Ammonia as Maritime Fuel

May 7, 2021

David Hume
Marine Energy Manager
david.hume@pnnl.gov

PNNL is operated by Battelle for the U.S. Department of Energy

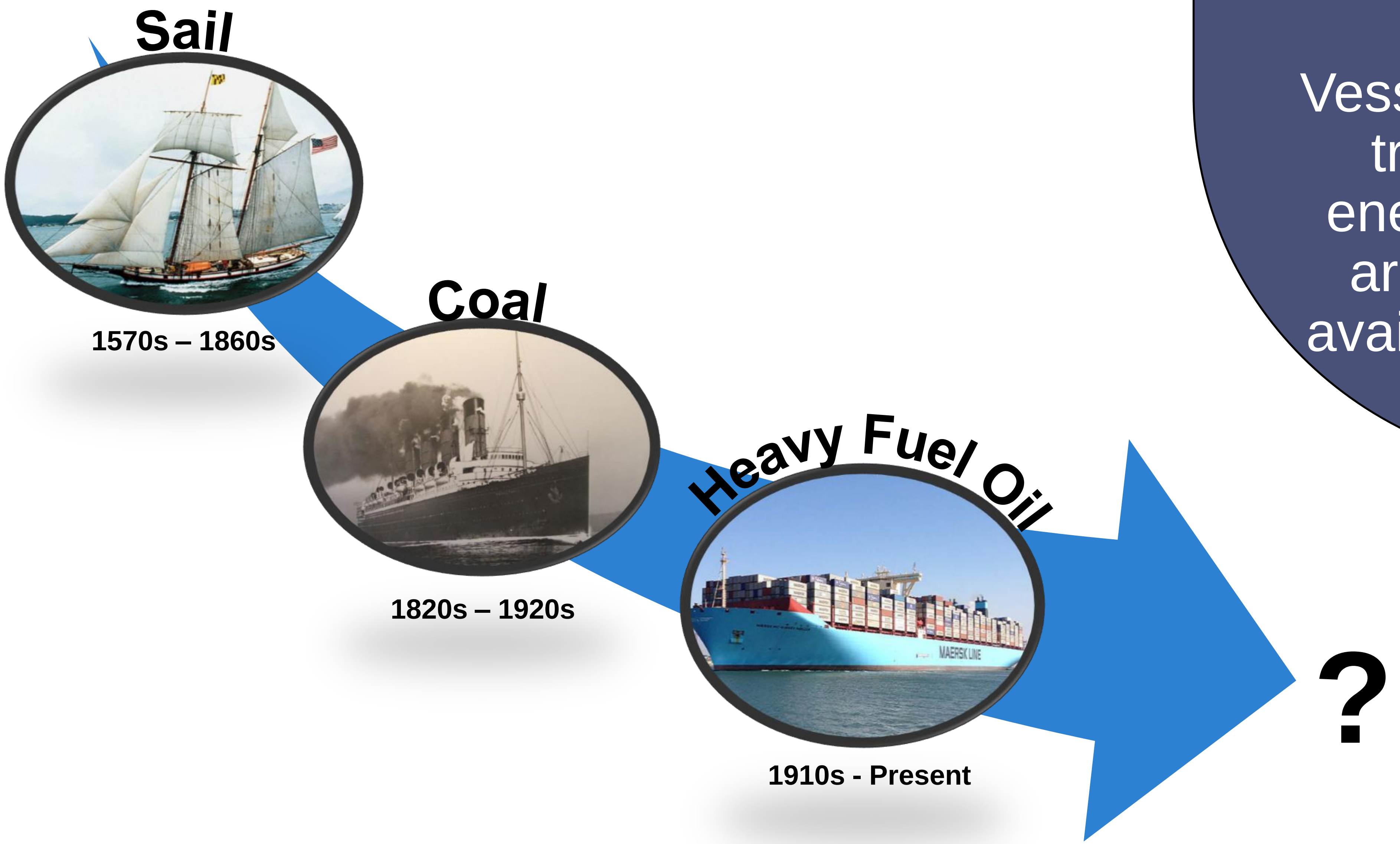
Ships are Unique

Vessels are as varied as the missions they serve and the cargoes they carry. Vessel types include:

- Ferries
- Fishing boats
- Harbor tugs
- Offshore workboats
- Cable-laying ships
- Container ships
- Roll-on/Roll-off ships
- Tankers
- and more…

Ships and Energy

Vessel propulsion has trended towards energy sources that are cheap, readily available, and energy dense

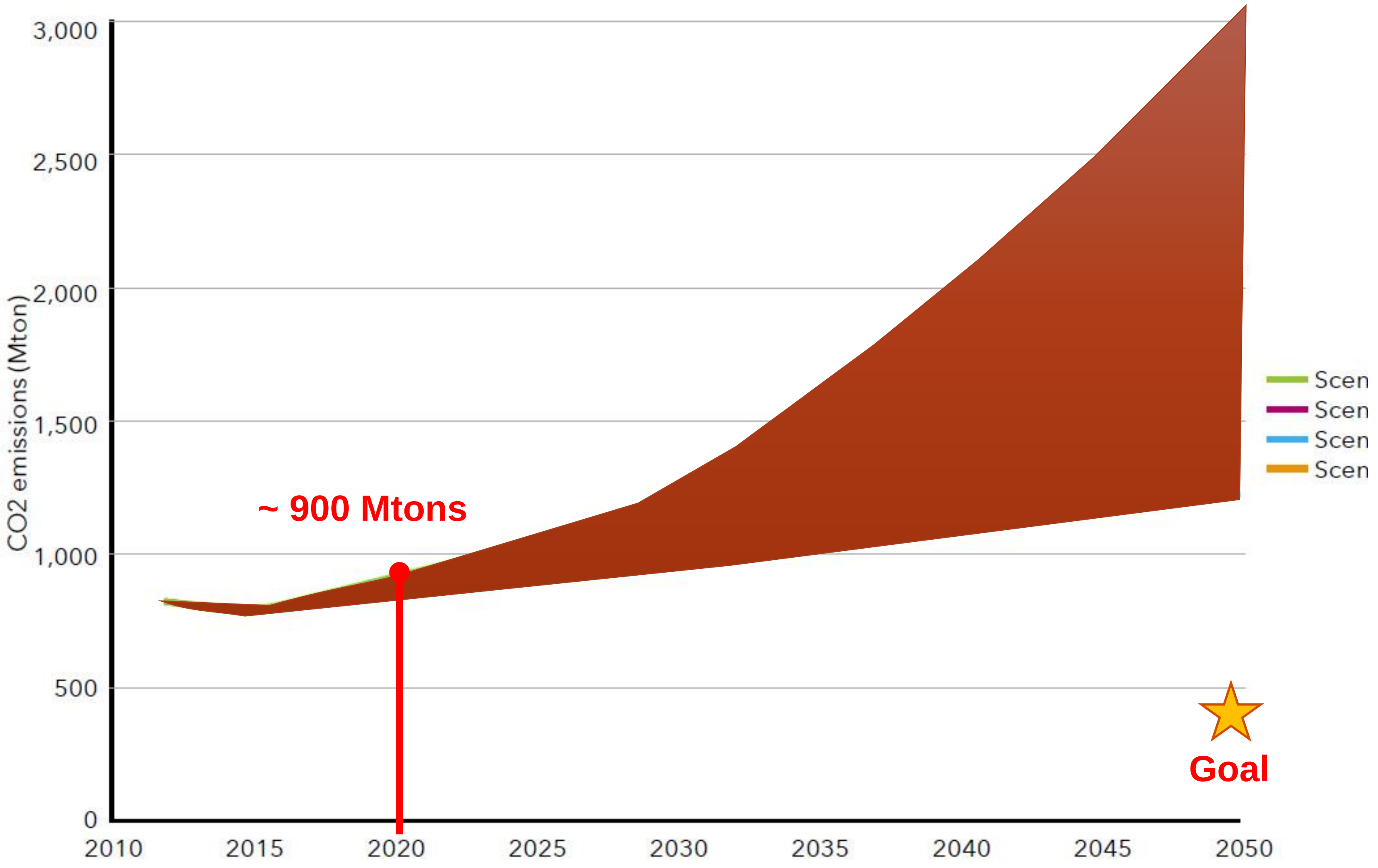


The Maersk Triple E Class vessels can carry more than 18,000 TEUs, their propulsion plant is rated at approximately **60 megawatts**

At cruising speed they will use about 100-150 tons of fuel oil each day

Shipping Emissions Projected to 2050

Under business-as-usual scenarios, shipping could account for 17% of global carbon emissions by 2050

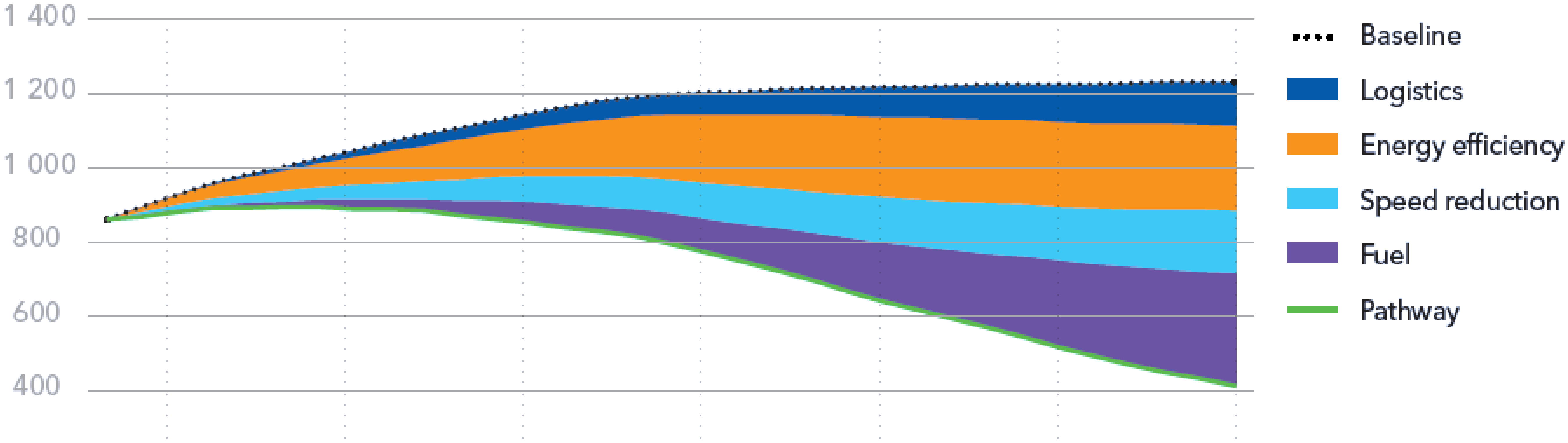


Source: IMO 4th GHG Study

Need Multiple Solutions for Maritime Decarbonization

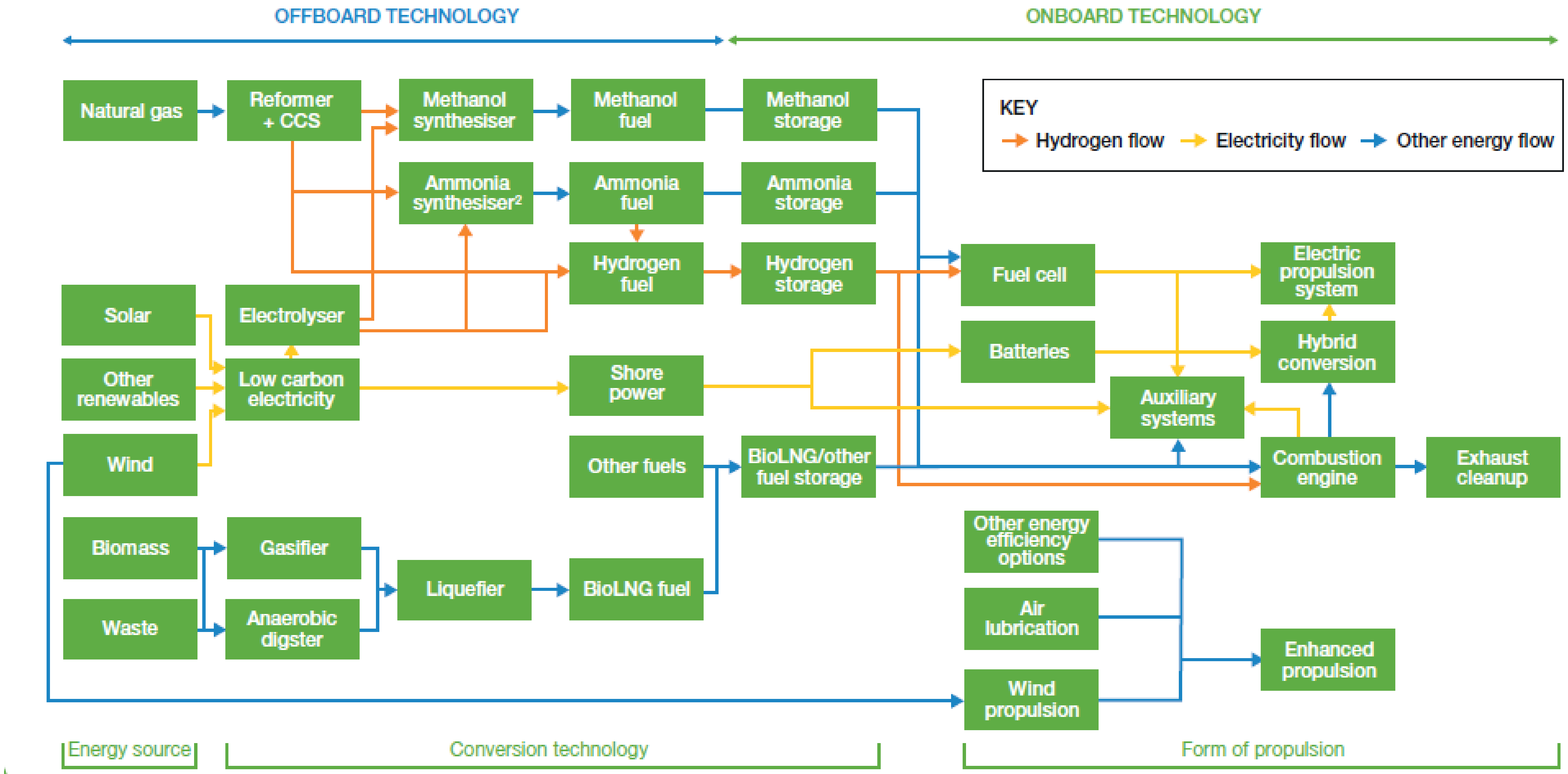
Shipping emissions reduction by measure (2018–2050) for the 'design requirements' (DR) pathway (see Table 6.1)

Units: Megatonnes of carbon dioxide ($MtCO_2$)



Maritime Forecast To 2050 - Energy Transition Outlook 2019. DNV GL

Technology and Fuel Pathways



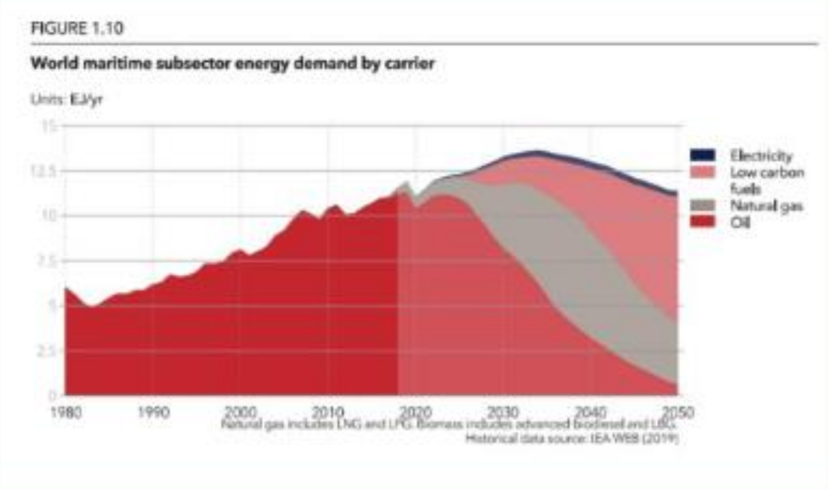
1 Steam Methane Reformer (SMR) + Carbon Capture & Storage
2 Equipment used for the Haber Bosch process

Source: Frontier Economics for DfT

Uncertainty in Fuels of the Future

DNV GL Energy Transition Outlook

60% Low carbon fuels / 30% LNG / 10% Fuel Oil



ABS sustainability Outlook

40% Fuel Oil / 10% LNG / 35% Ammonia+ H2 /

7% Biofuels / 7% Methanol

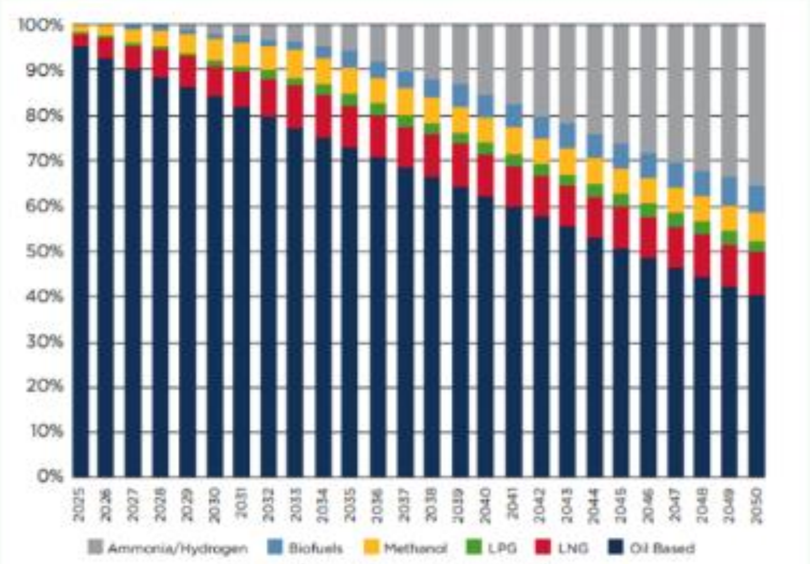
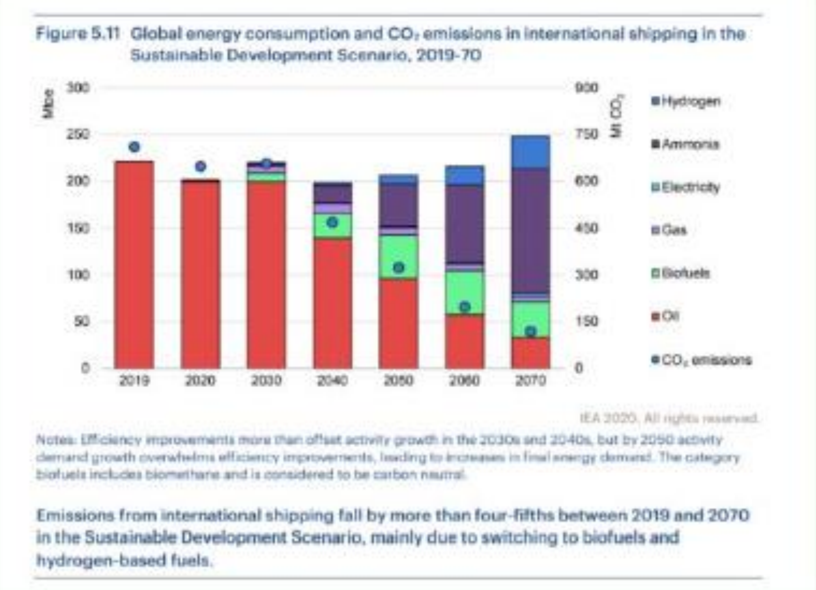


Figure 24: Projected marine fuel use to 2050

IEA

50% Fuel Oil / 25% Ammonia + H2 / 20% Biofuels

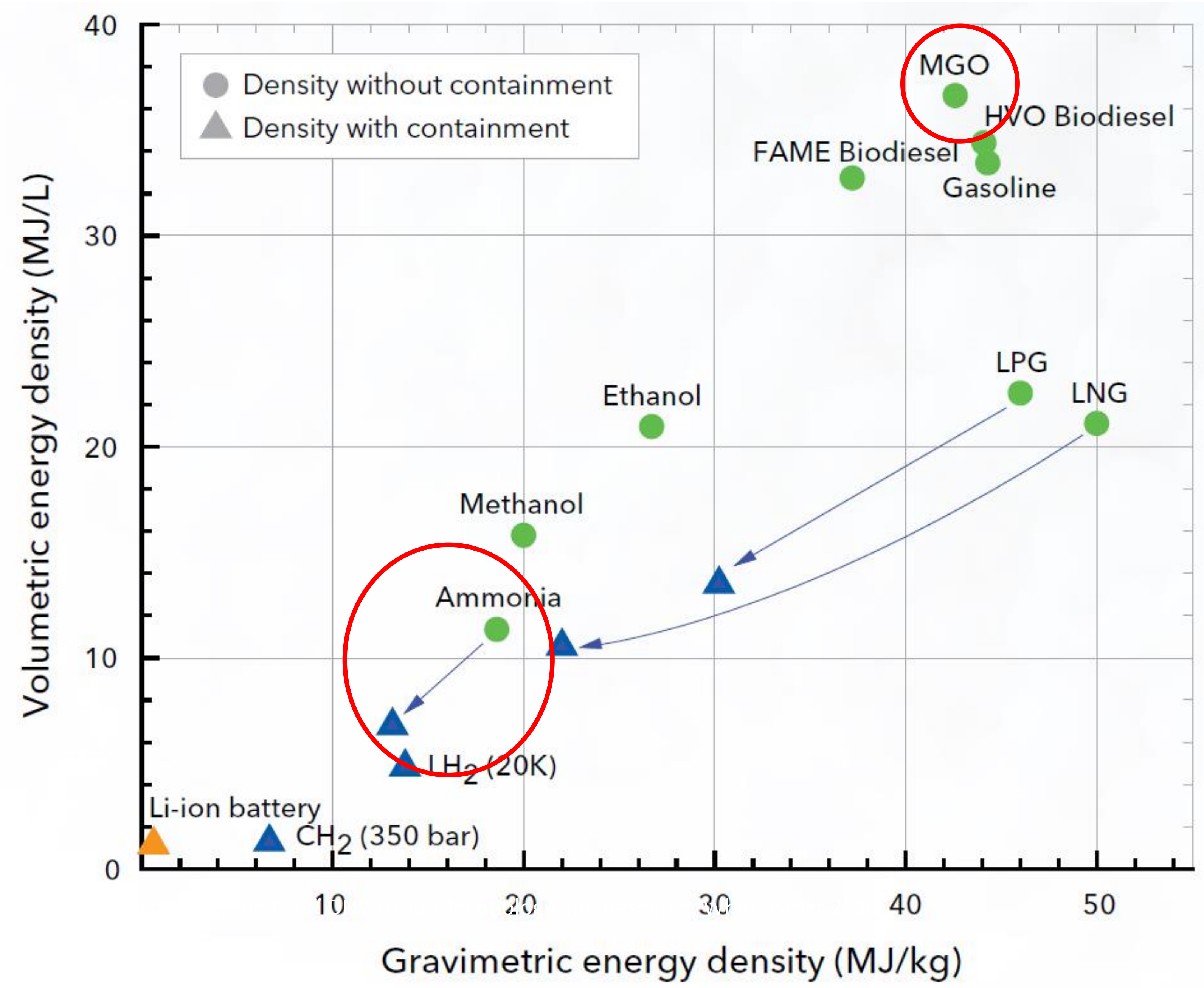
(Total consumption 210 MTOE)



Ammonia Energy Conference 2020 (T. Johannessen) 19.11.2020

MGO to NH_3

Compared to MGO, ammonia's energy content is less than half on a mass basis and about 30% on a volume basis in liquid state.



Advantages and Disadvantages of Ammonia as a Marine Fuel

Advantages

- Storage is easier and cheaper than H_2
- Has been carried by ships as a cargo and been used in Selective Catalytic Reduction (SCR) systems for decades
- As a cargo, there are established safe handling procedures
- Its use as a fuel will nearly eliminate particulate matter and black carbon emissions, and CO_2 if produced using renewables
- Can be used by both internal combustion engines and fuel cells, potential for retrofits of ships using ICEs

Disadvantages

- It’s toxic, engine rooms will need additional safety equipment, such as emergency ventilation and gas-absorption systems
- Below deck piping will likely need to be double walled
- When burned at high temperatures, ammonia produces NOX emissions, currently under strict regulations, requires the addition of an SCR
- Industry has limited little operating experience using it as a fuel in internal combustion engines
- Ships will need to accommodate larger storage tanks, potentially eating into cargo space

Ammonia as a Marine Fuel – Market Opportunities

- About 180 million tons of ammonia are produced worldwide, about 10% are transported by sea. Currently there are ~200 gas tankers that can take ammonia as cargo and typically 40 of them are deployed with ammonia cargo at any point of time. These are potential early adopters.
- One ocean-going vessel would require approximately 60,000 tons of ammonia as fuel each year, or about $15M at current spot market rates.
- Researchers estimate that up to US $1.4 – 1.9 trillion will be needed to achieve the IMO's emissions-reduction target. One consultancy predicts that ammonia could make up 25% of the maritime fuel mix by midcentury, with nearly all new builds running on ammonia from 2044 onward
- MAN B&W, one of the largest marine engine manufacturers, claims that more than 3,000 existing MAN engines can be modified into ammonia engines

Ammonia as a Marine Fuel: Challenges

- Food vs. fuel - Ammonia may compete with fertilizer for food production, with potentially serious socio-economic ramifications. Can ammonia production scale to meet the demands of agriculture and maritime?
- Globally, ships consume an estimated 300 million tons of marine fuels every year. Given that ammonia's energy density is half that of diesel, ammonia producers would need to provide twice as much liquid ammonia if it were to completely displace fuel oil, or about 550 million tons. Is the capacity available?
- The cost of green ammonia is currently at least twice the 2019 cost of VLSFO. Research suggests prices would have to be about 15% lower for ammonia to be financially viable. Is a carbon price needed to close the gap in the short term?
- Most commercial vessels have operating lives of 20-30 years, many of the ships being built this decade will be in operation in 2050. Retrofits will be key to reach IMO goals – this will likely mean modifying existing diesel engines and engine rooms (double walled piping, new ventilation systems, new fuel storage tanks)
- IGC Code and IGF Code currently do have regulations, or do not allow, ammonia as a fuel, this will require working with the appropriate regulatory bodies to change, can take years

Tipping Point for Alternative Marine Fuels?

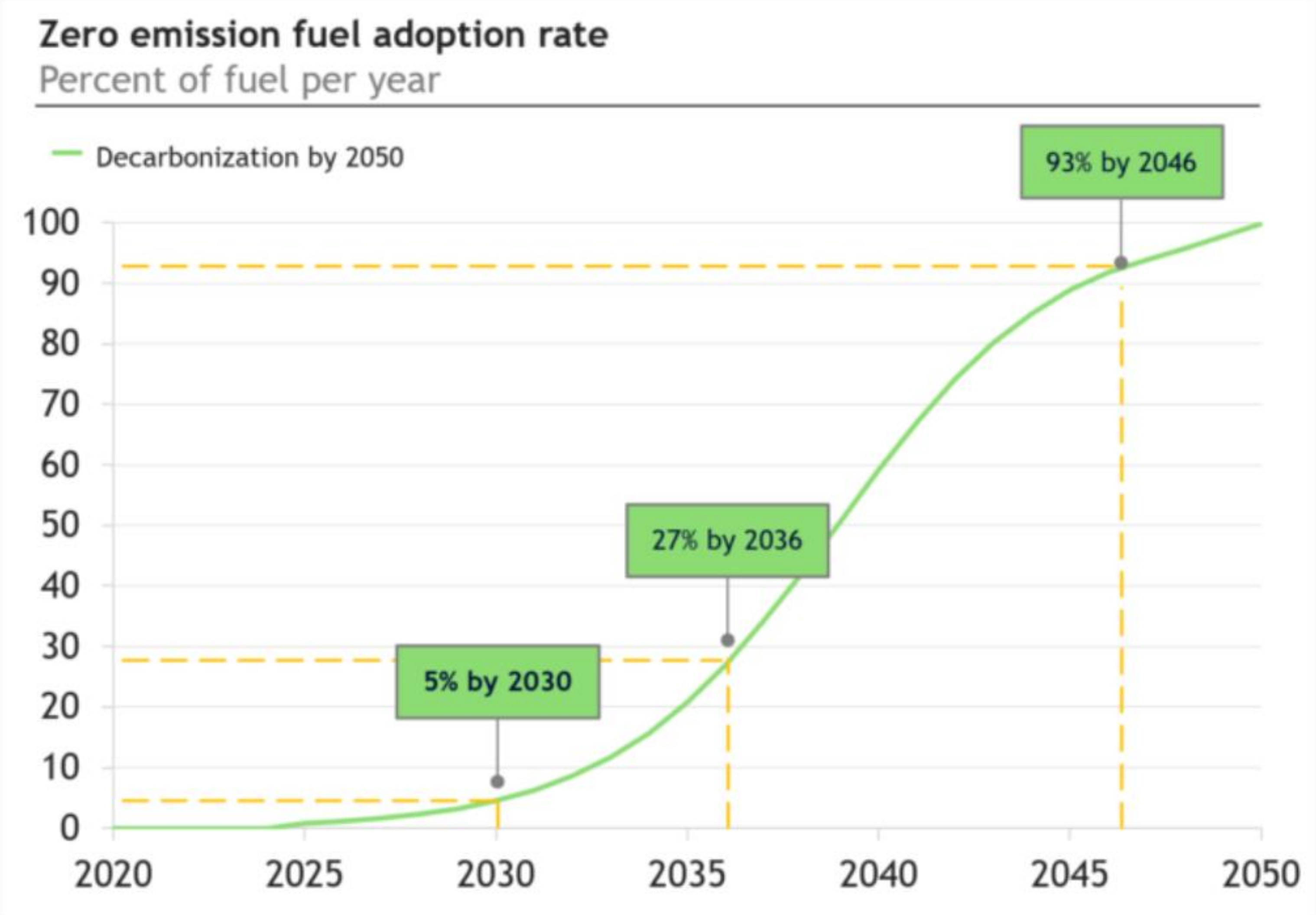


Figure 2: Zero emission fuel adoption rate (Source: COP26 Climate Champions, UMAS)

Getting to Zero Coalition, "Five percent zero emission fuels by 2030 needed for Paris-aligned shipping decarbonization" March 2021

Pacific Northwest
NATIONAL LABORATORY

Thank you