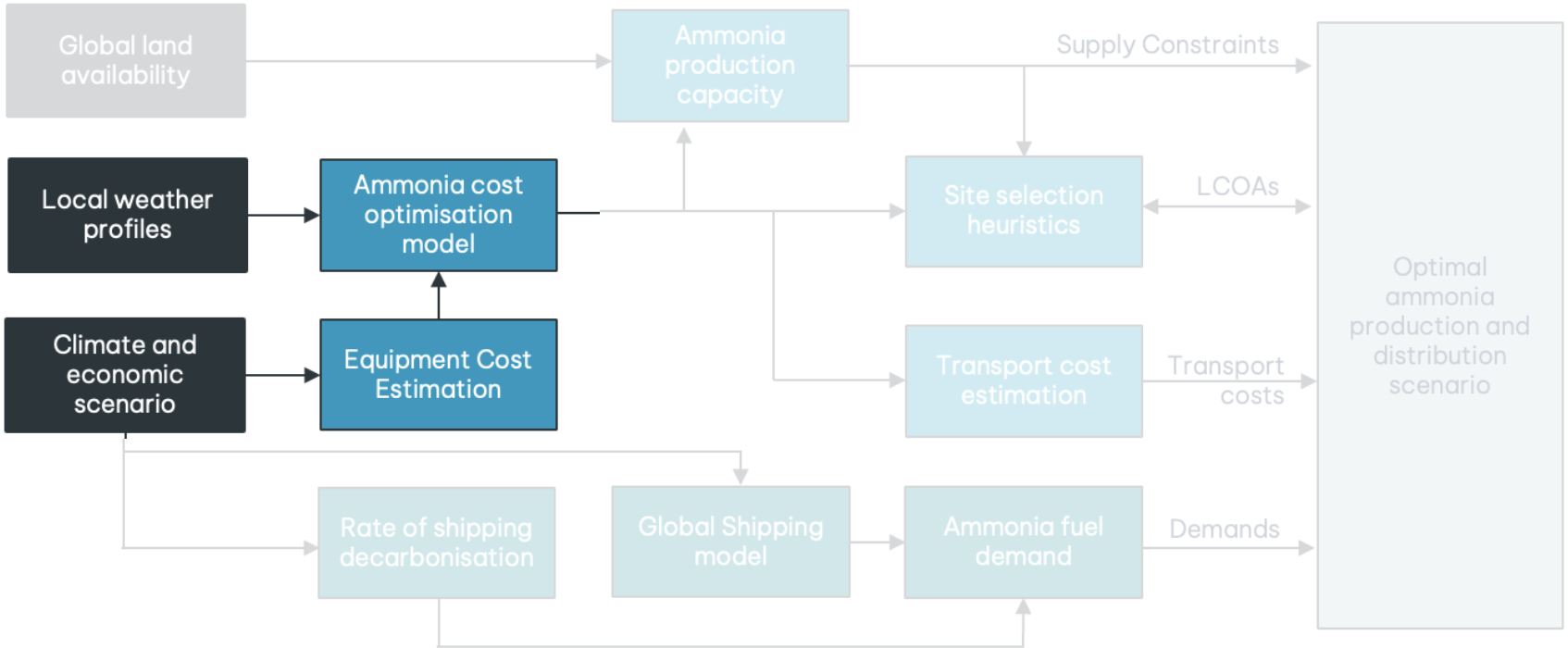
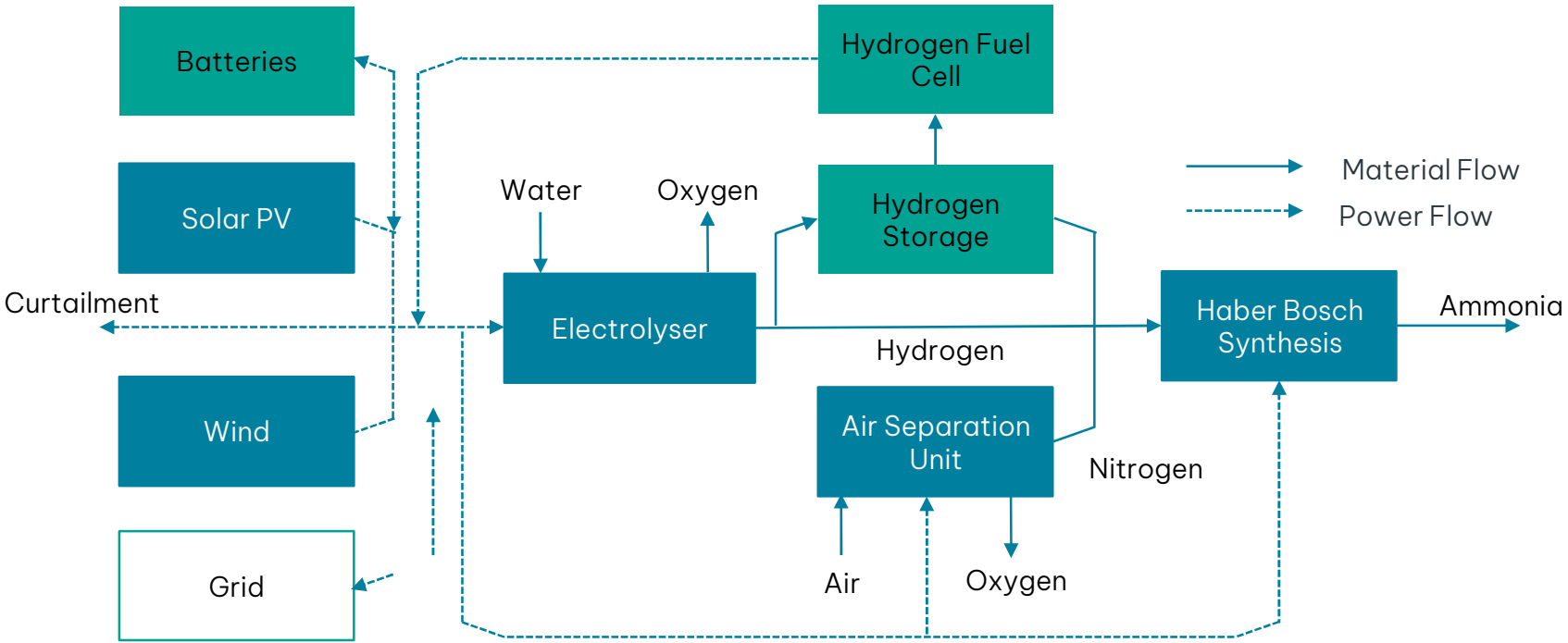
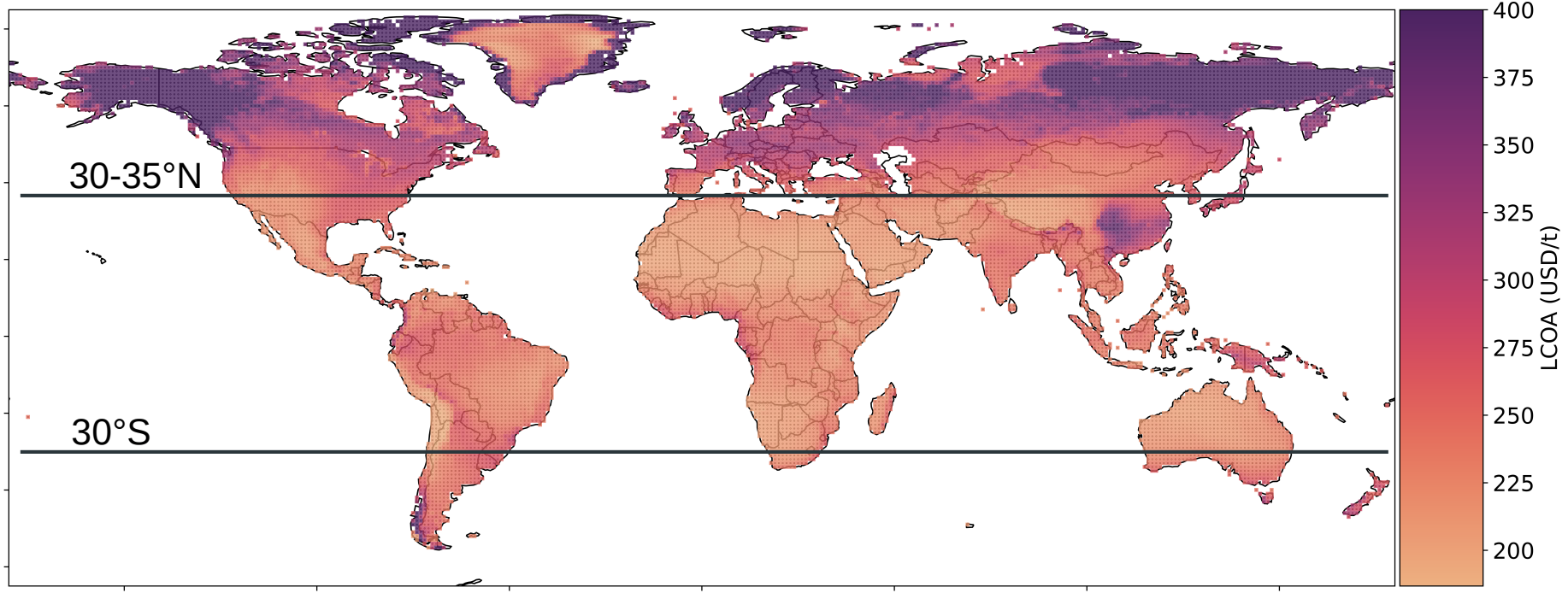


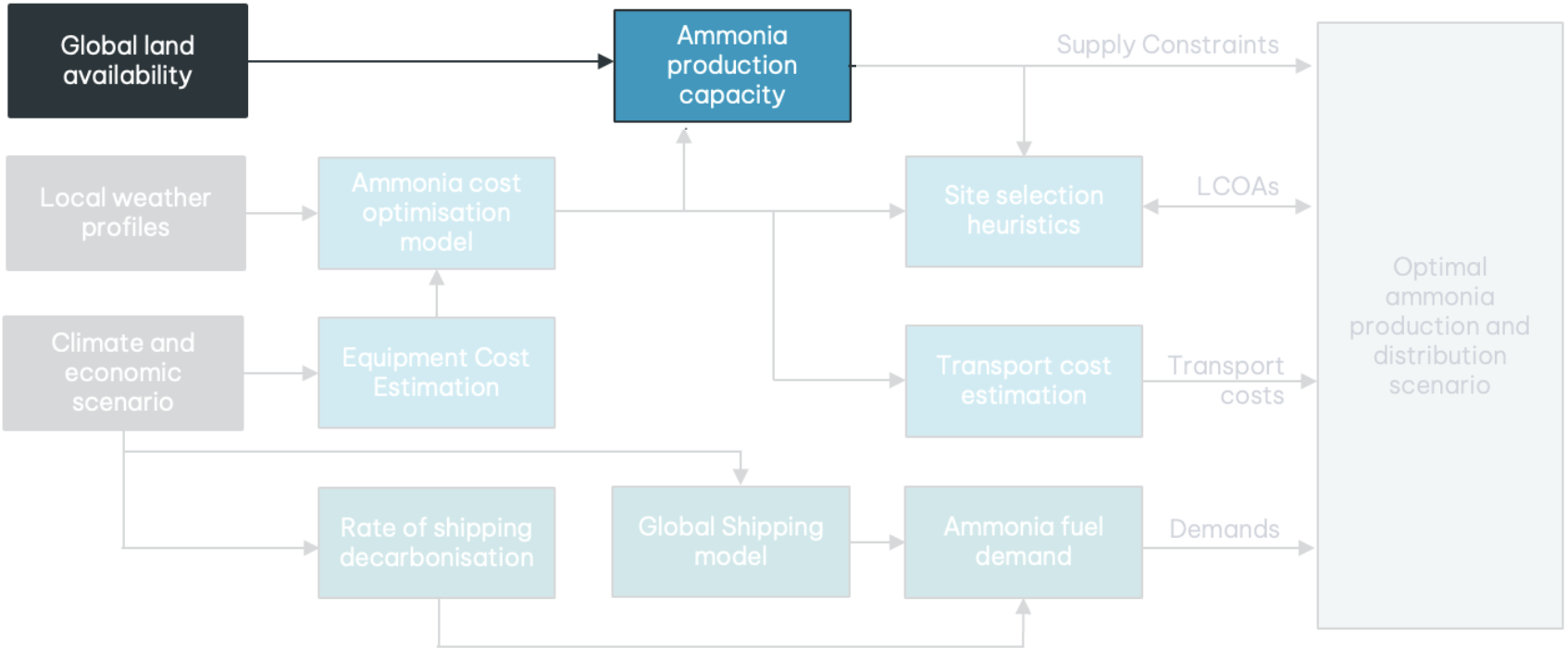
Production cost estimates



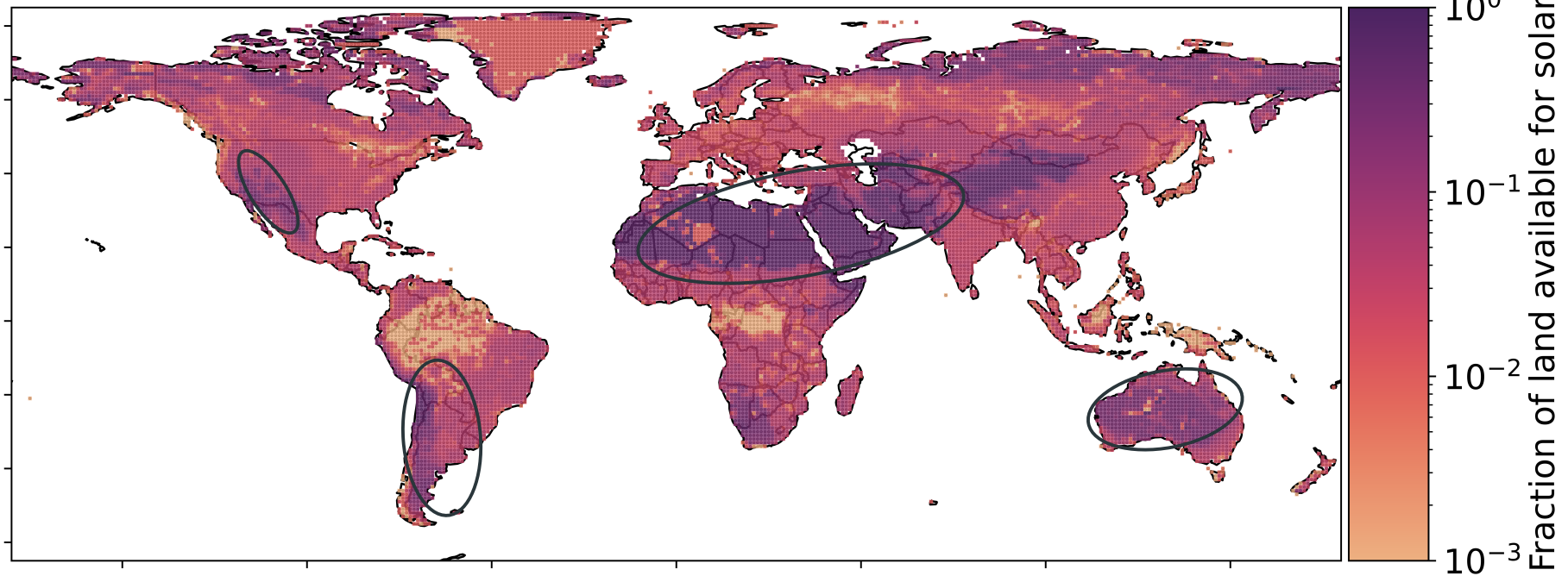
Production cost of green ammonia in 2050



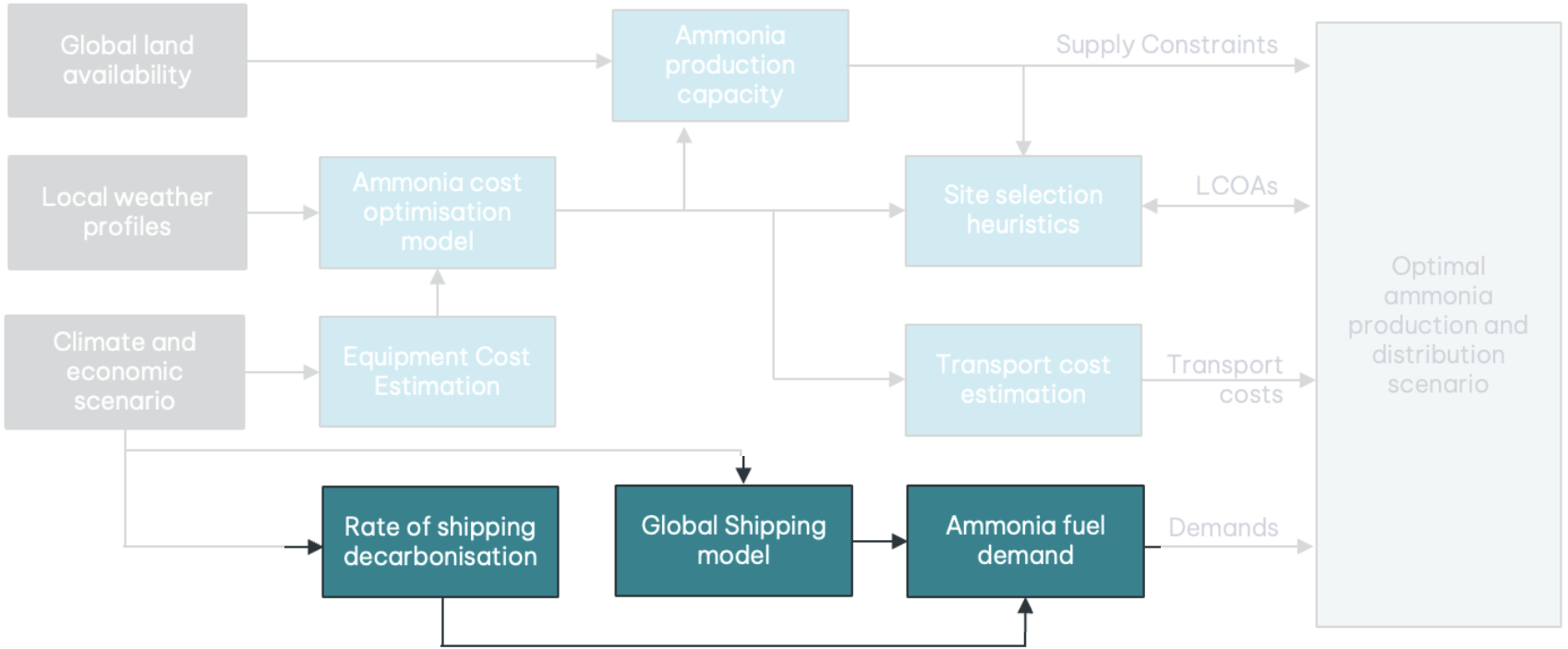
Model Summary



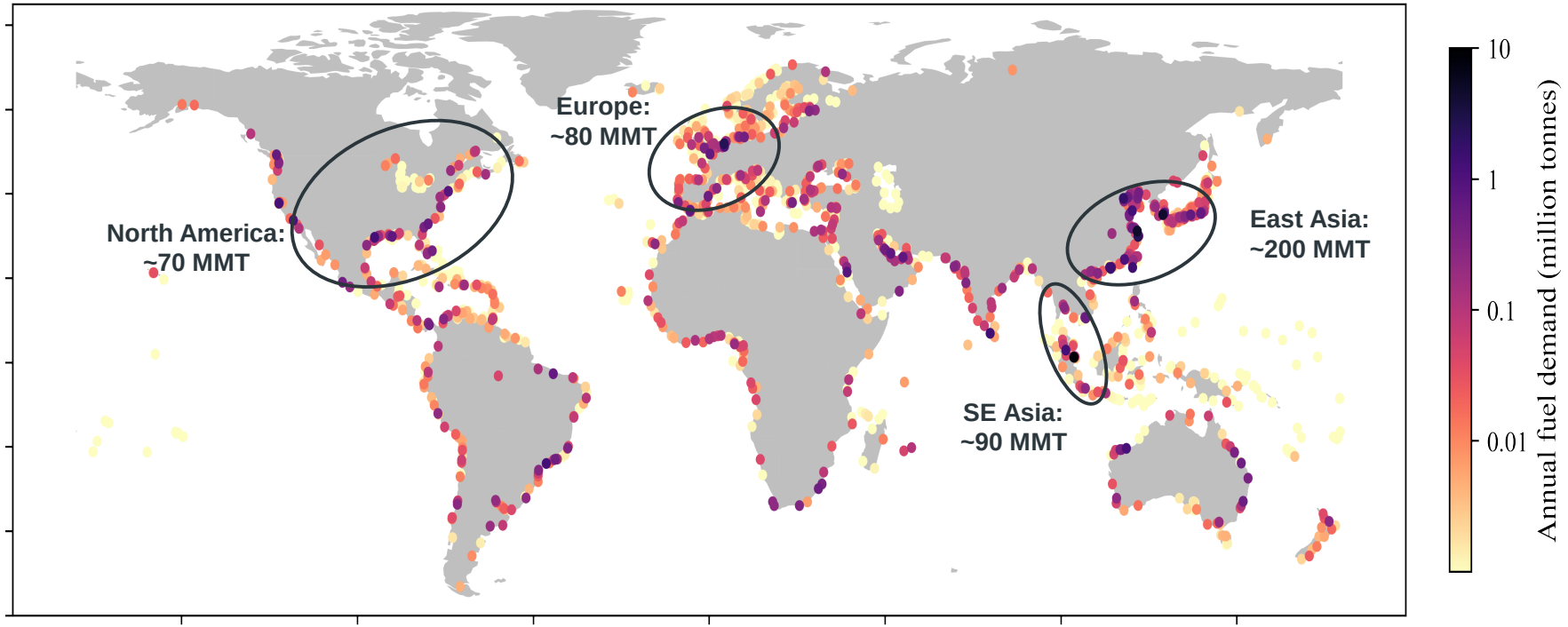
Land Availability



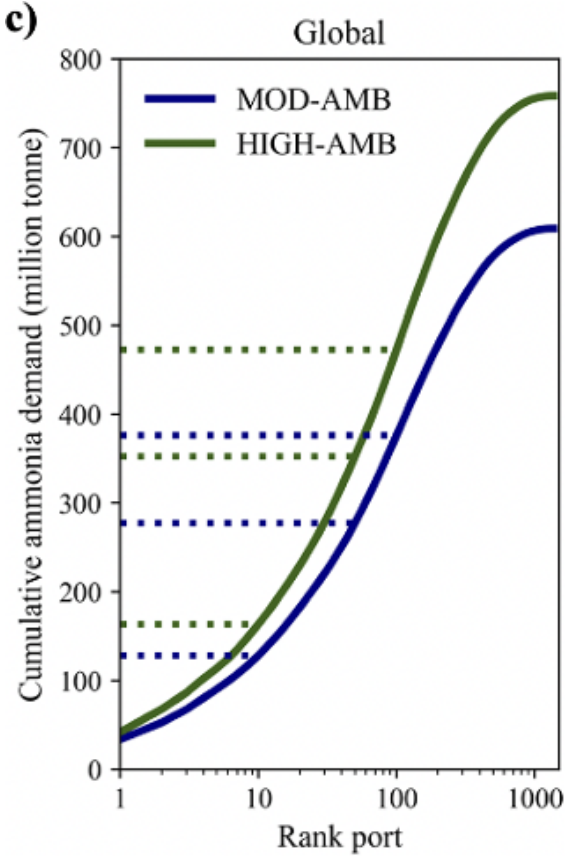
Model Summary



Fuel demand estimates at ports



Fuel demand estimates globally



Moderate ambition (**MOD-AMB**) scenario:

600 million tonnes

High ambition (**HIGH-AMB**) scenario:

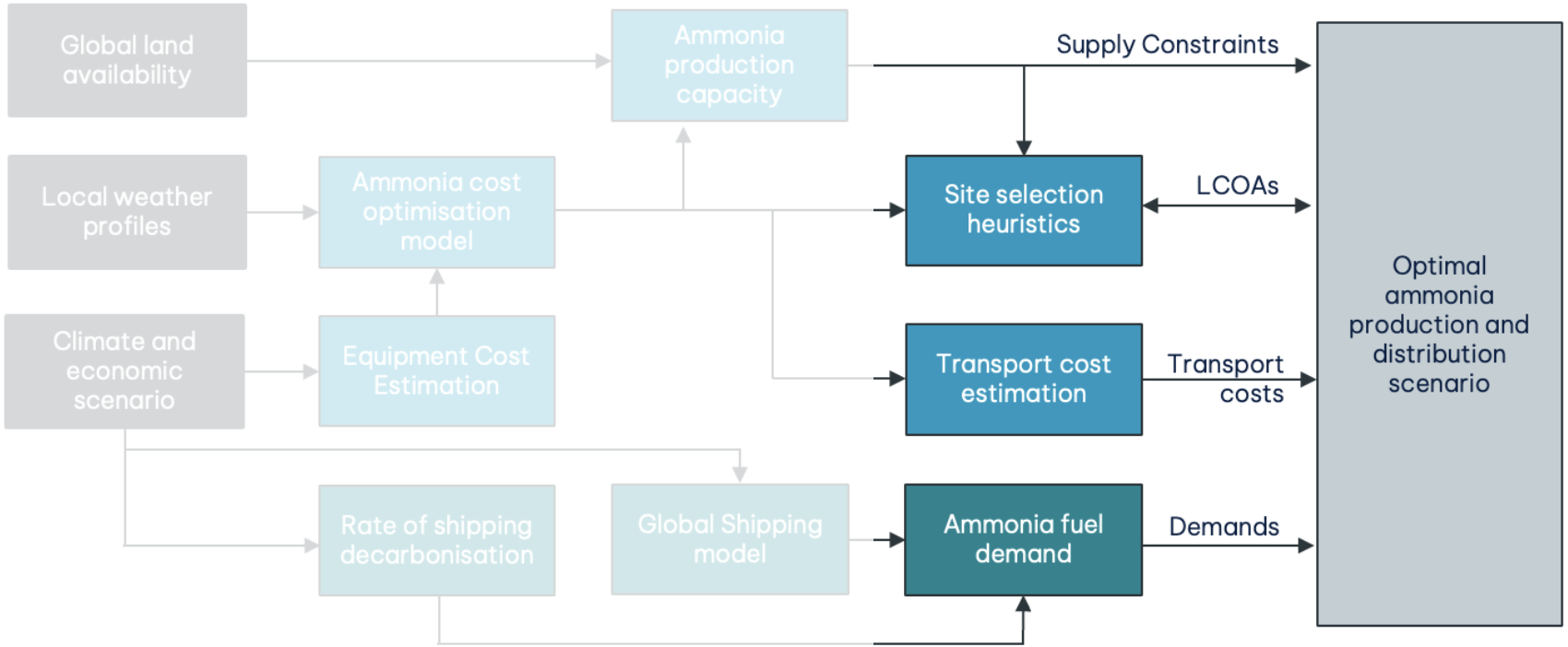
750 million tonnes

Description	MOD-AMB	HIGH-AMB
Socio-economic growth	Shared Socioeconomic Pathway 'Middle of the Road' (SSP2)	Shared Socioeconomic Pathway 'Sustainability' (SSP1)
Decarbonisation	Representative Concentration Pathway 4.5	Representative Concentration Pathway 2.6
Fleet adoption rate	70%	90%

Fuel demand estimates

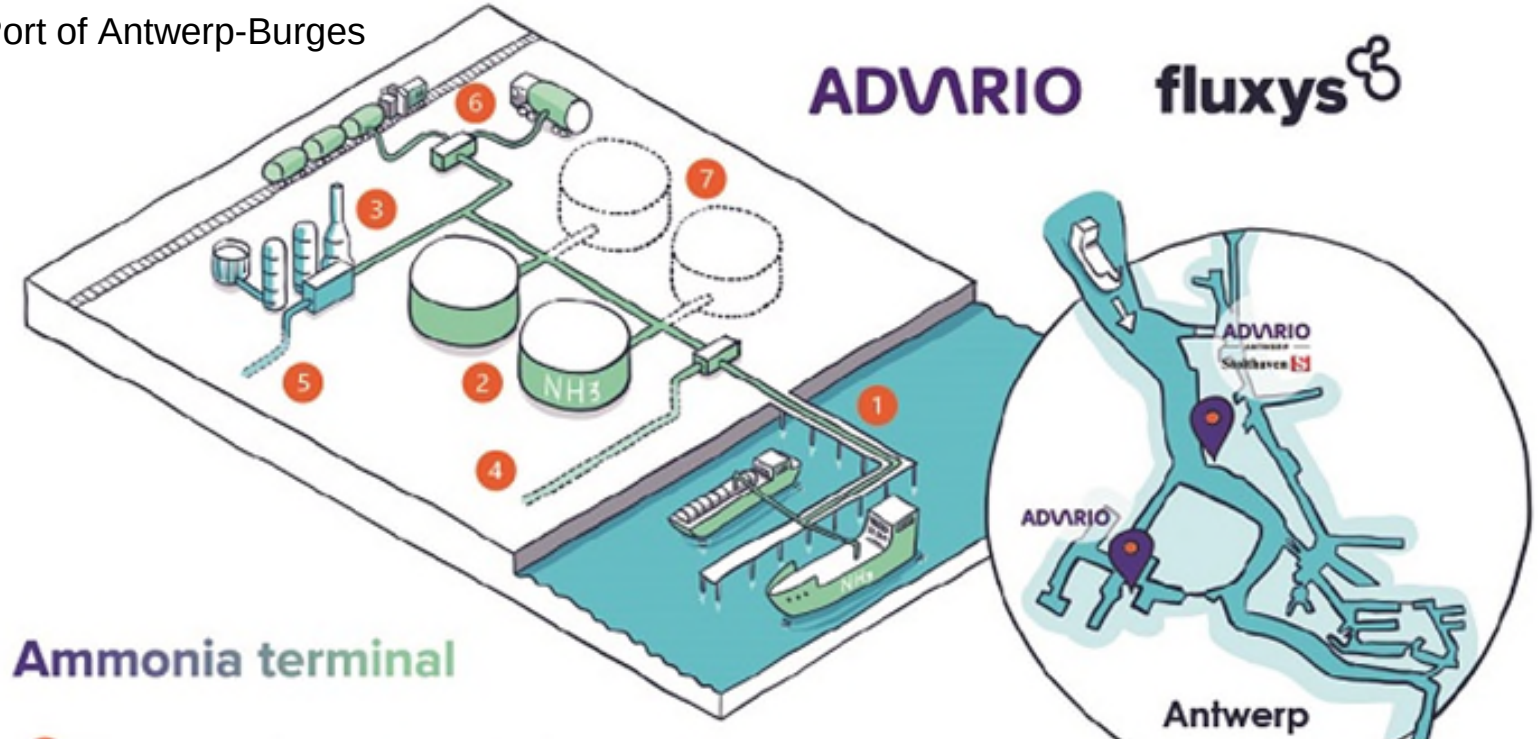
x10,000

Model Summary

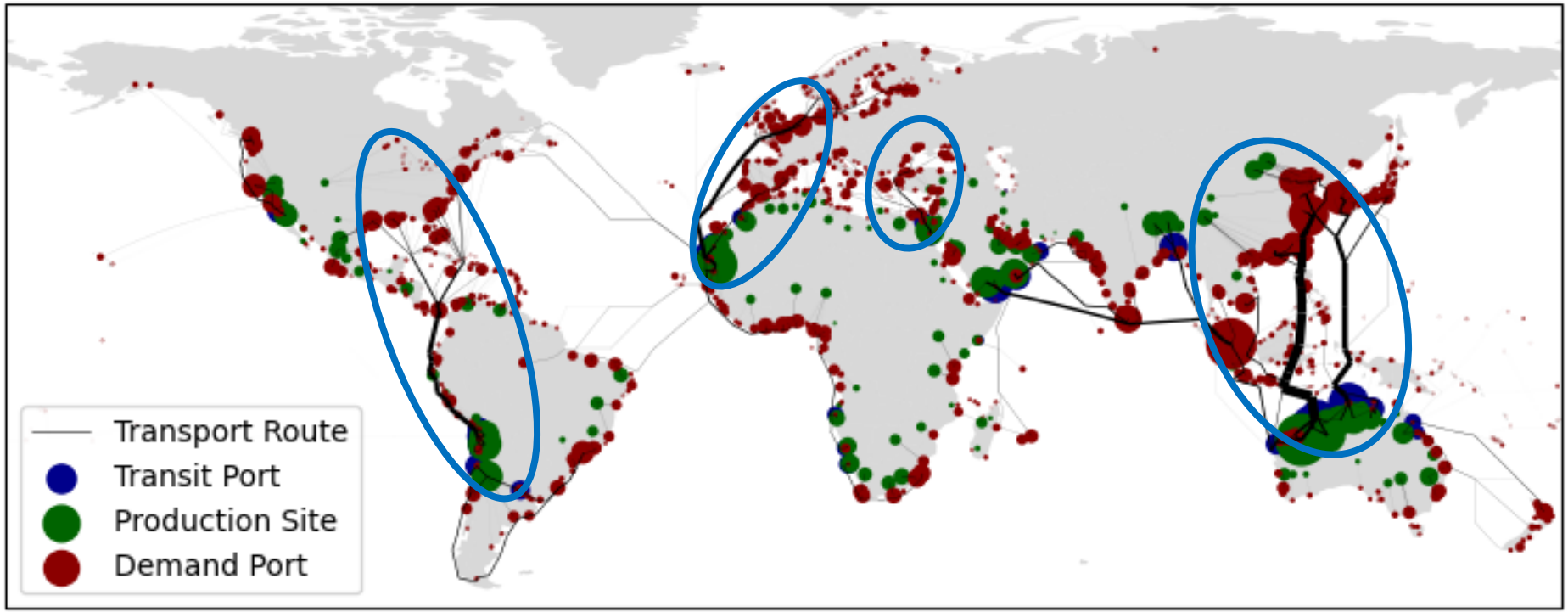


Green ammonia fuel supply

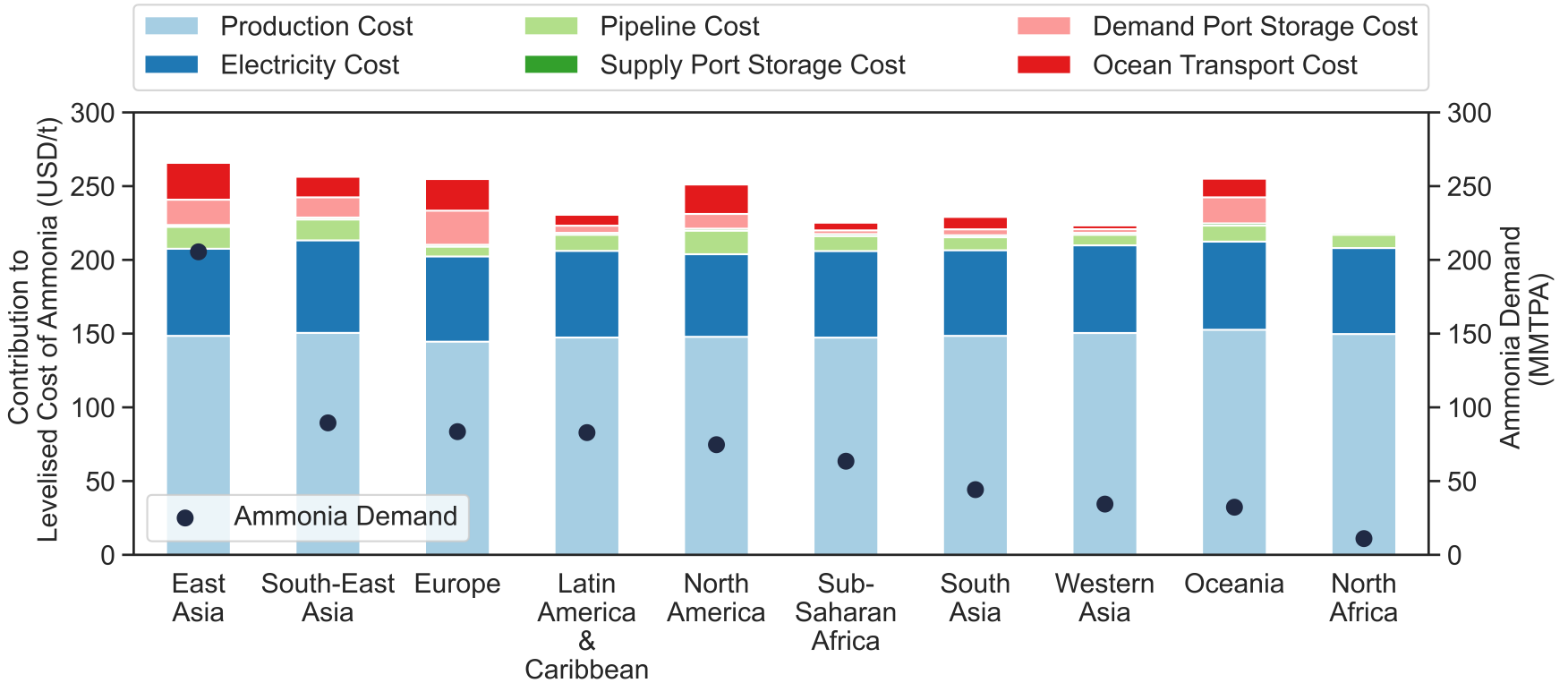
Source: Port of Antwerp-Burges



Global optimal fuel supply network



Regional Distribution

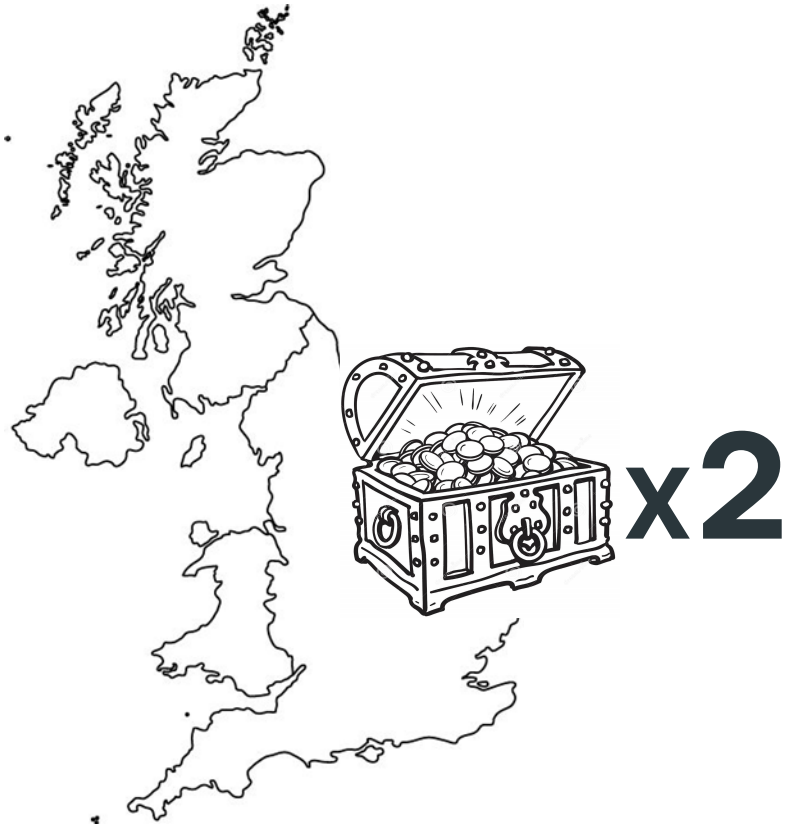


Investment costs

USD 2 trillion

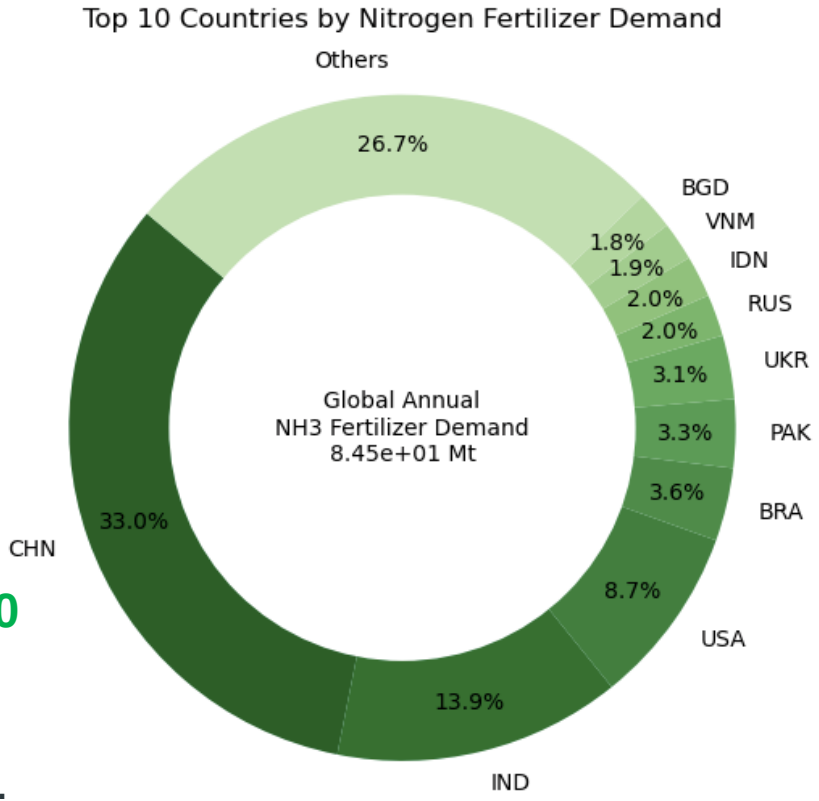
investment

50% in low and middle-income countries



Sensitivity analysis

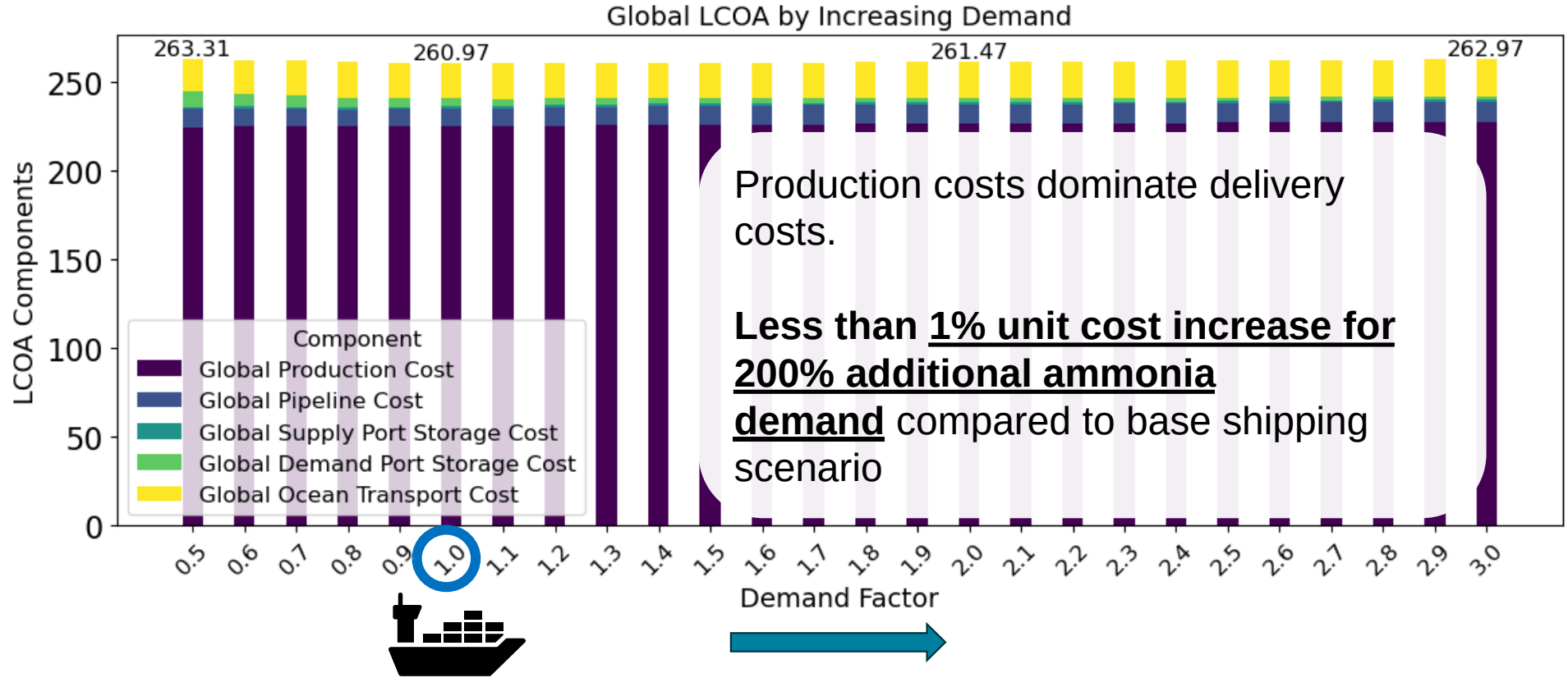
Additional demand for ammonia for fertilizer



Fertilizer demand is an **additional 14% to 2050** bunkering demand

Minimal impact on LCOA and supply patterns.

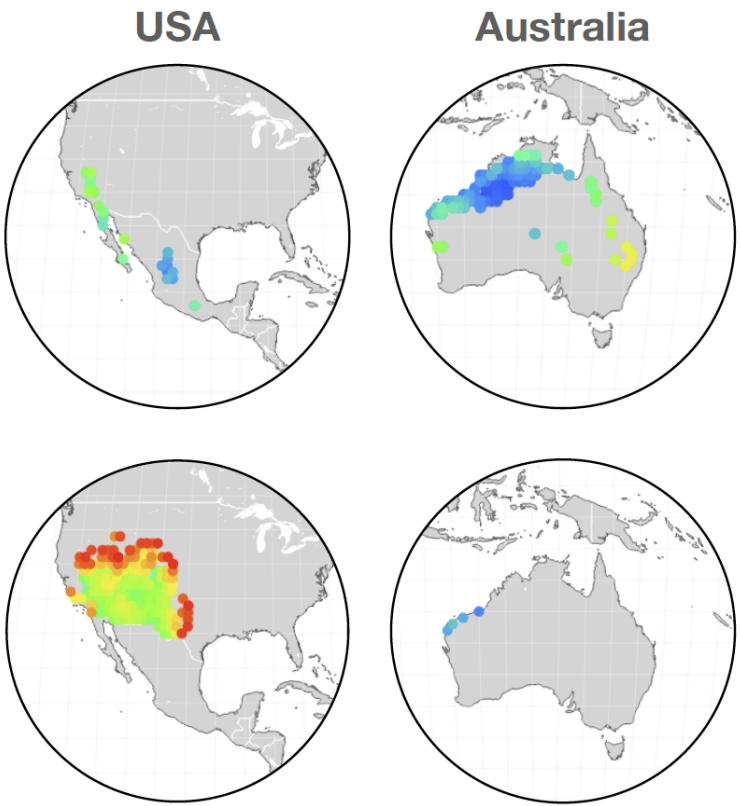
Cost robust to additional demand



Hydrogen subsidies

Country	H_2 subsidy (USD/tonne)		NH_3 subsidy (USD/tonne)		Max budget (USD billion)
	Low	High	Low	High	
USA	2500	3500	450	630	369
EU27	1000	4000	180	720	5.68
Australia	1000	2000	180	360	1.33

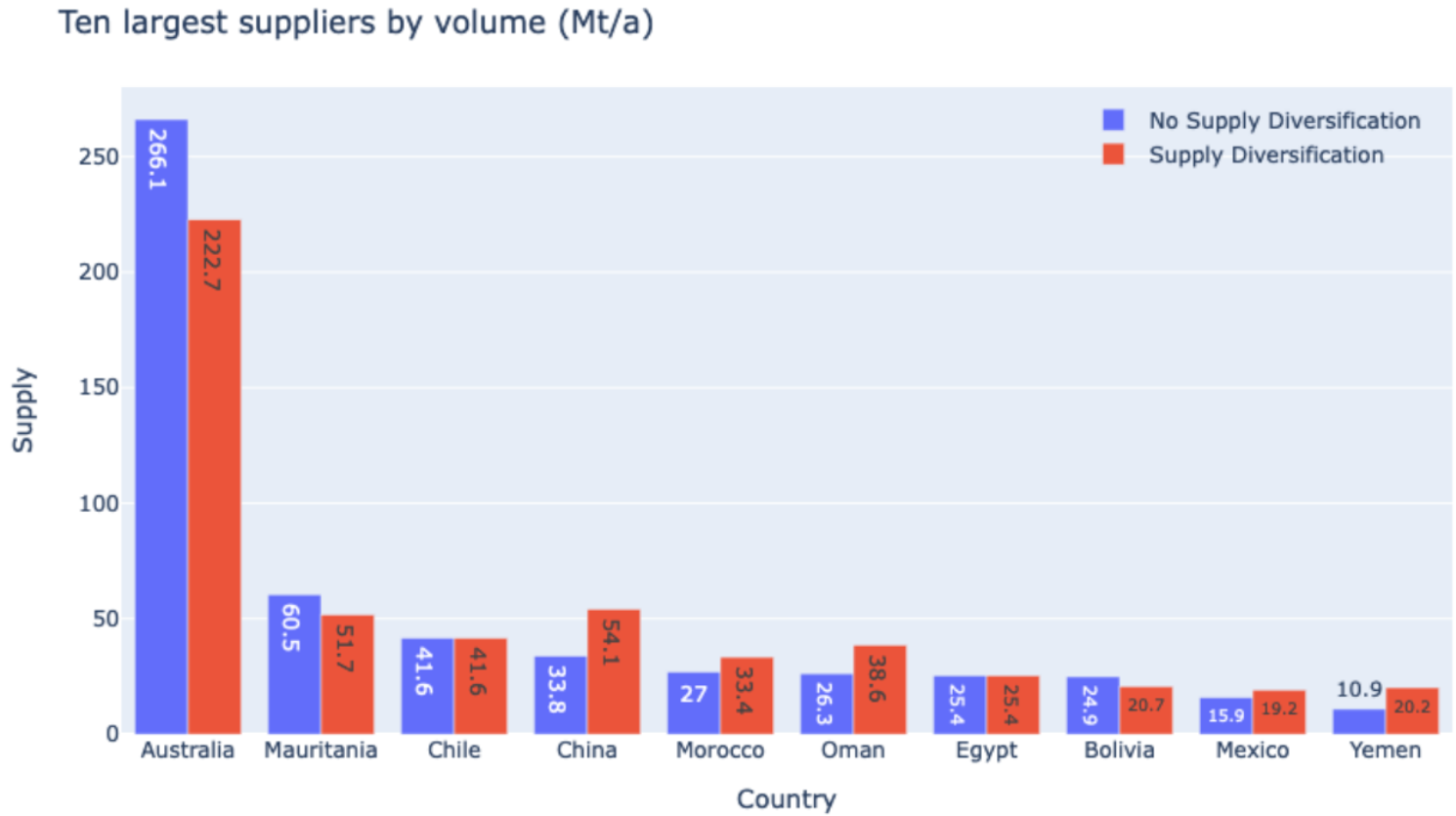
Hydrogen subsidies



Without subsidy

With subsidy

Supply diversification



Increases production in a few “second best” countries

Global characteristics are mostly unchanged.

Conclusions

If green ammonia becomes the main shipping fuel

- Production concentrated **between 30 degrees S and N**
- **2 trillion of investments** needed, with large share in LI + MI countries
- **Regional fuel supply** networks
- **Target regional fuel hubs** can decarbonize a large share of shipping

Fuel network robust against uncertainties

- Additional demand and supply diversification

Subsidies may distort “optimal solution”

- Hydrogen subsidies shape first mover projects

Challenges to overcome:

- Safe handling of a toxic and corrosive product
- Requires steep cost decline of renewables, electrolysers and fuel cells

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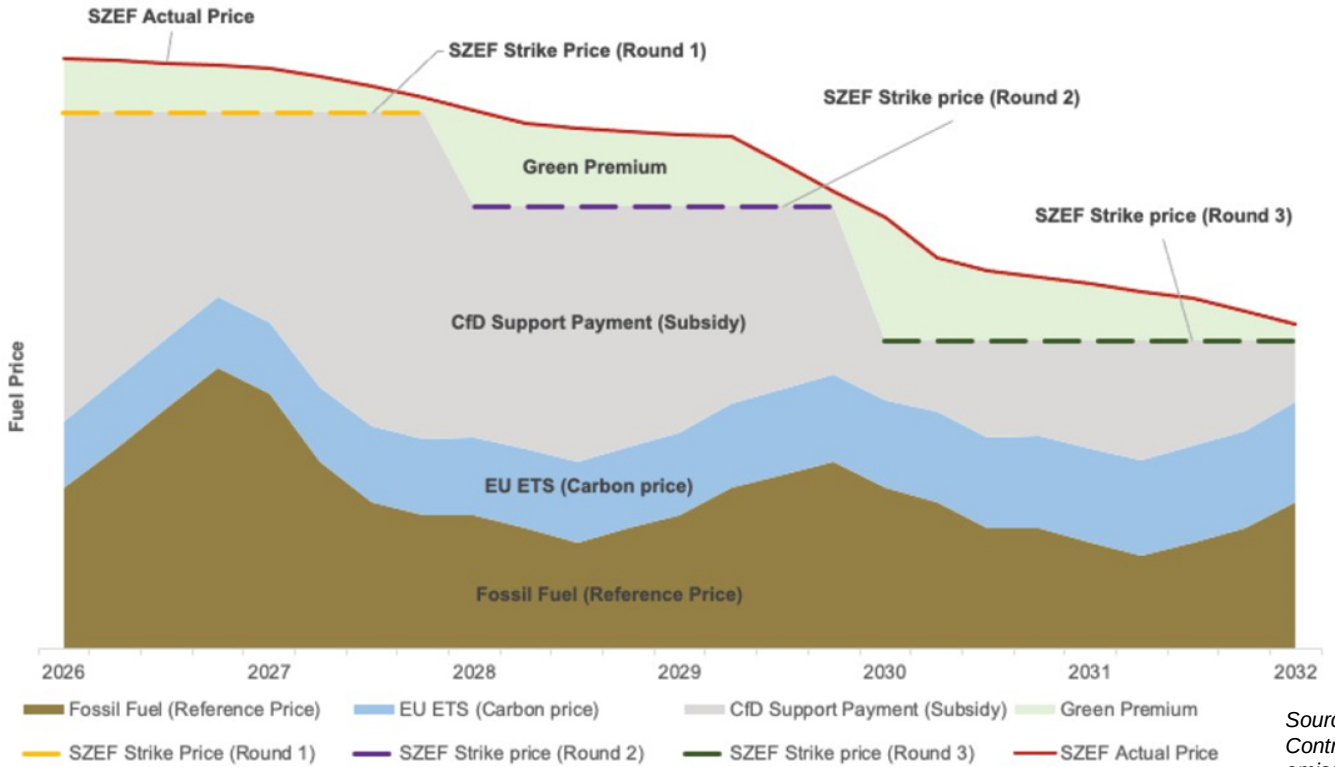
Policy instruments

- **Contracts-for-Difference:** equalize "market" prices of conventional and zero-emissions fuels/vessels in short-term to incentivise deployment
- **Renewable fuel mandates:** set progressively increasing targets for renewable fuel uptake by suppliers or other actors
- **Fuel intensity standards:** set progressively stricter targets to reduce GHG-intensity of sectors
- **Carbon pricing:** value on negative externalities/GHG emissions (includes border carbon adjustment mechanisms)
- **Public procurement:** mandates public sector support in growing demand for renewable fuels
- **SDG obligations:** obligations on developed countries to support zero emissions technology in relation to SIDS/LDC economic growth
- **Package legislation:** macro-level fiscal & monetary support

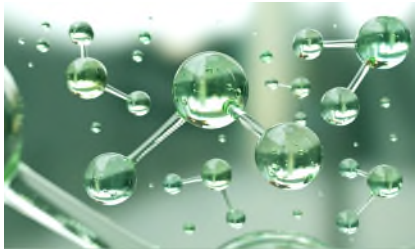
CfDs in shipping



Source: Pandey et al. (2022). "How EU Contracts for Difference can support zero-emission fuels", Getting to Zero Coalition, WEF, and Global Maritime Forum

CfD variants

Fuel-only



- Supply & use of zero-carbon fuel on ship
- Reference price: MGO
- Transparent, simple, aligns with industrial strategy
- Open to any firm, financial institution, fuel supplier, shipping firm
- Requires proof of zero-carbon credentials and proof of use of ship

Total Cost of Ownership

- Supply & use of a ship with zero-carbon propulsion.
- Reference price: benchmark Capex for standard ship; Opex based on MGO
- Complex, covers incremental Capex and Opex vs. standard vessel; aligns with innovation
- Requires proof of zero-carbon credentials and proof of use of ship

Source: Clark et al. (2021) "Zero-Emissions Shipping: Contracts-for-difference as incentives for the decarbonisation of international shipping", Oxford Smith School for Enterprise and the Environment

Key parameters

1 **Administrating body** ← *Independent counterparty (EU, IMO, public entity)*

2 **Bidder eligibility** ← *Qualification criteria (FI, broker, company)*

3 **Route eligibility** ← *Any; or green corridor*

4 **Technology eligibility** ← *Zero emission*

7 **Enforcement** ← *Performance security; percentage-terms penalty*

5 **Reference price** ← *Single fuel, or weighted average price*

6 **Strike price** ← *Zero-emission fuel; administrative, then competitive*

Source: Clark et al. (2021)

Thanks for coming.

Read the paper at the following link:
https://iopscience.iop.org/article/10.1088/2634-4505/ad097a
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