Creating a world
fit for the future

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Technological, Operational and Energy Pathways for Maritime Transport to Reduce Emissions Towards 2050

14th Concawe Symposium

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www.ricardo.com

Our Vision:

We want to create a world where everyone can live sustainably

Breathe Clean Air | Access Clean Water | Use Clean Energy | Travel Sustainably | Conserve Resources

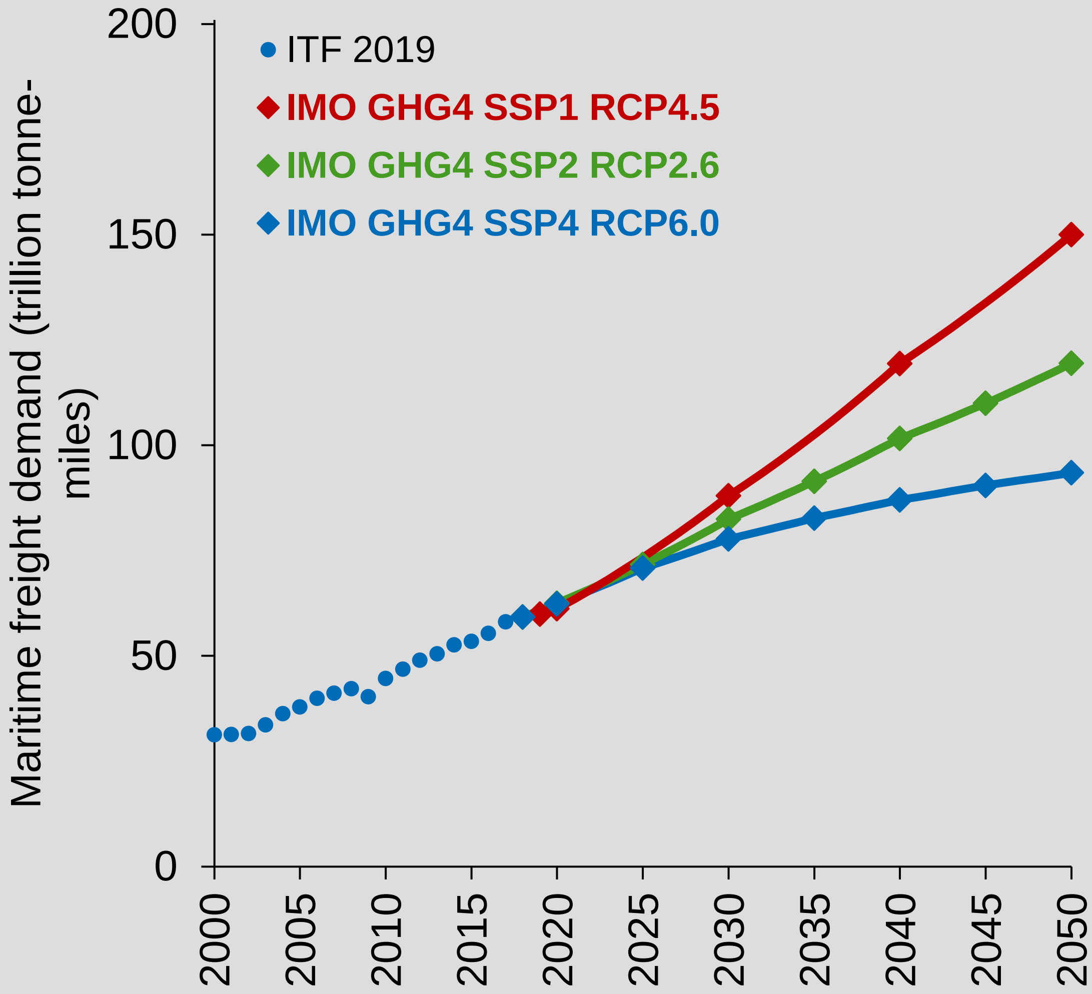
Our Mission:

Solving the world's most pressing energy and environmental challenges

The objectives of the study were:

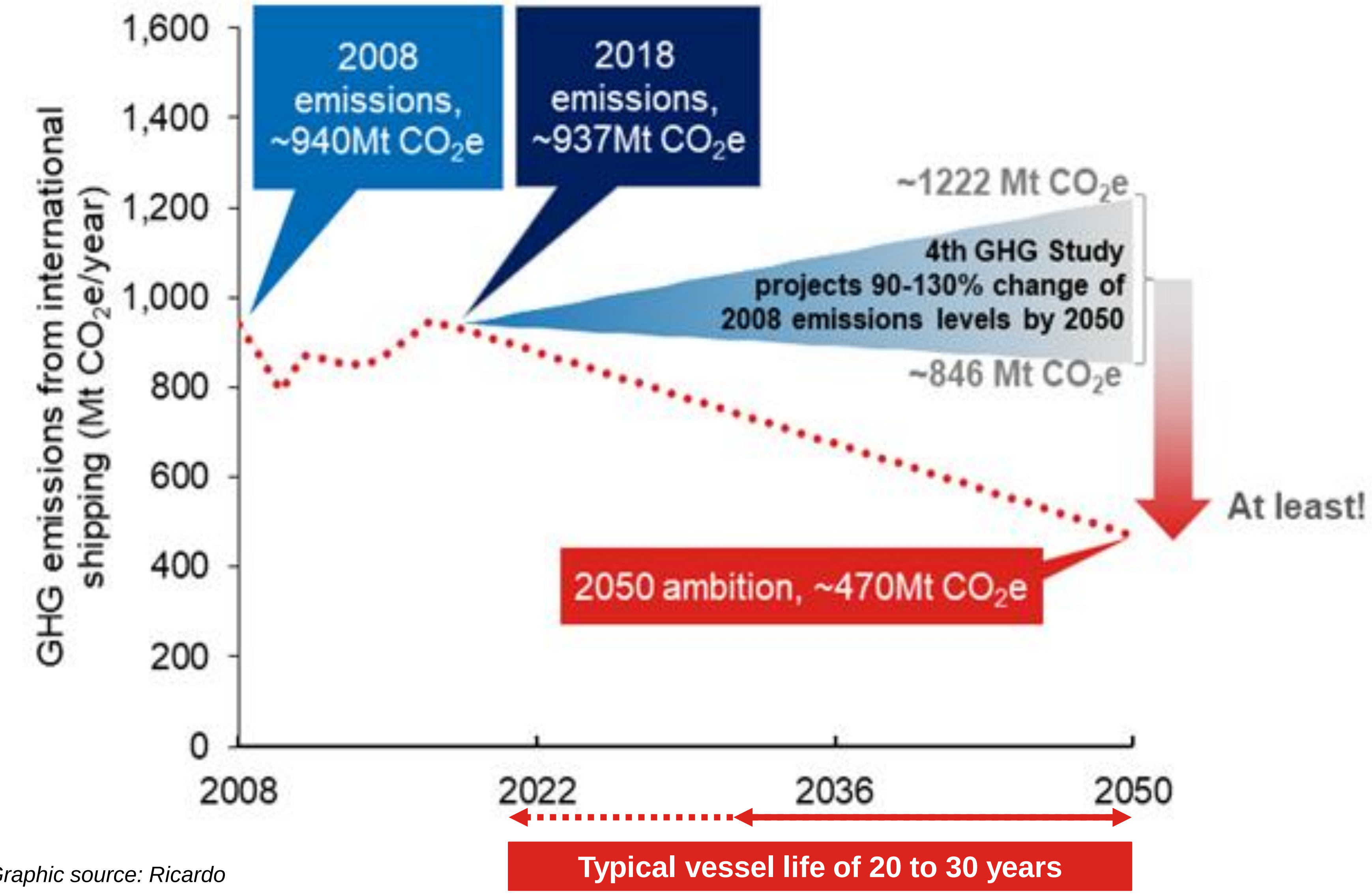
- Develop holistic **evidence-based** view (literature, external expert input, modelling)
- Describe **scientific understanding of decarbonisation opportunities** by 2050, including
  - **fuels / energy carriers**
  - **technologies**
  - **operational measures**
- **Quantify GHG emission reductions** of packages of most promising opportunities
- Identify **challenges**: **barriers and enablers** to unlock and scale-up potential solutions

Context: Demand for maritime freight is forecast to continue rising significantly



Data sources: International Transport Forum Transport Outlook (2019), IMO 4th GHG study

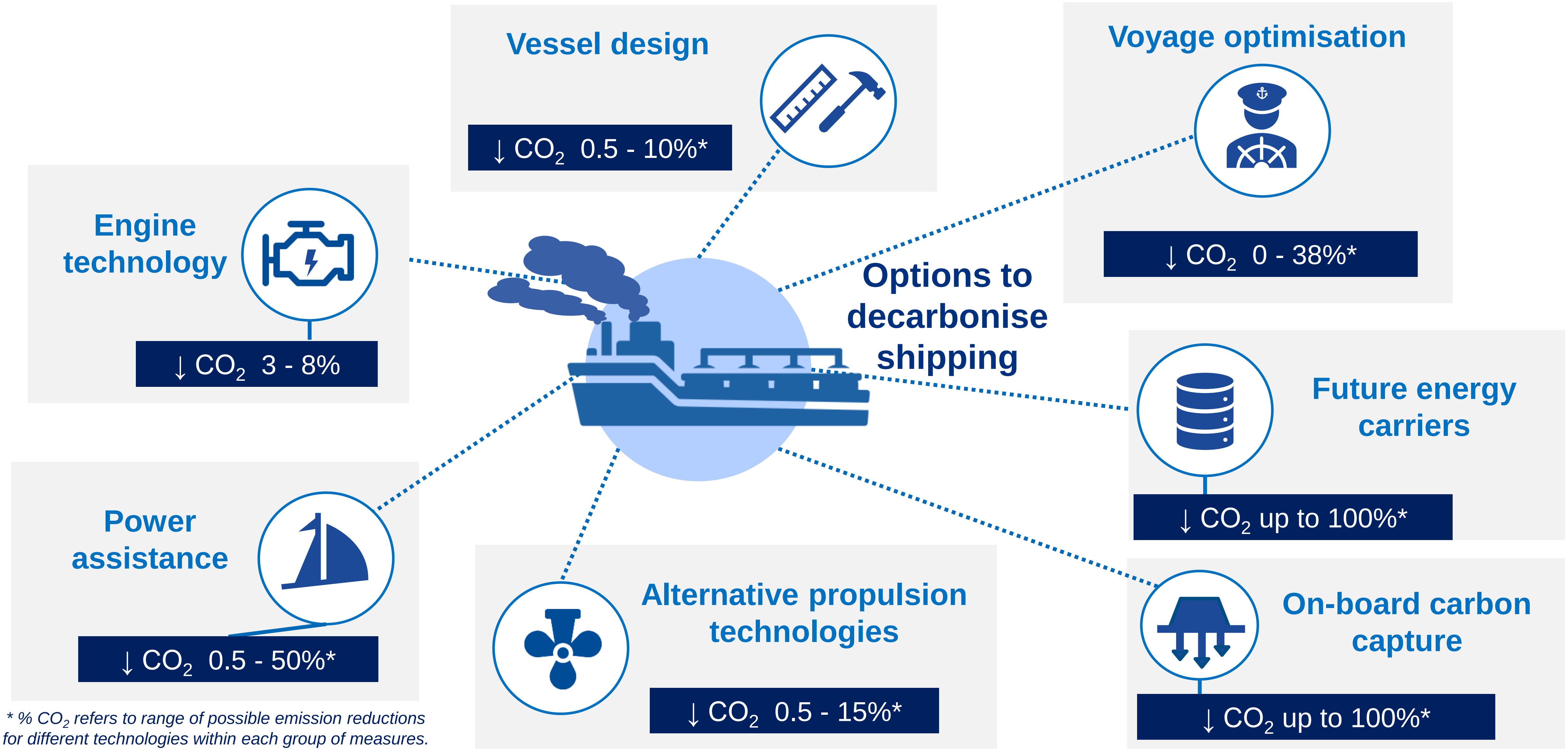
IMO's initial GHG strategy set a level of ambition that will require not just technical innovation but also zero carbon, net zero and low carbon fuels



Graphic source: Ricardo

- IMO's short-term measures at the vessel level supporting this ambition:
  EEDI, EEXI, CII, SEEMP
- Revised IMO strategy planned for 2023
- Current "tank-to-wake" estimates may give way to "well-to-wake"
- New vessels should start using zero GHG energy carriers by 2030

A range of technical and operational measures, as well as alternatives to conventional fuels, are – or will be – available to decarbonise shipping



** % CO_2 refers to range of possible emission reductions for different technologies within each group of measures.*

Three packages of measures were assembled as plausible pathways to achieving the IMO’s decarbonisation ambition level

Package 1	Package 2	Package 3
Characterised by **an early pursuit of carbon-free alternative fuels**	A **moderate uptake of an interim alternative fuel** (represented by LNG) **in the short-term**	**Maximum use of decarbonisation measures** while using conventional fuels.
Introduction of new build ships using grey **hydrogen** and grey **ammonia**, and battery electric (coastal shipping) from 2025. Followed by a transition from grey to blue fuel pathways and to green from 2035 onwards. **Medium take up** of energy efficiency technologies and operational measures. A **10% speed reduction** is assumed for slow steaming. No onboard CCS.	From 2025, HFO and MDO use is assumed to be increasingly substituted with drop-in biofuels (**FAME, HVO**). LNG transitions to bio methane (bio-LNG) from 2030 onwards. **Medium take up** of energy efficiency technologies and operational measures. A **20% speed reduction** is assumed for slow steaming. No onboard CCS.	Conventional fuels, **HFO and MDO,** with a **later transition to reduced carbon alternative fuels** using pathways that provide some reductions in emissions Gradual transition to use of bio-LNG, green methanol and green ammonia. **High take up** of energy efficiency technologies and operational measures. A **30% speed reduction** is assumed for slow steaming. Onboard CCS post 2030.

We modelled costs and emissions of the three packages compared to a baseline scenario up to 2050, incorporating fleet turnover, with three demand scenarios

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Inputs

- Base year fleet (Clarksons)
  Vessel lifetimes
  Productivity (MRV)
  Fuel consumption (MRV)
- Demand scenarios
- Package definitions per measure: adoption rates
- Technology and fuel abatement efficiencies
- Fuel prices
- Technology costs
- Ship costs (Capex, opex)
- Infrastructure costs

Model

Modelling the fleet, fuel, emissions, costs

Baseline | Package 1 | Package 2 | Package 3

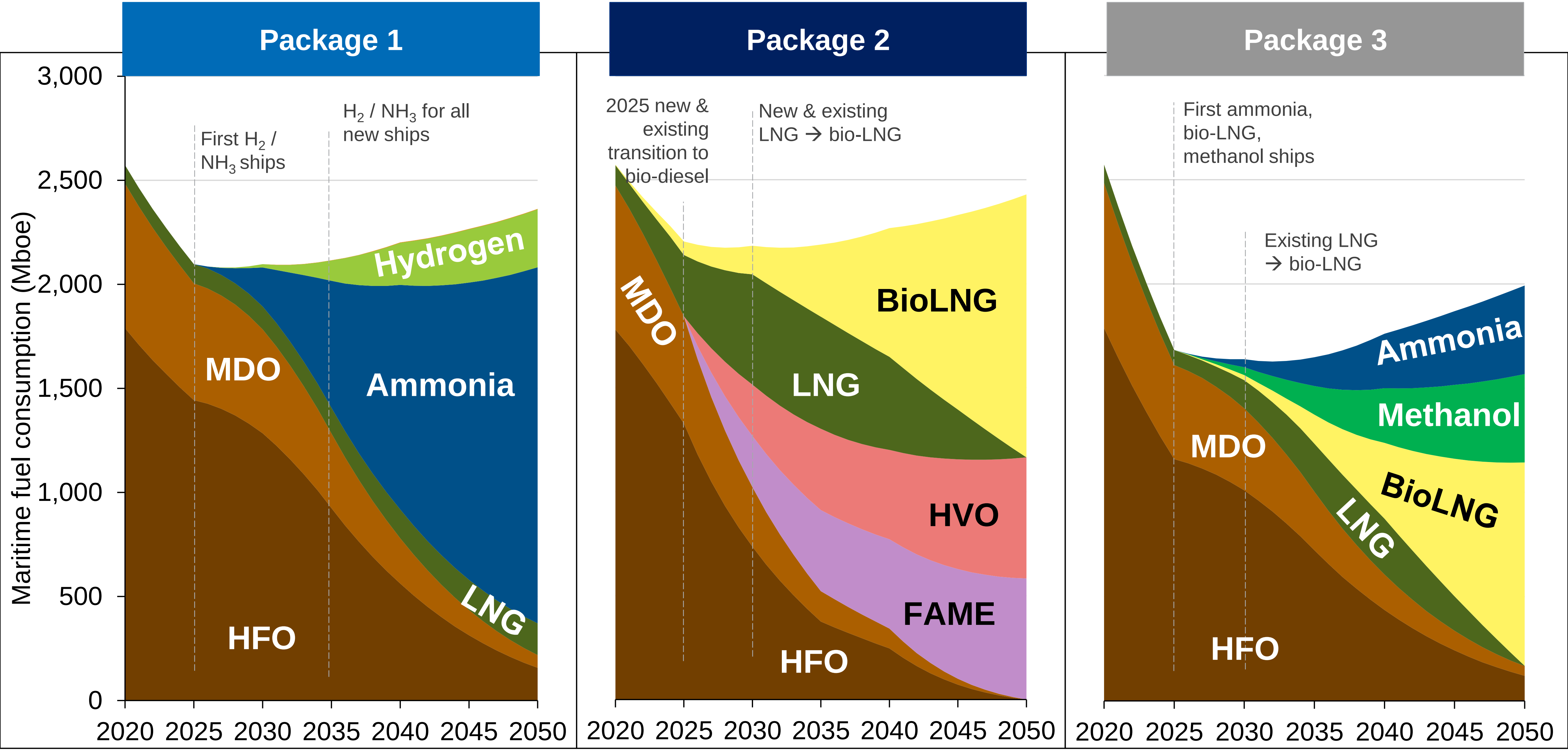
Computes outputs by following splits:

- 10 vessel types, and sizes
- New/existing ships
- 9 fuel types
- Years 2020 to 2050
- WTW/TTW

Outputs

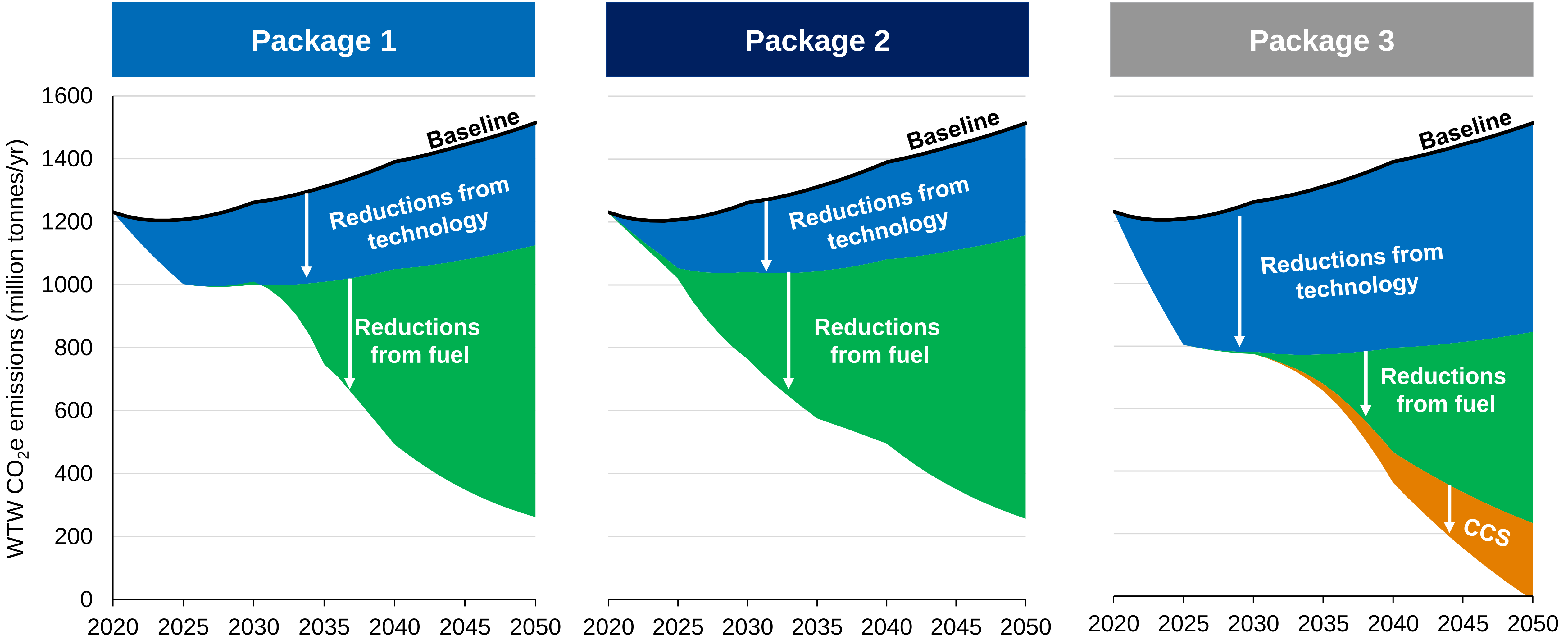
- New build ships each year
- Number of vessels (fleet)
- Fuel consumption
- GHG emissions WTW
- GHG emissions TTW
- Costs (annual or NPV)
- Cost effectiveness $/t

Fuel consumption of the three packages out to 2050



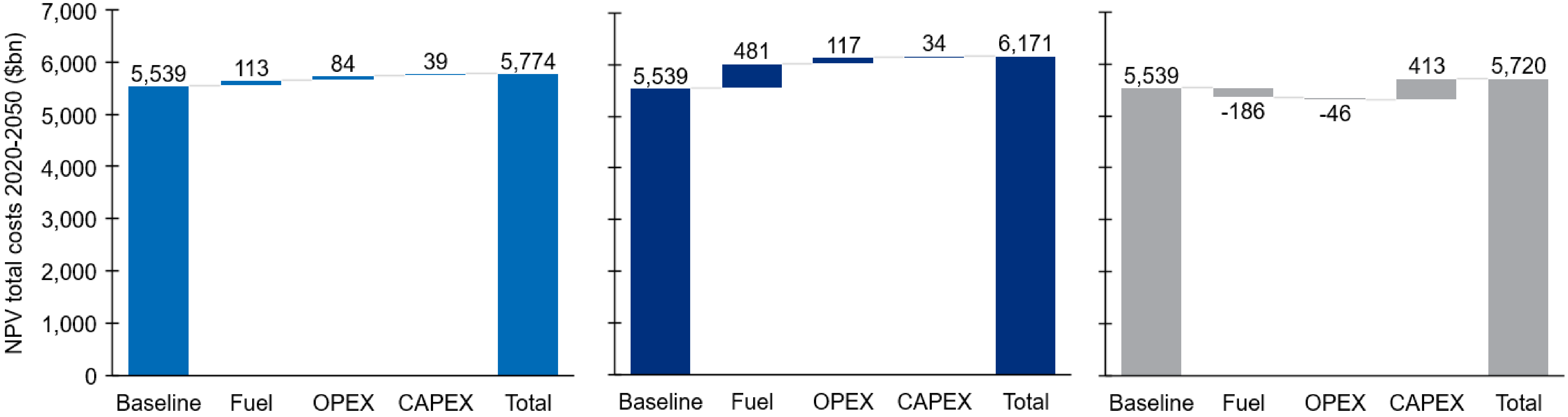
Energy efficiency technologies are key in providing shorter term GHG reductions but are insufficient alone to meet IMO ambition; higher risk CCS a small benefit. The largest reductions in WTW GHG emissions result from fuel switching

WTW CO_2e emissions - contribution of technology and fuels - Central scenario



Net present value (10% discount rate) of cost increments from baseline costs range from +3% to +11% among packages

Package 1 | **Package 2** | **Package 3**



Package 1

- +$235bn above baseline (+4%)
- Half of additional cost is fuel (inc. infrastructure)

Package 2

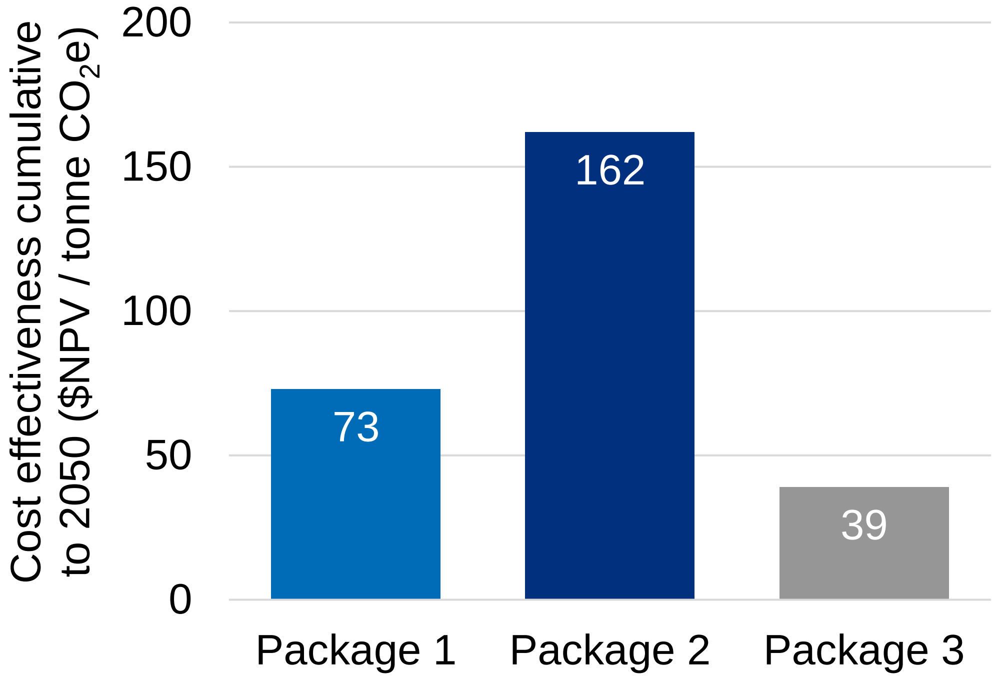
- +$632bn above baseline (+11%)
- 3/4 of additional cost is fuel (inc. infrastructure)

Package 3

- +$181bn above baseline (+3%)
- Lower fuel spend
- Cost increase driven by capex spend on vessels

Package 2 - highest cost per tonne CO_2e abated (higher costs, similar abatement)
Package 3 - lowest cost per tonne CO_2e abated (similar costs, higher abatement)

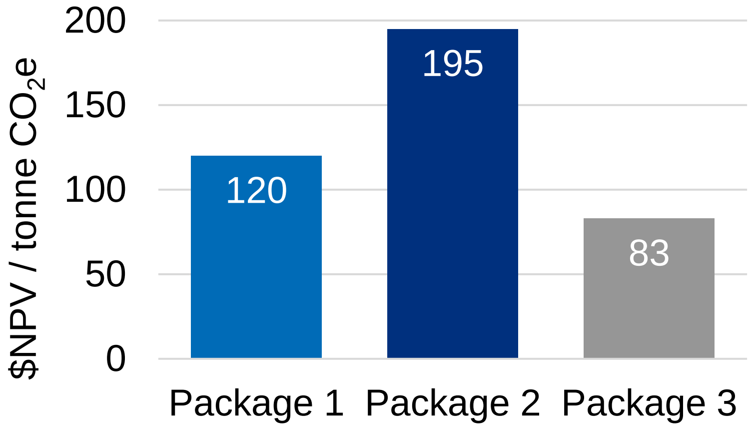
- Cost effectiveness calculated from total net present value of cumulative costs up to 2050 divided by total CO_2e abated in that period
- Central case assumes both costs and emissions discounted at 10% (i.e. additional benefits on short-term reductions relative to the longer-term)



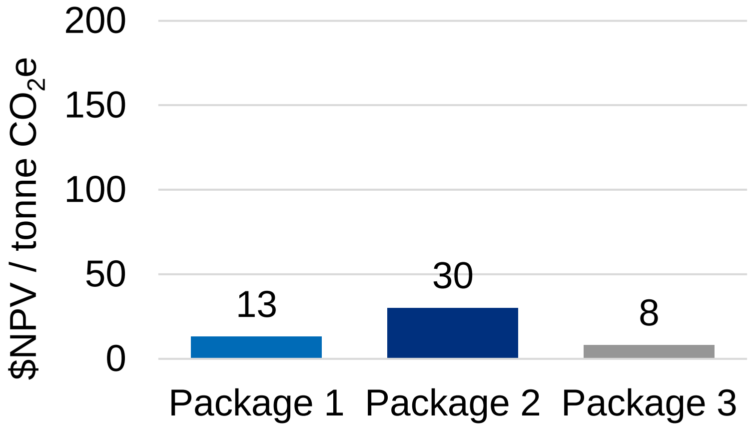
10% discount rate for costs and emissions

EUA (EU ETS) price ~50-60€/t ~60-70$/t

Sensitivity analysis of discounting



5% discount rate for costs and emissions



10% discount rate for costs, 0% for emissions

Risks and barriers

This study and others show it should be technologically possible to decarbonise the global shipping sector to the level of the IMO ambition. However, despite this technical feasibility we have not so far seen rapid decarbonisation at the rate and scale required; barriers to decarbonising the shipping sector remain.

GHG reduction potential

- Uncertainty between TtW and WtW, and in how WtW defined
- 20 year GWPs make LNG/bio-LNG less palatable

Price differential

- HFO price and scale difficult to match
- Regulatory intervention may help reach price parity

Infrastructure

- Bunkering infrastructure and port refuelling facilities need to be scaled up
- *(Not a barrier for 'drop-in' fuels)*

Production increase, location

- Alternative fuel production needs to substantially increase and be appropriately located (→ dedicated new facilities? Or convert existing assets?)
- Renewable electricity sources may be in different geographies to existing assets

Split incentives

- Customers and charterers not willing to pay or co-fund lower emission solutions
- No clarity on how the preferred fuel(s) will be chosen to allow for scale

Sustainability certainty

- Chemically identical brown/blue/green fuels need reliable certification schemes to provide assurance / guarantees
- Uniform / standardised sustainability criteria may also need global consensus

Implications for the fuel production industry

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Opportunities and Challenges

- **Exploration & production** – Demand for marine fuels derived from petroleum and natural gas is expected to reduce in the long term, but with uncertainty about how demand for specific products will change over time
- **Transport & storage** – Bulk transportation and import/export patterns are likely to change unevenly in different regions

Fuel production located nearer to demand centres would reduce need to ship oil/products globally	Uncertain trends for natural gas demand make predictions difficult

- **Refining and distribution** – Opportunities to capitalise on unique expertise and experience but with challenges in the transition away from petroleum products

Increased demand for H_2 and synthetic fuels (especially 'blue' fuel)	Transitioning away from petroleum products difficult due to demand prediction uncertainty

Fuel suppliers' role in the transition and overcoming barriers and reducing risk

- Help shortlist the fuel choices
- Support proof of concept demonstrations
- Accommodate increased alternative fuel demand (10-14 EJ/year by 2050)
  - Plan for associated bunkering infrastructure & port refuelling facilities, est. $500-1,300bn (from 2020-50), excepting 'drop-in' fuel pathways
- Provide 'Green' certification and fuel sustainability information
- Support change to well-to-wake

Implications for the global maritime industry

- **Vessel designers and builders** should incorporate best available energy efficiency technology.
- **Vessel owners and operators should plan for new vessels investments**, accounting for additional technology and fuel costs, and target “green” finance from banks to support these investments.
- **Vessel operators could lobby for regulatory changes to support zero carbon fuels uptake** and reduce price differential and make more commercially competitive.
- As fleets transition to alternative fuels, **vessel operators will need to ensure the relevant fuels are available at the ports needed**. Early discussions with port operators are required to ensure that the necessary fuels infrastructure will be in place as they begin to use the new fuels.
- The industry should **monitor and support the future development of onboard CCS** to ensure that it can be incorporated in new vessels if the demand arises. However, **CCS (including its costs and risks) will not be needed if a rapid switch to zero carbon fuels is made**.

Conclusions

- There are a range of fuel options currently being assessed; **multiple pathways of different alternative fuels could meet IMO's initial ambition for 2050** (remains to be seen if **2023 update may be tighter**)

- **The IMO ambition is estimated to be met by all three packages when emissions are calculated on a well-to-wake basis**; but only packages 1 (fuel switch: ammonia, hydrogen) and 3 (greater efficiency technology emphasis, CCS, + bioLNG, ammonia, methanol) would meet the ambition on a tank-to-wake basis

- Fuel costs are such a large component of total costs, that **energy efficiency measures to reduce fuel consumption are total cost savers** (reduced spend on fuel; increased capex spend on vessels; reduced impact on fuel supply industry)

- **The 'drop-in' fuel package 2 (biofuel, bio-LNG) which faces fewer barriers to deployment is estimated to be much more expensive** compared to the fuel switches of packages 1 and 3 that would require new vessel engine investments

- Long vessel lifetimes means emission pathways become locked in for longer (e.g. than road transport) hence **important to act sooner rather than later to effect meaningful change**

Thank you for your attention

Tim.Scarbrough@Ricardo.com