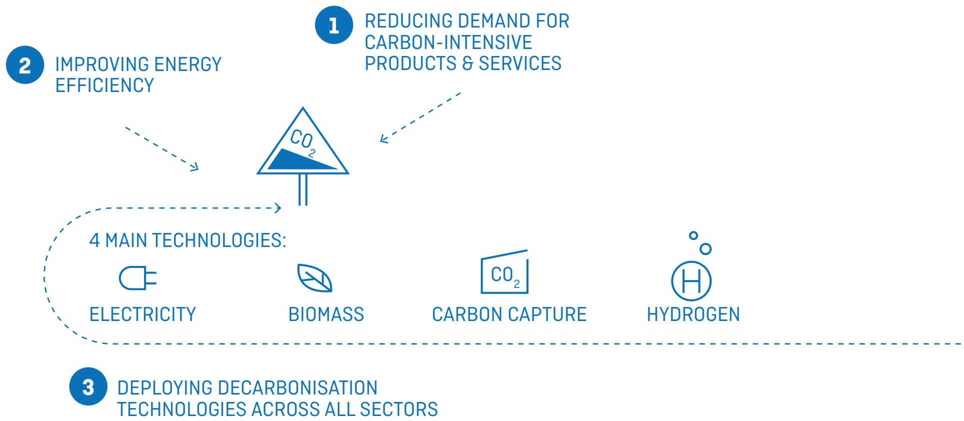


1

SYSTEM EFFICIENCY

Only 4-5% emissions reduction achievable from modal shift and optimisation of logistics

2

ENERGY EFFICIENCY

Improvement potential from energy efficiency measures:

- 30-55% for new ships
- 15% for retrofits

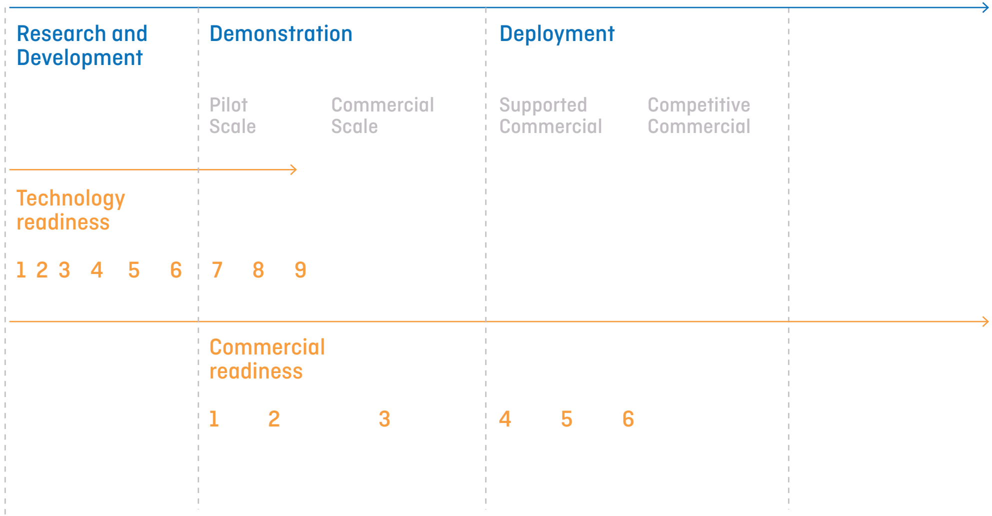
3

ALTERNATIVE FUELS AND PROPULSION TECHNOLOGIES

Multiple technology options:

- Short-haul: electric engines with battery or hydrogen fuel cells
- Deep sea: various liquid fuels from bio or synthetic sources

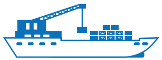
TRL and CRI mapped on the Technology Development Chain



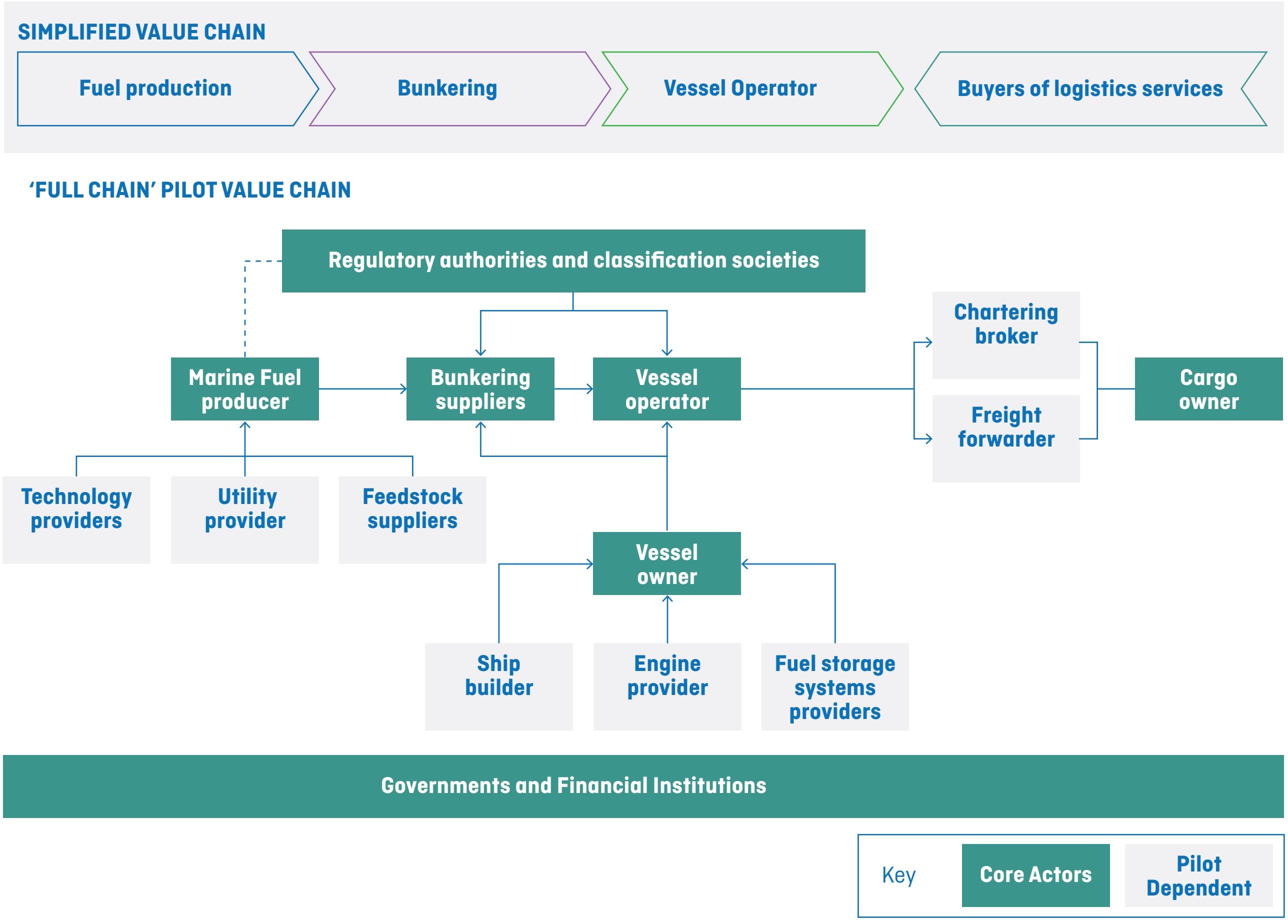
Source: IRENA (2014), Commercial readiness Index for Renewable Energy Sectors

	Fuel production	Bunkering	Vessel	Comment
Green Ammonia	⊕ Strong long-term scalability potential ⊕ Emerging consensus as most viable zero emissions-capable fuel	! High toxicity levels; lack of existing maritime handling regulations ! Existing distribution, but not for fuel purposes	! Dual fuel ICE close to market but not yet commercially available ! Lower volumetric density relative to HFO	• Likely to be the most scalable fuel option in the long-term
Green Methanol	! Carbon feedstock procurement can be difficult ! Carbon capture technology still at nascent stage with uncertain costs	⊕ Soon to be passed maritime handling regulation ⊕ Relatively easy to repurpose existing infrastructure	⊕ Dual fuel ICE available ! Lower volumetric density relative to HFO	• Proven technology with ease of use throughout value chain • Carbon procurement can be problematic
Biofuels	⊕ Close to cost parity with HFO/MGO for select feedstocks ! Long-term scalability concerns due to feedstock and sustainability constraints	⊕ Limited/no new bunkering infrastructure required	⊕ Drop-in fuel potential ⊕ ICE engines available with mature capex	• Proven technology with ease of use throughout value chain • Doubts about long-term scalability
Green Hydrogen	⊕ Multi-sector demand to underpin scale and cost reductions	! Minimal transportation by ship at present (1-2 ships) ! High flammability; lack of existing maritime handling regulations	! ICE options not commercially available ! Cost-intensive storage options	• Low technology readiness • Low economic feasibility in short term
Synthetic Diesel	! Carbon feedstock procurement can be difficult ! Carbon capture technology still at nascent stage with uncertain costs	⊕ Limited/no new bunkering infrastructure required	⊕ Drop-in fuel potential ⊕ ICE engines available with mature capex	• Lowest technology readiness • Low economic feasibility in short term

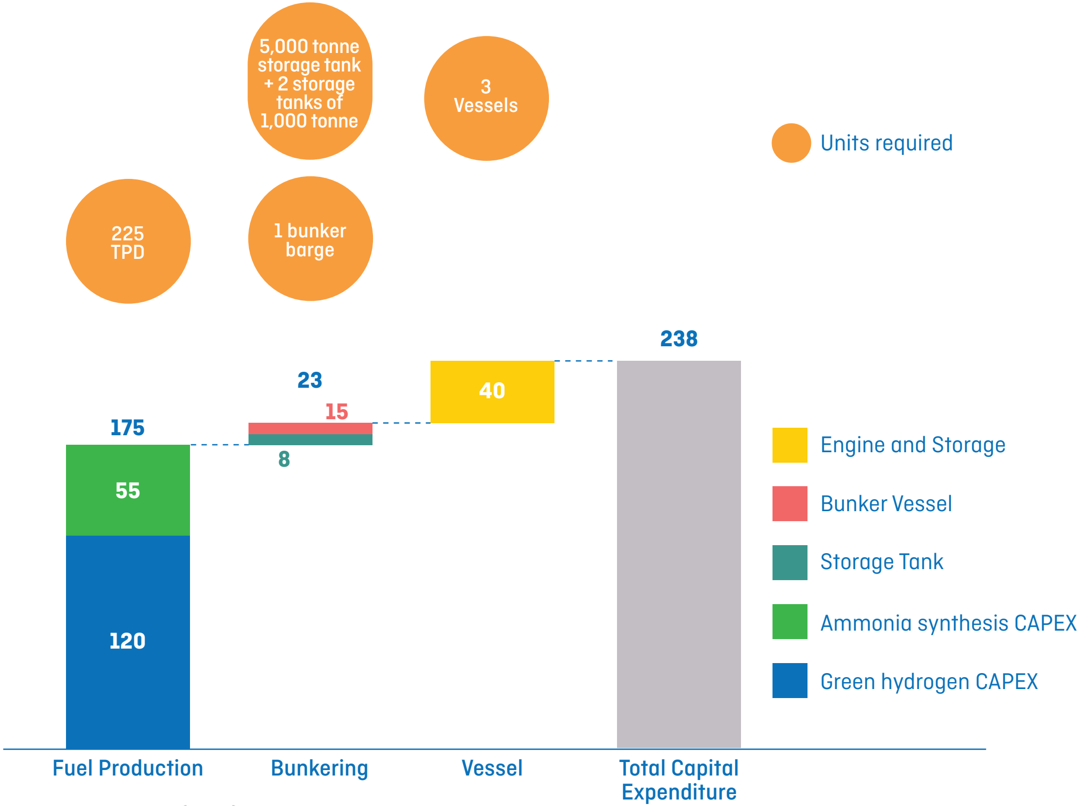
Focus for the Blueprint

Vessel Segment	Description	Relevance for ‘first mover’ pilot
 **Containership**	Used to transport manufactured goods in intermodal containers	(+) Known and predictability trade routes allow for the development of infrastructure at limited number of pre-determined ports (+) Higher potential of cost pass-through to end-use markets (+) Less stringent fuel handling procedures at containership terminals
 **Bulk Cargo**	Used to transport unpackaged bulk cargo in cargo hold	(+) Increasing pressure for end-use sector to reduce Scope 3 emissions (!) Variable trade route selection raises minimum level of infrastructure investment (!) Tight margins limit potential of passing through cost to end-use markets
 **Tanker**	Used to transport liquids or gases in bulk	(+) Lower expense related to fuel storage system and crew training costs (+) Homogenous cargoes and concentrated customer base simplifies cost pass-through (!) Variable trade route selection raises minimum level of infrastructure investment (!) Technical challenges in accessing engine and fuel storage systems increase complexity of testing and validation

Focus for the Blueprint

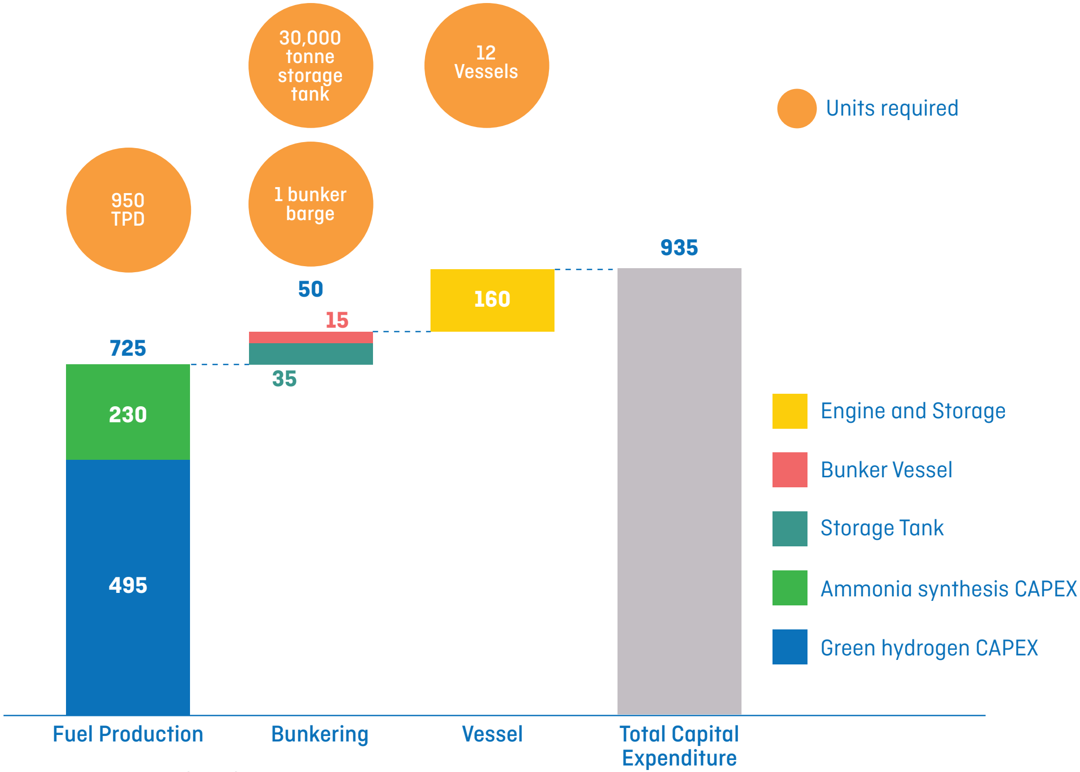

SIMPLIFIED VALUE CHAIN
Fuel production
Bunkering
Vessel Operator
Buyers of logistics services
'FULL CHAIN' PILOT VALUE CHAIN
Regulatory authorities and classification societies
Chartering broker
Marine Fuel producer
Bunkering suppliers
Vessel operator
Cargo owner
Freight forwarder
Technology providers
Utility provider
Feedstock suppliers
Vessel owner
Ship builder
Engine provider
Fuel storage systems providers
Governments and Financial Institutions
Key
Core Actors
Pilot Dependent

'SMALL SCALE FULL CHAIN' 225 TPD GREEN AMMONIA PILOT
Capital expenditure needed across value chain, $m



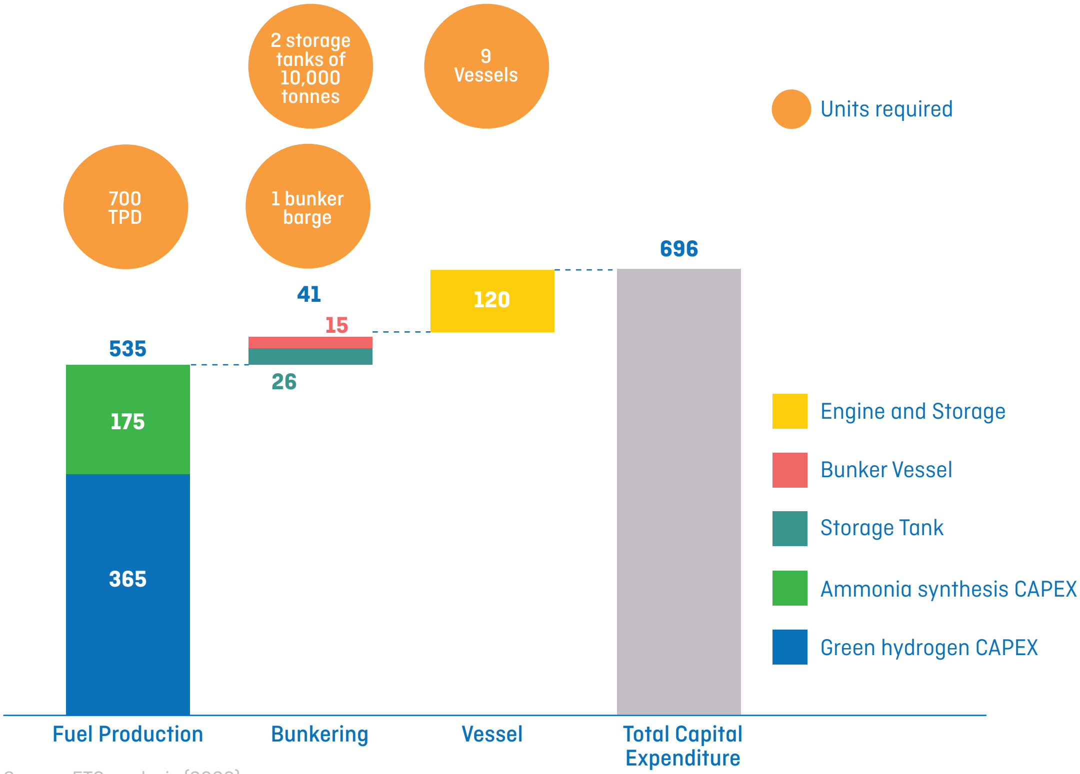
Source: ETC analysis (2020)
Key assumptions listed in Appendix

'LARGE SCALE FULL CHAIN' 950 TPD GREEN AMMONIA PILOT
Capital expenditure needed across value chain, $m



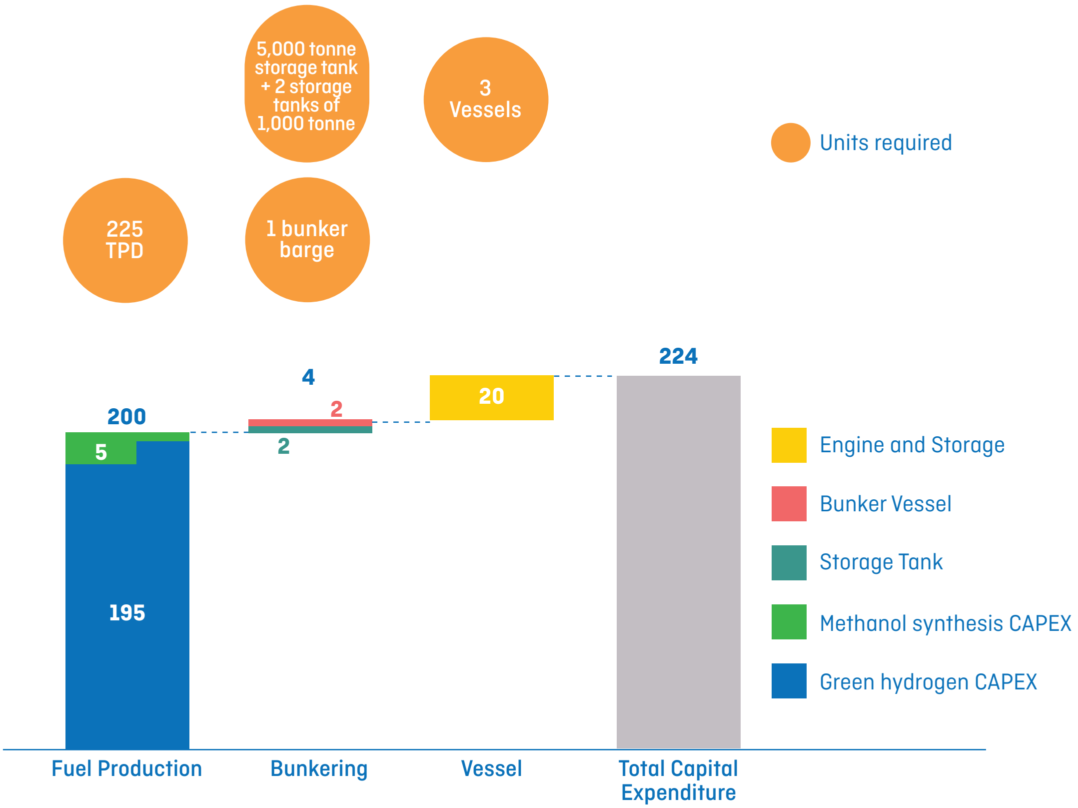
Source: ETC analysis (2020)
Key assumptions listed in Appendix

‘REFERENCE CASE FULL CHAIN’ 700 TPD GREEN AMMONIA PILOTCapital expenditure needed across value chain, $m



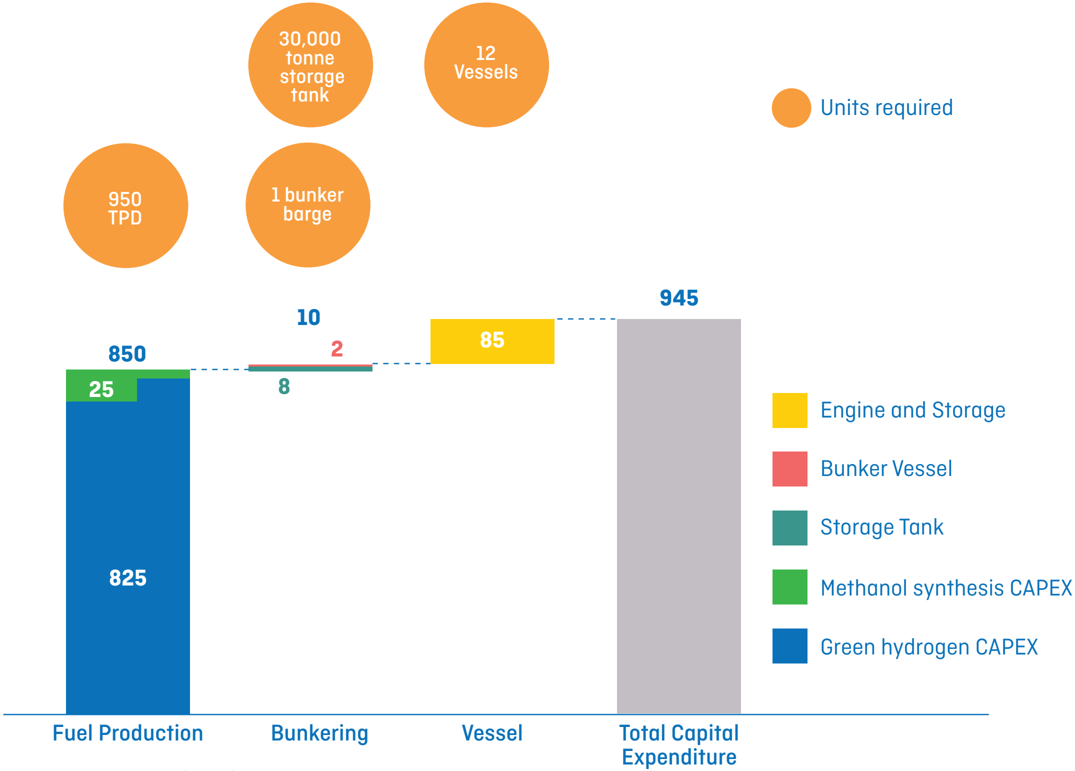
Source: ETC analysis (2020)
Key assumptions listed in Appendix

‘SMALL SCALE FULL CHAIN’ 225 TPD GREEN METHANOL PILOT
Capital expenditure needed across value chain, $m



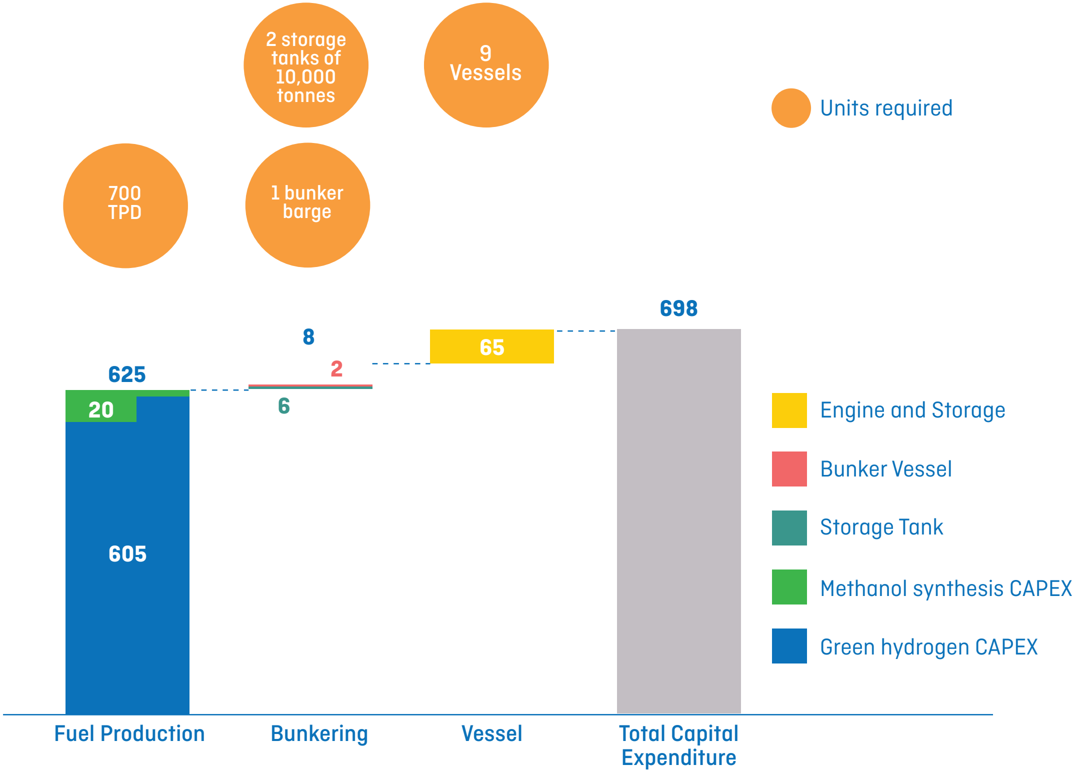
Source: ETC analysis (2020)
Key assumptions listed in Appendix

‘LARGE SCALE FULL CHAIN’ 950 TPD GREEN METHANOL PILOT
Capital expenditure needed across value chain, $m



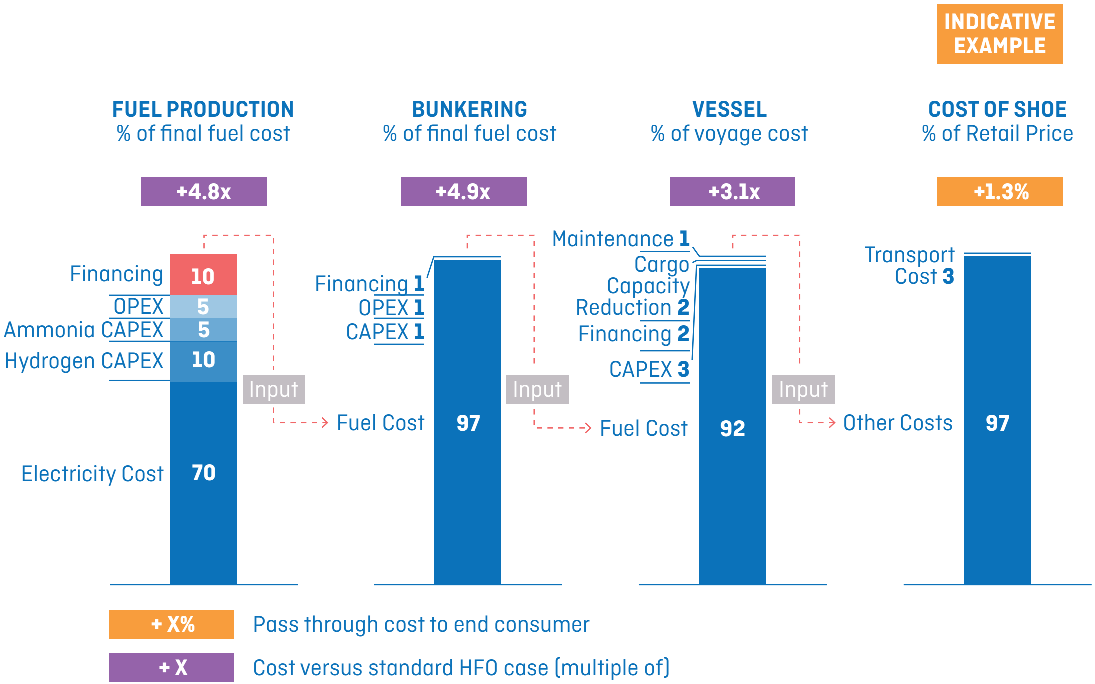
Source: ETC analysis (2020)
Key assumptions listed in Appendix

'REFERENCE CASE 'FULL CHAIN' 700 TPD GREEN METHANOL PILOT
Capital expenditure needed across value chain, $m



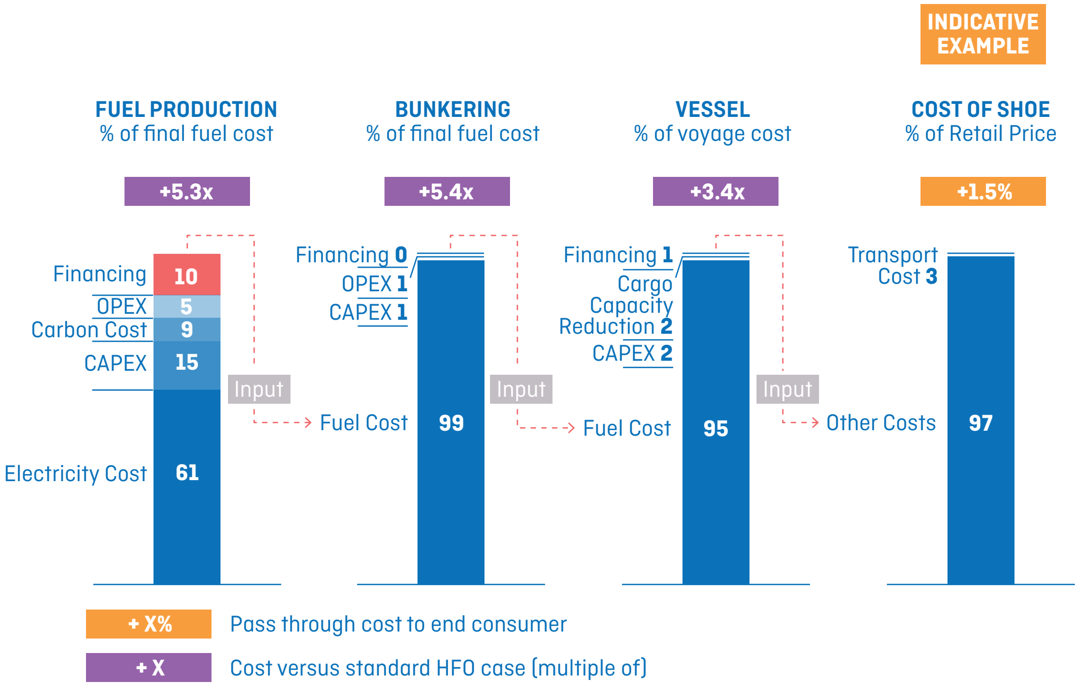
Source: ETC analysis (2020)
Key assumptions listed in Appendix

'FULL CHAIN' 700 TPD GREEN AMMONIA PILOT
Breakdown of cost at each step of the value chain

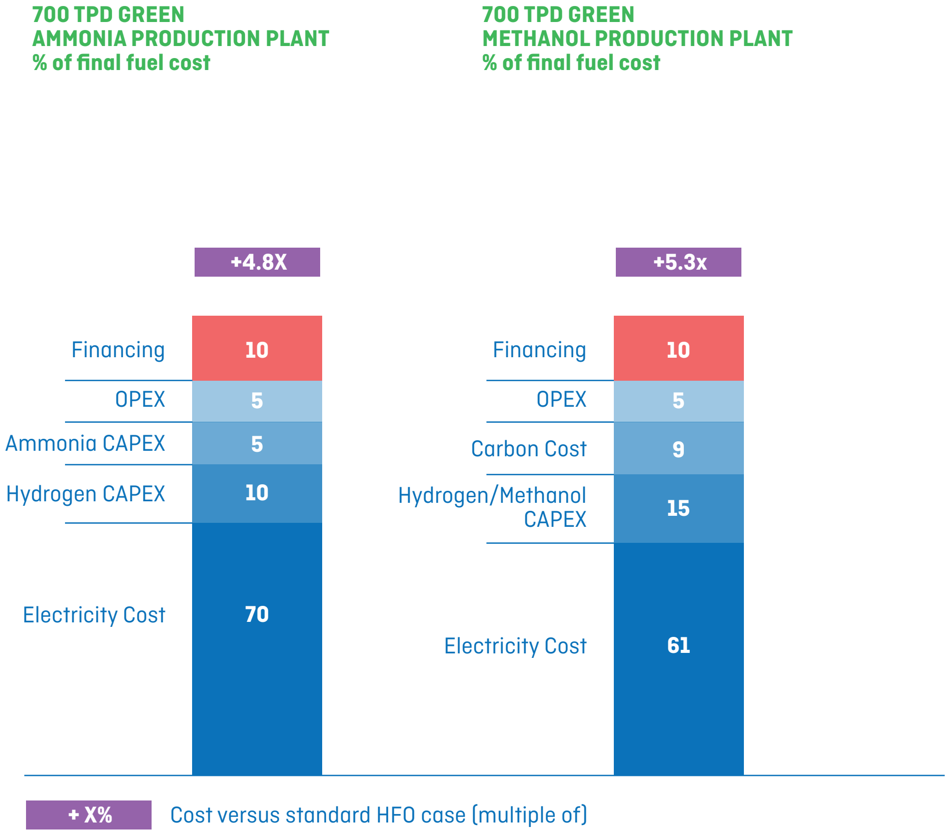


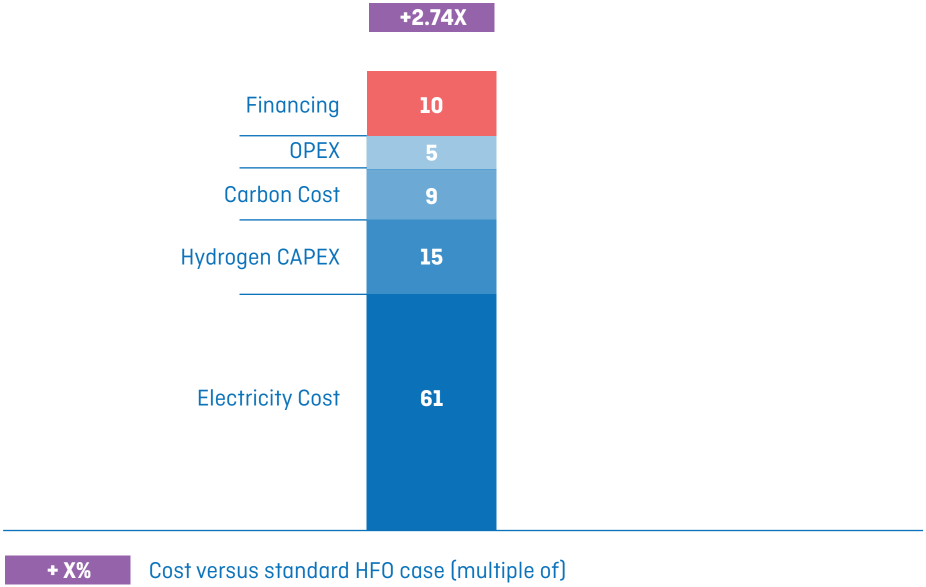
Source: ETC analysis (2020)
Key assumptions listed in Appendix

'FULL CHAIN' 700 TPD GREEN METHANOL PILOT (w/ BECCS)
Breakdown of cost at each step of the value chain



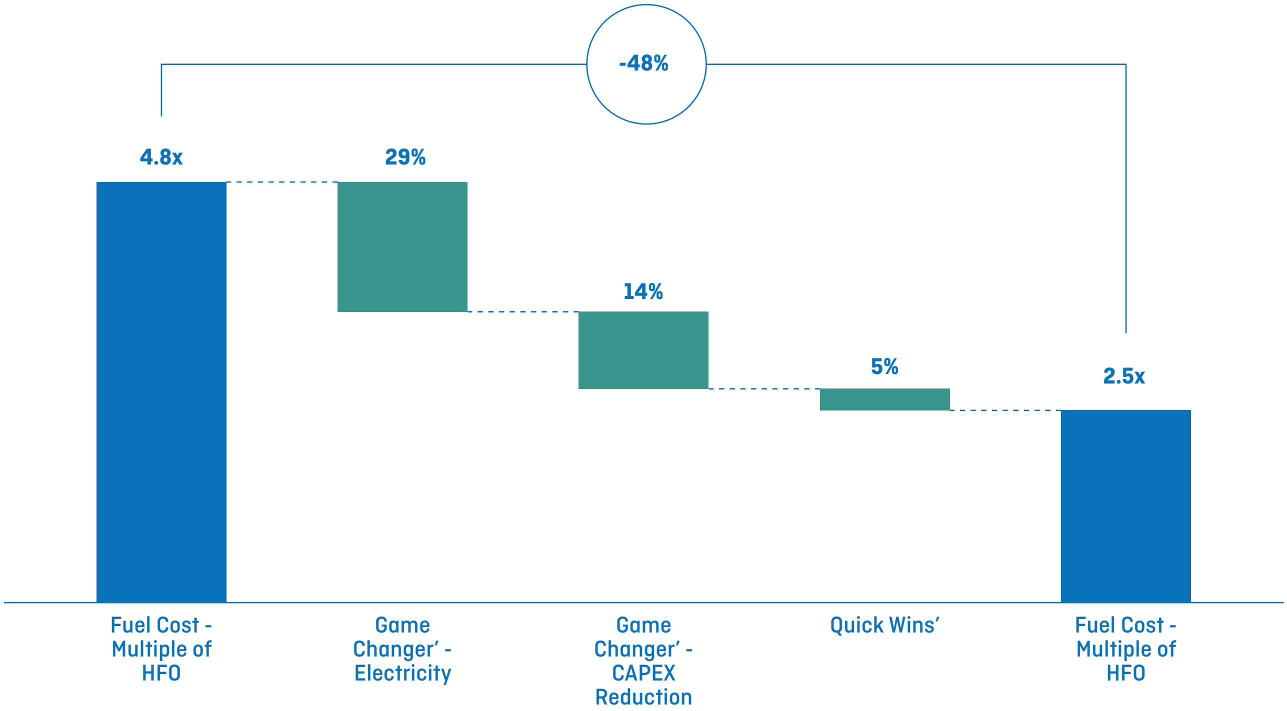
Source: ETC analysis (2020)
Key assumptions listed in Appendix


700 TPD GREEN
AMMONIA PRODUCTION PLANT
% of final fuel cost
+4.8X
Financing
10
OPEX
5
Ammonia CAPEX
5
Hydrogen CAPEX
10
Electricity Cost
70
700 TPD GREEN
METHANOL PRODUCTION PLANT
% of final fuel cost
+5.3x
Financing
10
OPEX
5
Carbon Cost
9
Hydrogen/Methanol CAPEX
15
Electricity Cost
61
+ X%
Cost versus standard HFO case (multiple of)



Source: ETC analysis (2020)
Key assumptions: Electrolyser CAPEX $1,200/kW (source: BNEF 2020); LCOE - $60/MWh (assuming offshore wind with 60% capacity factor);); Delivered Carbon Cost per tonne - $60/tonne (source: global CCS Institute; Interest Rate: 10%; Gearing Ratio: 80%; HFO Price: $394/tonne; MGO Price (for reference): $457/tonne (Source: average from Jan 1, 2020 to Jul 1, 2020 for top 20 global ports from https://shipandbunker. com); Figures rounded to nearest significant figure

GREEN AMMONIA – FUEL PRODUCTION
% of final fuel cost

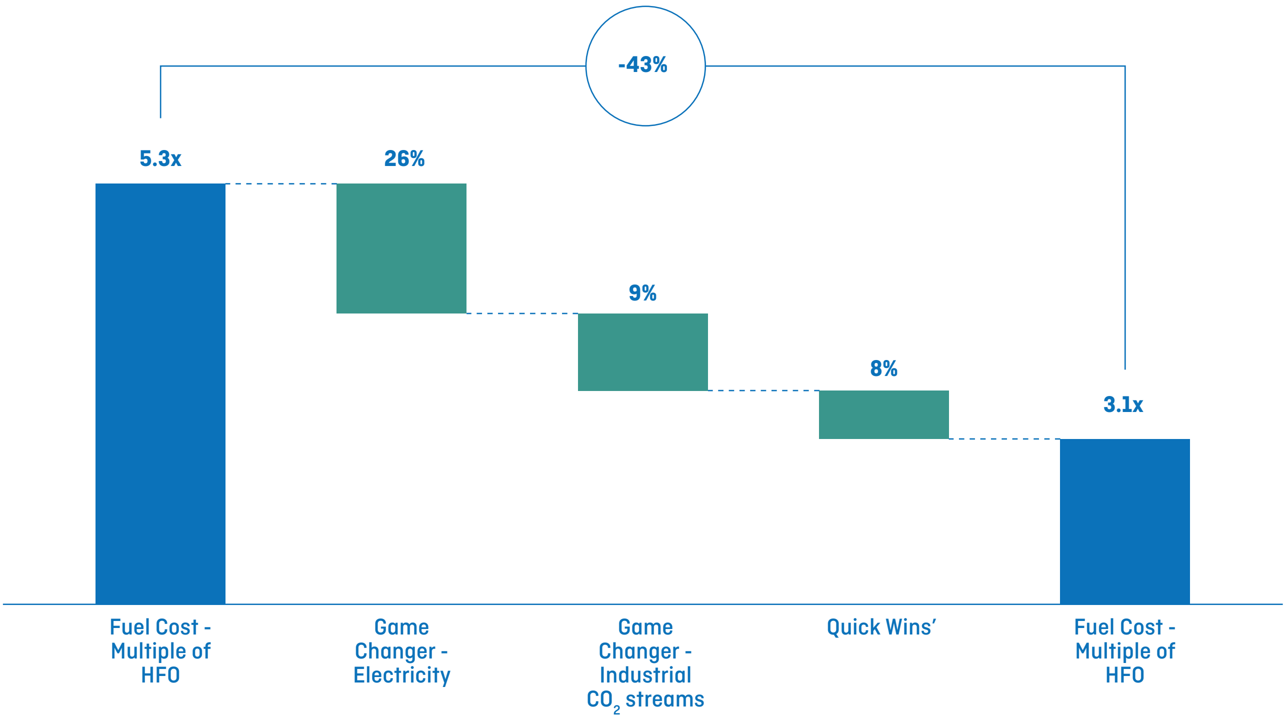


Lever utilised:
→ Location-based cost minimisation, long-term PPA and tax exemptions to lower cost of electricity to $39/MWh

Lever utilised:
→ Use of existing ammonia infrastructure to reduce ammonia production capex

Lever utilised:
→ Blended finance to reduce electrolyser related CAPEX and cost of capital
→ Concessional/Preferential Loans and Loan Guarantees to reduce interest rates to 4%

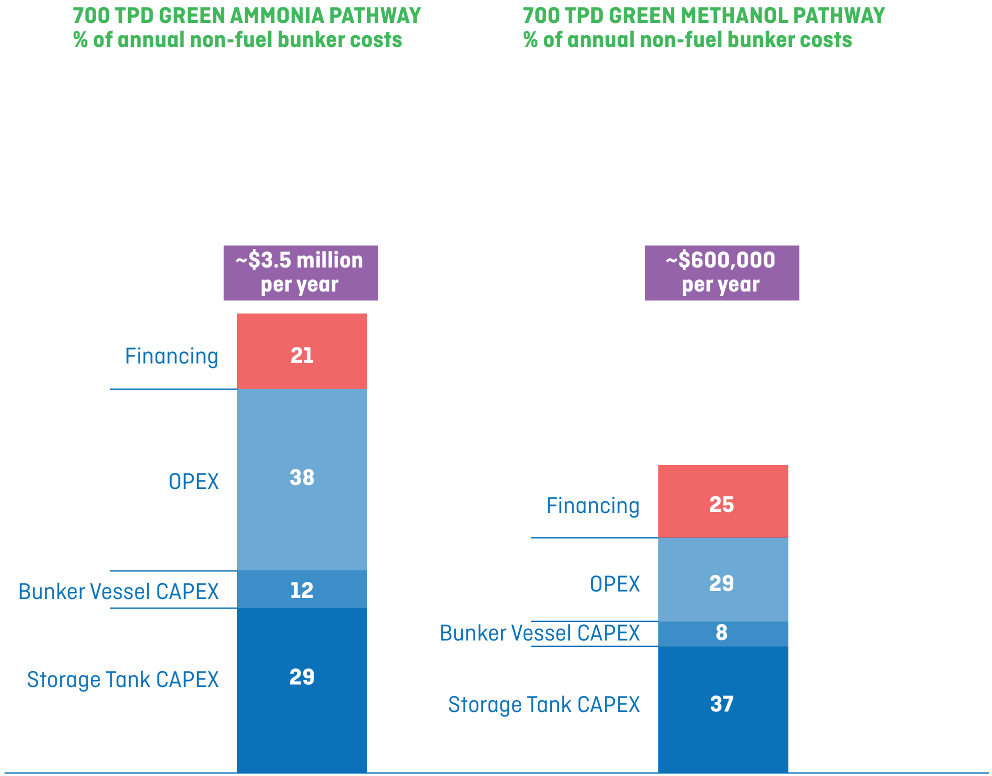
GREEN METHANOL – FUEL PRODUCTION
Cost versus standard HFO case, multiple of



Lever utilised:
- → Location-based cost minimisation and tax exemptions to lower cost of electricity to $35/MWh

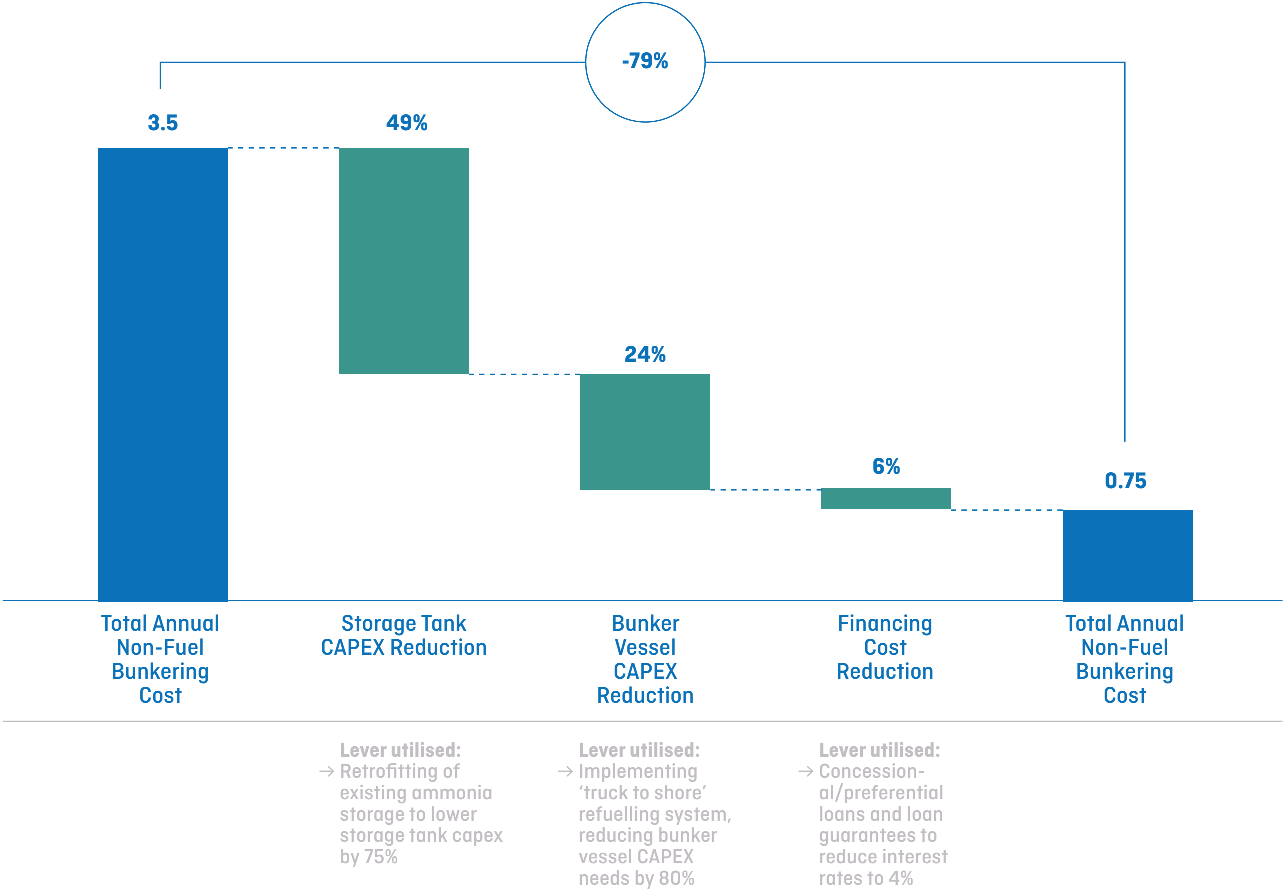
Lever utilised:
- → Use of existing methanol infrastructure to reduce methanol production capex
- → Use industrial CO_2 streams from least-cost sources to lower delivered cost of carbon to $35/tonne

Lever utilised:
- → Blended finance to reduce electrolyser related CAPEX and cost of capital
- → Concessional/preferential loans and loan guarantees to reduce interest rates to 4%

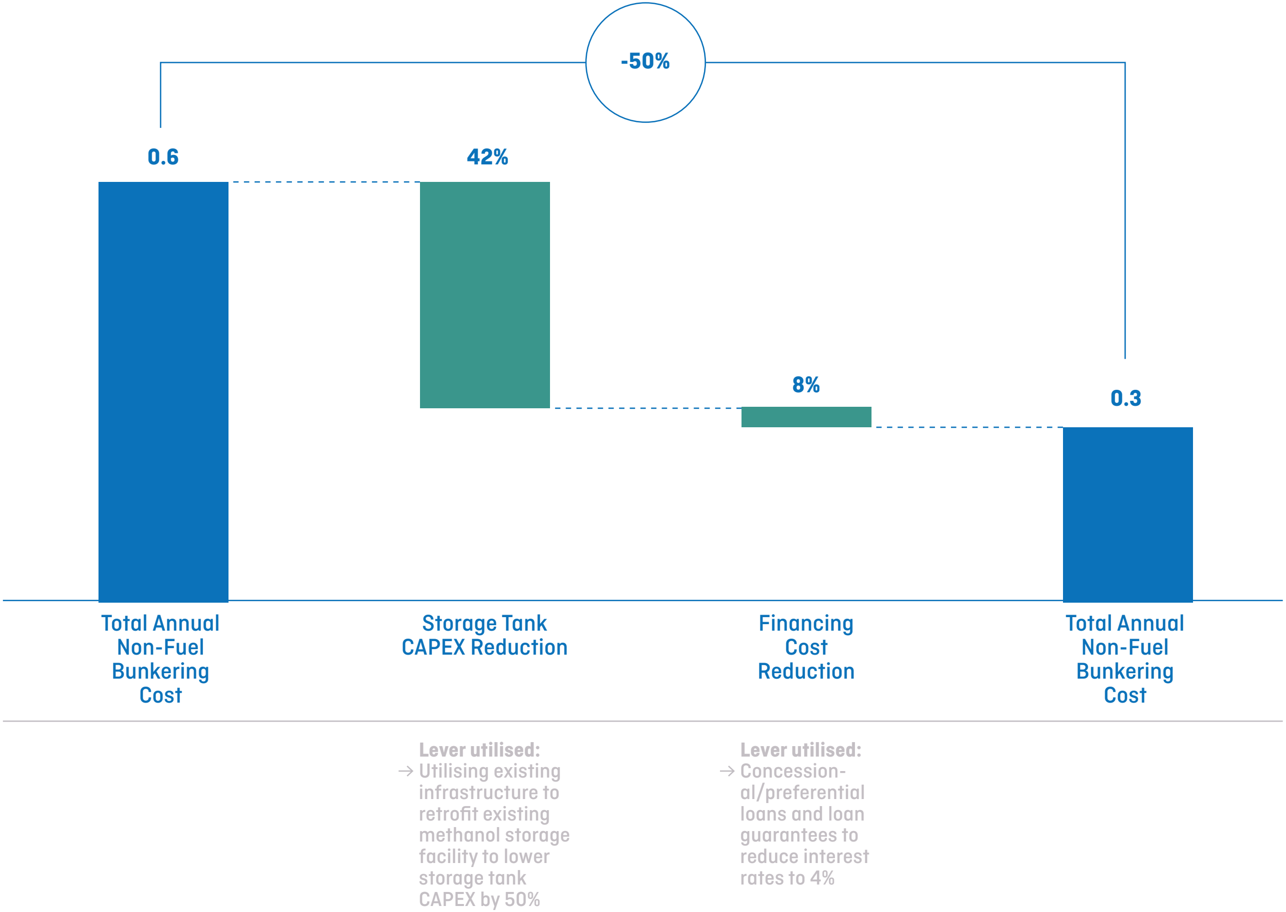


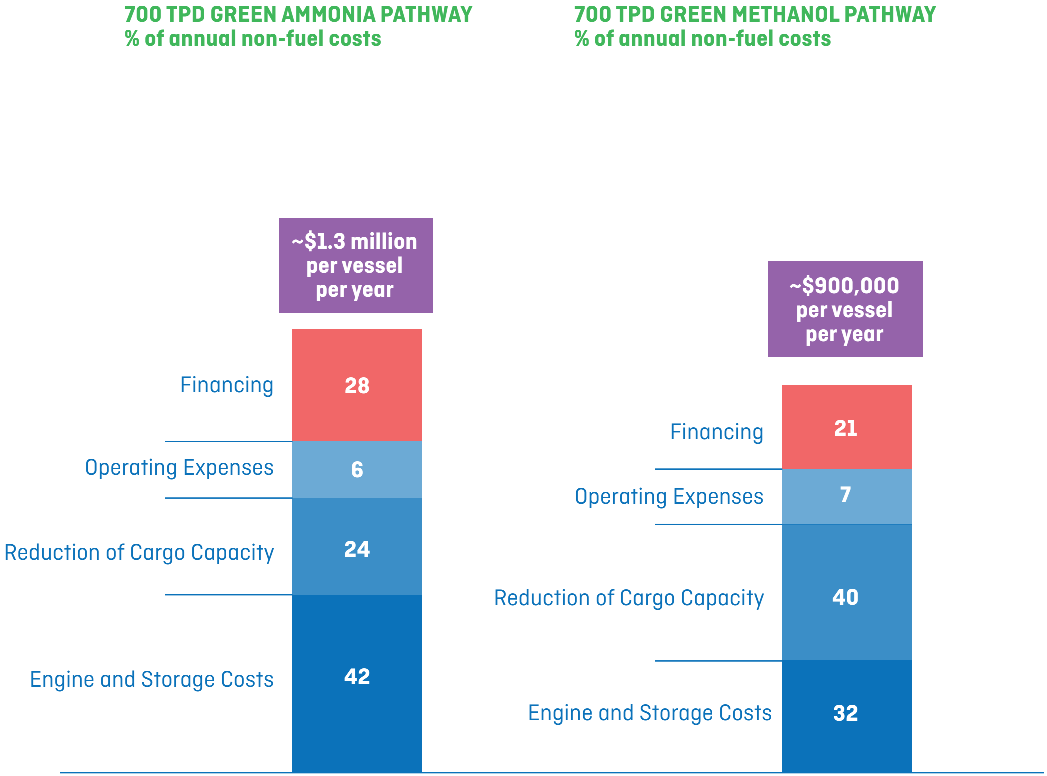
Source: ETC analysis (2020)
Key assumptions listed in Appendix

GREEN AMMONIA BUNKERING
Non-fuel Costs, $m



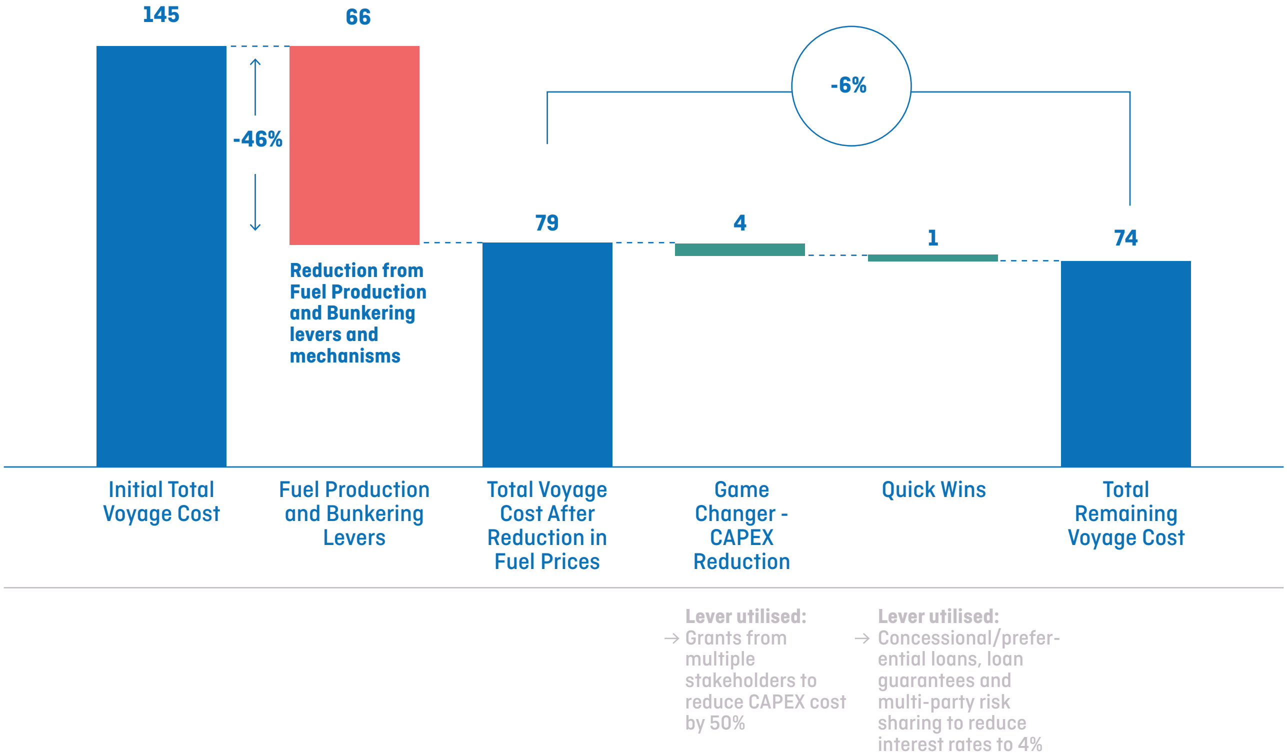
GREEN METHANOL BUNKERING
Non-fuel Costs, $m



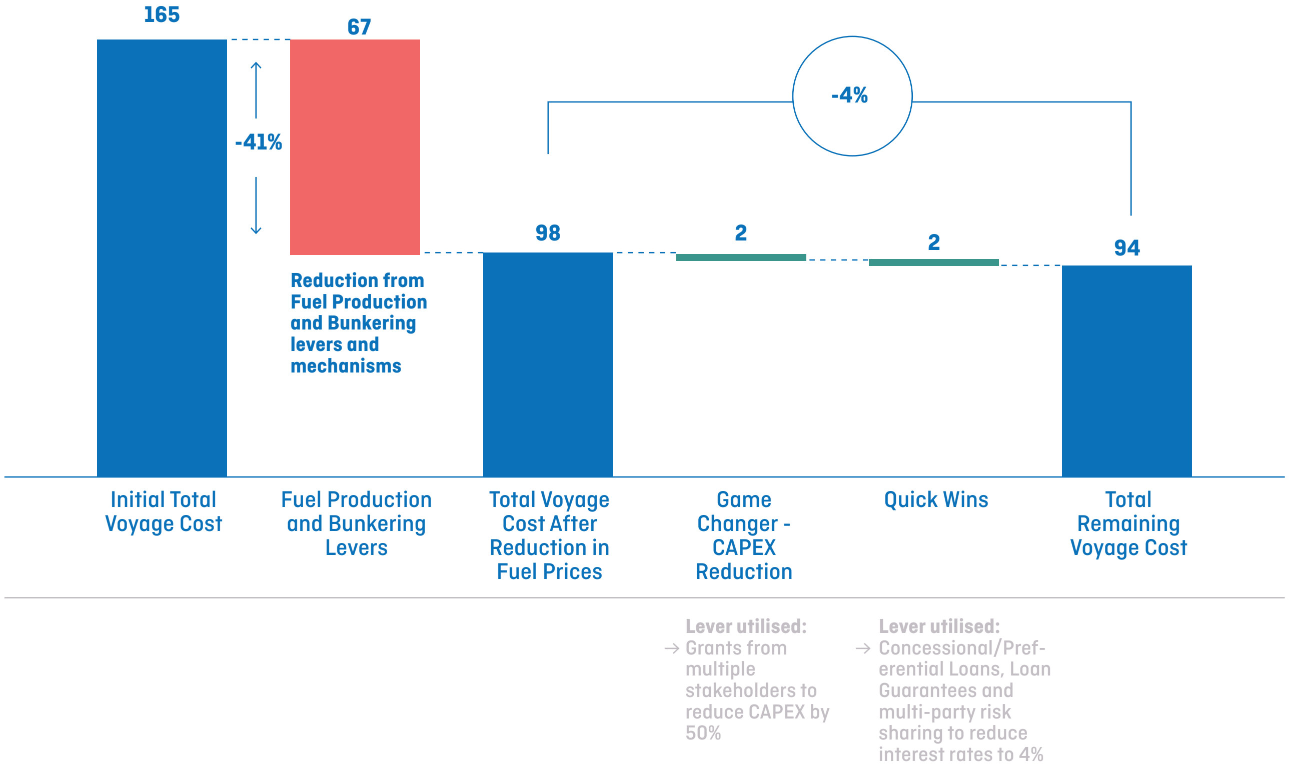


Source: ETC analysis (2020)
Key assumptions listed in Appendix

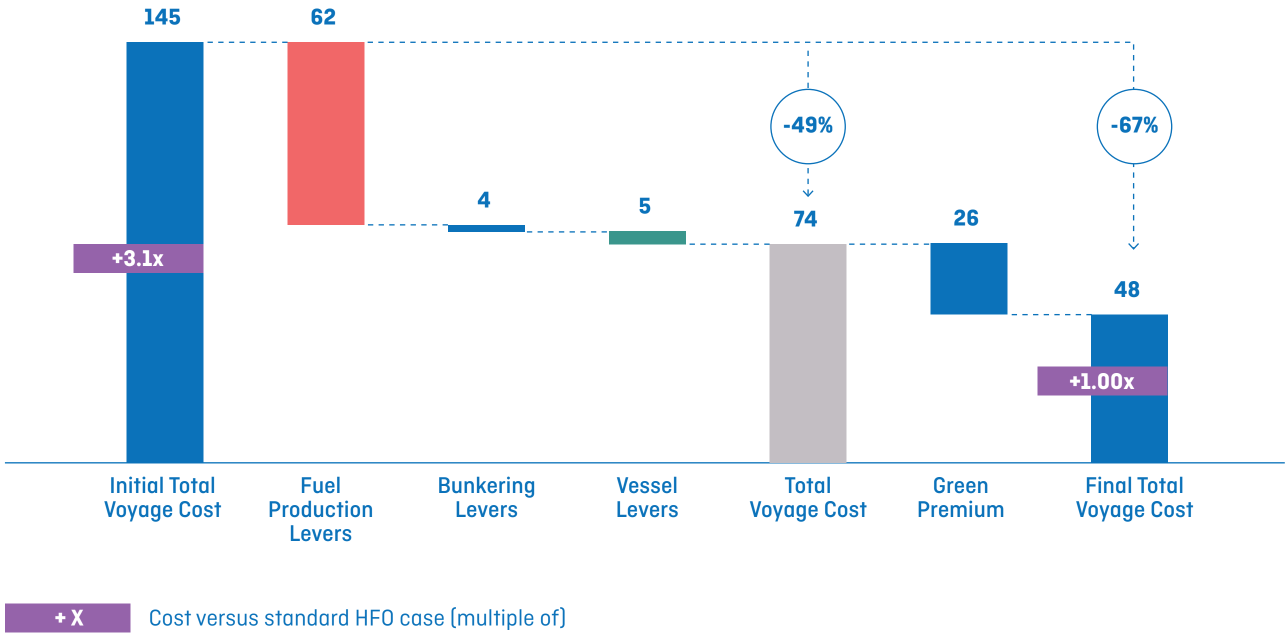
‘FULL CHAIN’ 700 TPD GREEN AMMONIA PILOT
Total voyage cost, $m



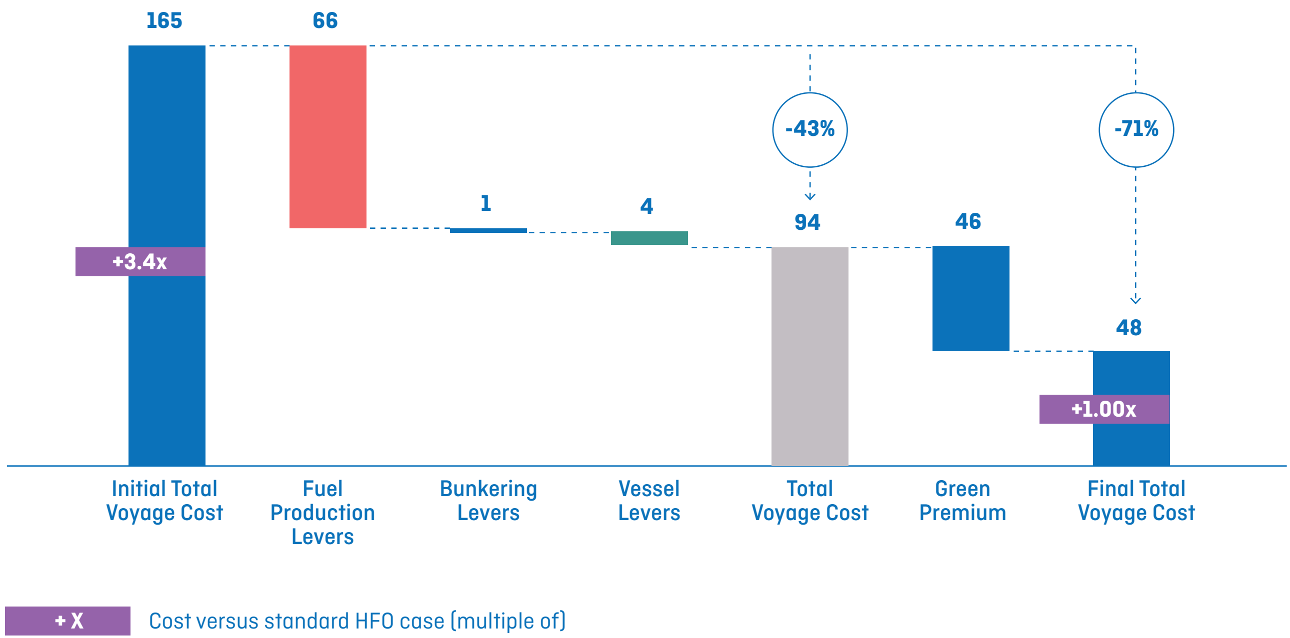
‘FULL CHAIN’ 700 TPD GREEN METHANOL PILOT
Total voyage cost, $m

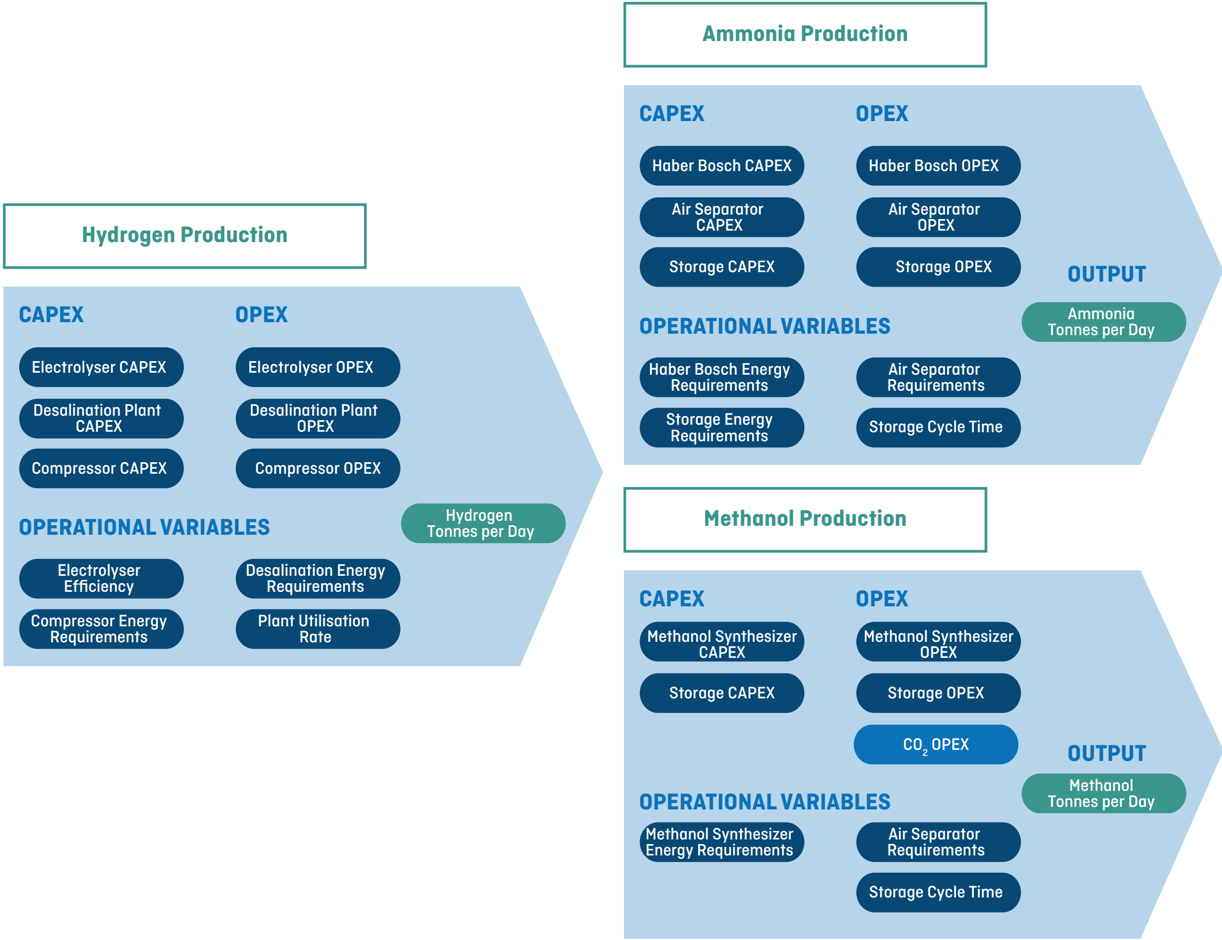


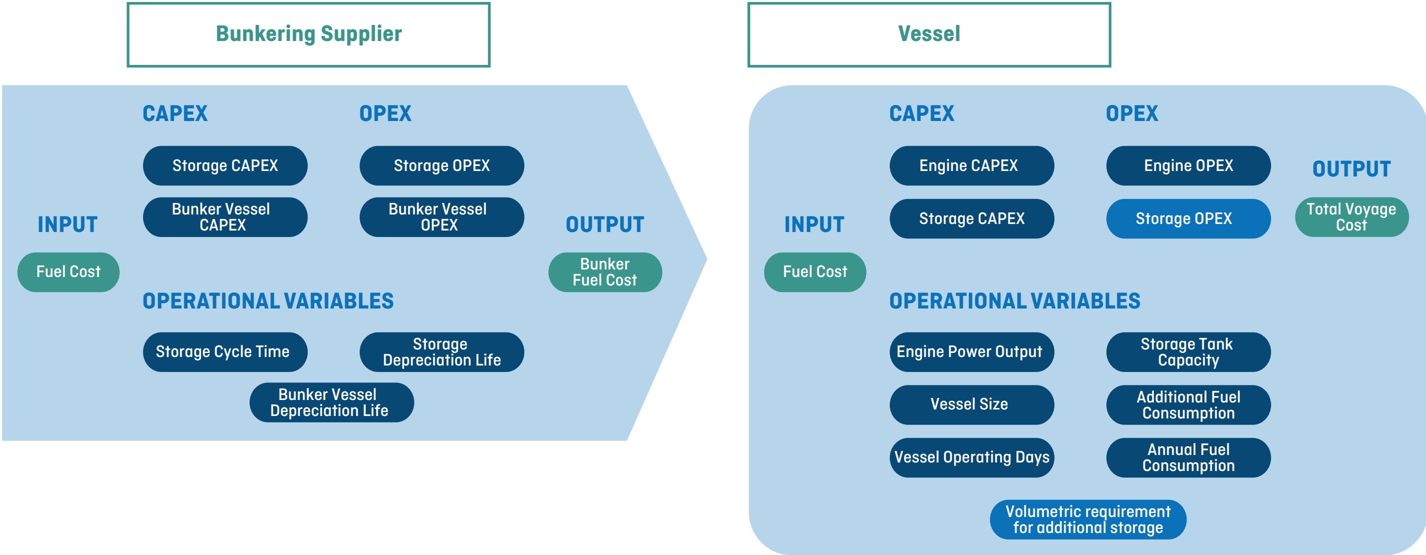
'FULL CHAIN' 700 TPD GREEN AMMONIA PILOT
Total voyage cost, $m



‘FULL CHAIN’ 700 TPD GREEN METHANOL PILOT
Total voyage cost, $m




Hydrogen Production
CAPEX
Electrolyser CAPEX
Desalination Plant CAPEX
Compressor CAPEX
OPEX
Electrolyser OPEX
Desalination Plant OPEX
Compressor OPEX
OPERATIONAL VARIABLES
Electrolyser Efficiency
Compressor Energy Requirements
Desalination Energy Requirements
Plant Utilisation Rate
Hydrogen Tonnes per Day
Ammonia Production
CAPEX
Haber Bosch CAPEX
Air Separator CAPEX
Storage CAPEX
OPEX
Haber Bosch OPEX
Air Separator OPEX
Storage OPEX
OPERATIONAL VARIABLES
Haber Bosch Energy Requirements
Storage Energy Requirements
Air Separator Requirements
Storage Cycle Time
OUTPUT
Ammonia Tonnes per Day
Methanol Production
CAPEX
Methanol Synthesizer CAPEX
Storage CAPEX
OPEX
Methanol Synthesizer OPEX
Storage OPEX
CO_2 OPEX
OPERATIONAL VARIABLES
Methanol Synthesizer Energy Requirements
Air Separator Requirements
Storage Cycle Time
OUTPUT
Methanol Tonnes per Day


Bunkering Supplier
CAPEX
OPEX
Storage CAPEX
Storage OPEX
Bunker Vessel CAPEX
Bunker Vessel OPEX
INPUT
Fuel Cost
OUTPUT
Bunker Fuel Cost
OPERATIONAL VARIABLES
Storage Cycle Time
Storage Depreciation Life
Bunker Vessel Depreciation Life
Vessel
CAPEX
OPEX
Engine CAPEX
Engine OPEX
Storage CAPEX
Storage OPEX
OUTPUT
Total Voyage Cost
INPUT
Fuel Cost
OPERATIONAL VARIABLES
Engine Power Output
Storage Tank Capacity
Vessel Size
Additional Fuel Consumption
Vessel Operating Days
Annual Fuel Consumption
Volumetric requirement for additional storage

High level methodology of the CO_2 shipping cost model

CO_2 shipping – user inputs

- Flow rate ($MtCO_2$ per annum)
- Shipping time (years)
- Starting port
- Destination (either port or offshore CO_2 storage site)
- Unloading option (Onshore, TMS, STL, SALM, platform with storage)

- Initial CO_2 pressure
- CO_2 liquefaction pressure (L/M/H)
- Discount rate
- Ship fuel (LNG/MDO)
- Fuel price scenarios

Cost and performance dataset

- **Specific CAPEX and OPEX for:**
  - Liquefaction
  - Temporary storage
  - Loading/unloading (onshore)
  - CO_2 ship
  - Unloading offshore (direct/buffer storage)
  - Gasification
- **Shipping operation data**
  - Loading/unloading time
  - Unloading time offshore
  - Port entry/exit time
  - Annual operation hours
  - Offshore connection time
  - Speed
  - Fuel consumption
- **Electricity and fuel prices**

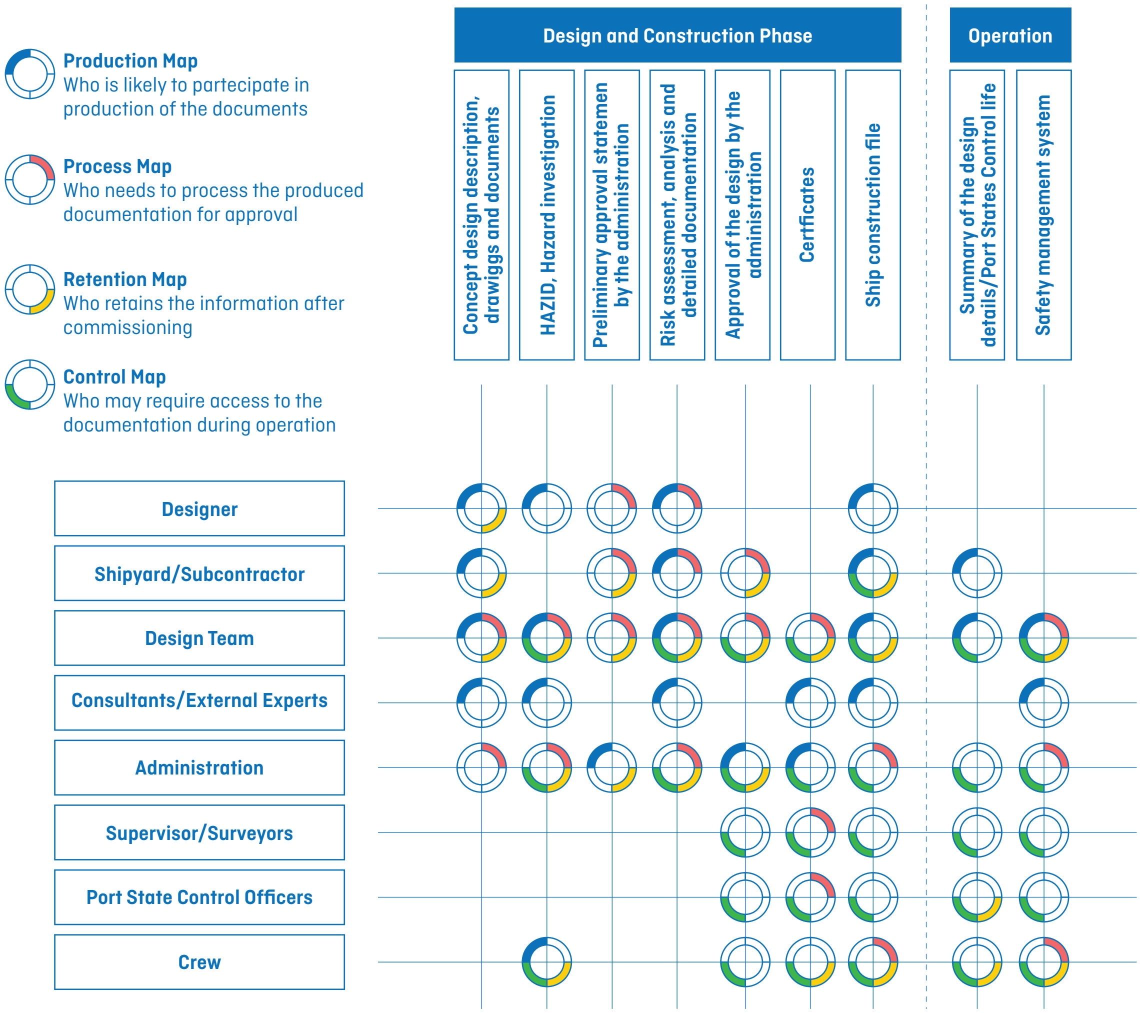
Infrastructure sizing and cost calculations

- Liquefaction capacity (MW_{el})
- Distance between start and destination
- Size of onshore/offshore storage
- Ship length and draft
- Total trip time
- Nr of trips per ship
- Optimum fleet size
- Utilisation of fleet

Key outputs

- Detailed cost breakdown for shipping and pipeline
- Levelised lifetime cost per stored tCO_2 for shipping and pipeline

Involvement Map



Source: Guidelines for the approval of alternatives and equivalents as provided for in various IMO instruments MSC.1/Circ.1455 24 June 2013