

Under the right conditions

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Uncertainties over the future supply and cost of carbon-neutral fuels are compelling reasons for shipowners, ports, and other stakeholders to consider all technology options for reaching net zero. DNV's latest [Maritime Forecast to 2050](#) includes case studies on whether onboard carbon capture and nuclear propulsion could be significant options.

In this decisive decade for shipping decarbonization, no stone should be left unturned in securing the future we need and want. Our research indicates conditions under which carbon capture and nuclear could help bridge the gap between short-term measures and the massive effort needed beyond 2030 to achieve 2040 and 2050 targets in the new International Maritime Organization (IMO) and forthcoming EU emission regulations.

The studies add fresh insight to assist maritime stakeholders who now have to make costly investment decisions on ship design and operations as well as on what fuels to produce, distribute and bunker. The research has two goals. One is to establish if using these technologies is realistic

operationally. The second is to compare their lifetime costs with fuel strategies most often discussed in the industry, such as fuel oil, liquefied natural gas (LNG), methanol and ammonia, each blending in carbon-neutral fuels (bio-/e-marine gas oil, bio-/e-LNG, bio-/e-methanol, blue/e-ammonia) to comply with greenhouse gas (GHG) emission reduction targets.

Results for various scenarios

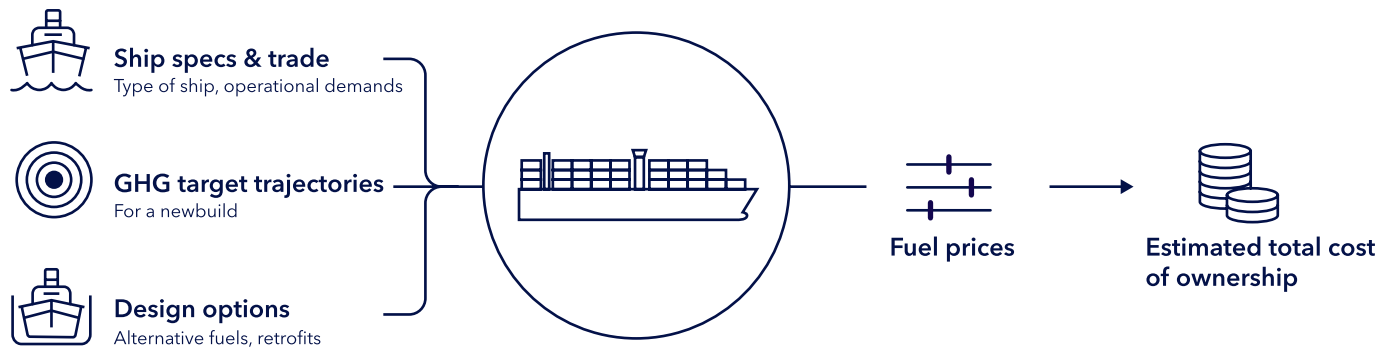
DNV's techno-economic evaluation involves two case studies using the company's tried and tested FuelPath model for a large, modern deep-sea ship, a 15,000 TEUs container carrier sailing between the Far East and Western Europe. Inputs that can be varied in the model include ship specifications and use, the new-build's GHG

emission targets, and design options such as converters and fuel systems.

Maritime Forecast to 2050 also describes the technical, operational and economic assumptions involved in the case studies. In essence, the model assesses the economic performance of available design options relative to fuel over a vessel's lifetime. The outputs include the total cost of ownership and the cost of fuel strategies under different fuel-price scenarios. Annual expenses include yearly payments on capital expenditure (CAPEX), fuel costs, carbon prices, and operating expenditure (OPEX).

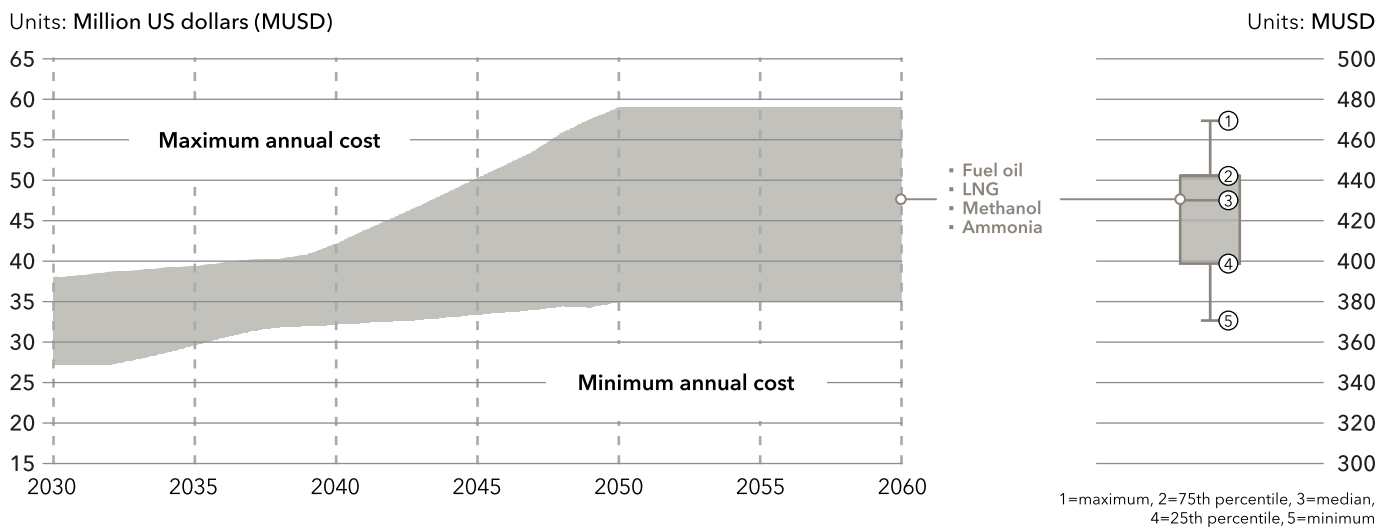
Based on real-world data and experience, the research first benchmarks the cost of the fuel strategies reflecting energy converter and fuel-system design options open to the case-study vessel over its lifetime.

Fig. 1. The DNV FuelPath model



Source for all figs.: DNV Maritime Forecast to 2050 (2023)

Fig. 2. The benchmark span of annual costs and net present value for the case-study ship (15,000 TEUs container carrier) with fuel strategies using fuel oil, LNG, ammonia, methanol, and all four with carbon-neutral blend-in for compliance



More specifically, DNV draws on its data-driven estimates of annual maximum and minimum fuel prices over 2030-60 to create benchmark spans of yearly costs and net present value for the case-study ship for various fuel strategies. It uses these spans to evaluate the feasibility of onboard carbon capture and nuclear propulsion.

Onboard carbon capture case study model

Assumptions for this study are described extensively in the Maritime Forecast to 2050. Briefly, though, the ship runs on heavy fuel oil (HFO), has a carbon dioxide (CO₂) capture unit and storage tanks, and is fitted with a scrubber for sulphur oxides and exhaust pre-treatment.

The study models annual costs under two onboard CO₂ capture and storage (CCS) scenarios, low- and high-cost, to compensate for economic uncertainties such as CAPEX and OPEX. It focuses on two parameters it assesses as impacting

the economics of onboard CO₂ capture the most. One is the ‘fuel penalty,’ the extra energy used for operating the capture unit. The other is the ‘CO₂ deposit cost,’ which is the sum of the captured carbon transport and storage costs.

For the annual cost range, the low-CCS (cost) scenario is seen to perform well against the other fuel strategies (Fig. 3). The Forecast attributes this partly to the HFO price in the scenarios and partly to fuel penalty and CO₂ deposit costs compared with the cost of buying a larger share of carbon-neutral fuels.

The high-CCS (cost) scenario performs around the middle of the studied fuel strategies. For net present value, this case is close to the mean for the fuel strategies by mid-century, while the low-CCS (cost) case outperforms three-quarters of them. Our research suggests there can be an economic case for onboard CCS if the capture technologies have low fuel penalties and the CCS industry can offer low CO₂ storage costs in our model.

Nuclear propulsion case study model

Assumptions for this are fully described in the Maritime Forecast to 2050. One is that the reactor and related systems and services are leased. This is because CAPEX for nuclear propulsion is uncertain but thought likely to be up to twice the cost of the ship itself. As with the carbon capture study, high-nuclear and low-nuclear cost scenarios are used to mitigate uncertainty over reactor costs for merchant vessels (the Forecast discusses cost drivers).

Figure 4 shows the estimated annual costs (CAPEX, OPEX, fuel cost, carbon cost) and net present values for nuclear propulsion compared with the benchmark fuel strategies (fuel oil, LNG, methanol and ammonia) during ship decarbonization.

The annual costs of nuclear appear to be more or less stable compared with the benchmark cost range that increases from 2030 to decarbonization in 2050. This, the Forecast concludes, indicates that nuclear propulsion will be increasingly

Fig. 3. Range of case-study annual costs (left) and net present value (right) for low- and high-cost scenarios for onboard carbon capture and storage compared with the benchmark

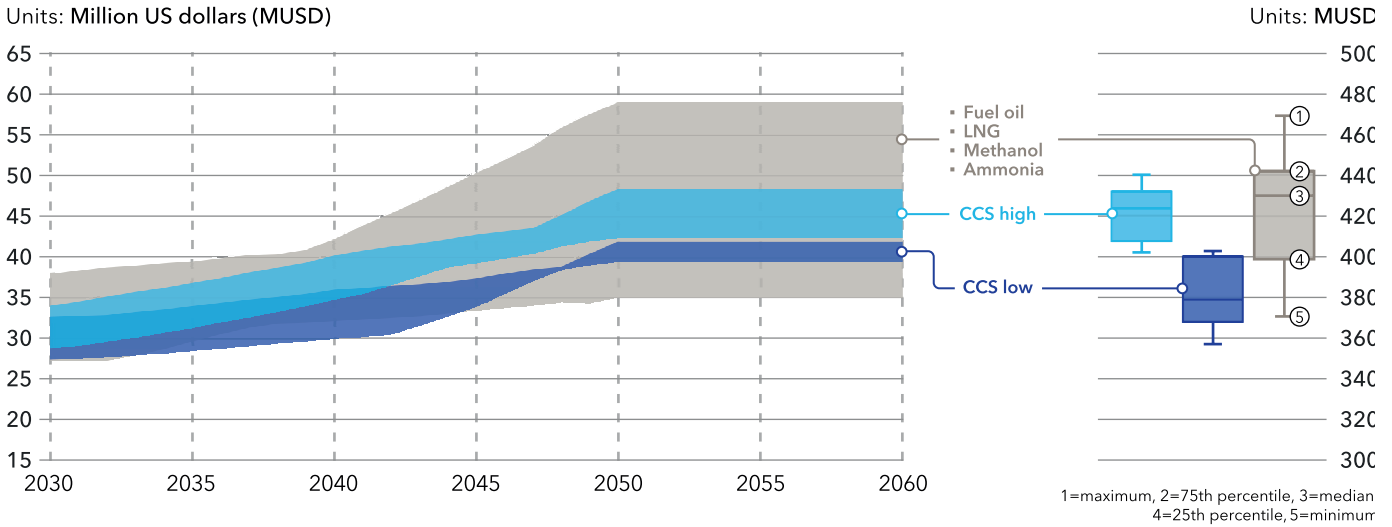
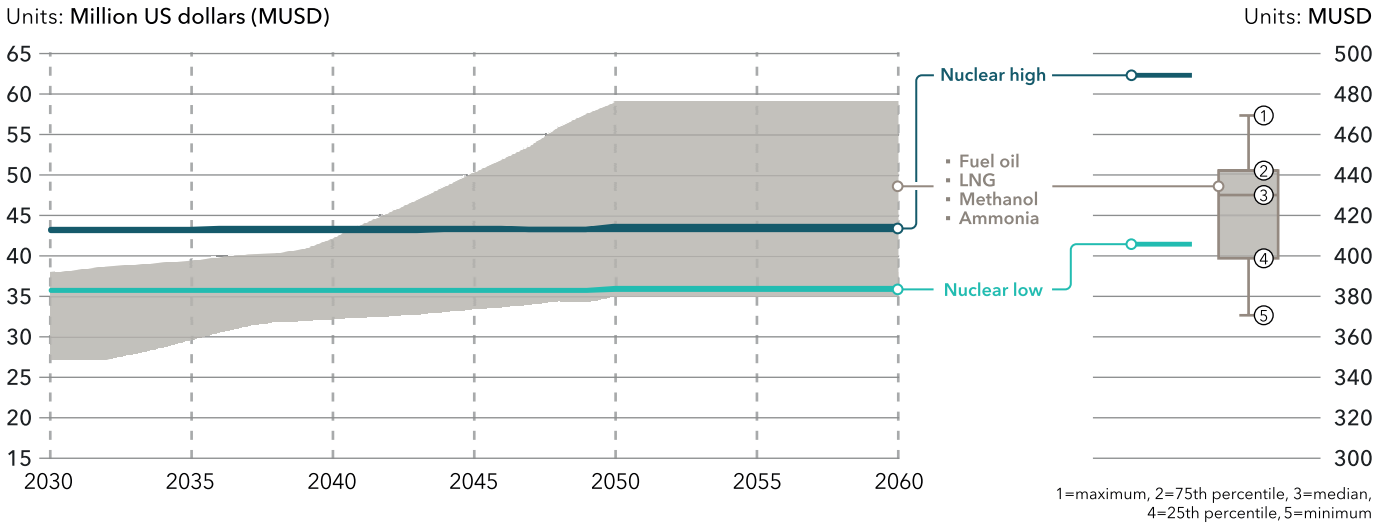


Fig. 4. Range of case study annual costs (left) and net present value (right) for low- and high-cost scenarios for ship nuclear propulsion compared to the benchmark



competitive as GHG limits are tightened. The takeaway is that there can be an economic case for nuclear propulsion, if reactors are developed, that can reach the lower range of cost levels described here.

Key takeaways

DNV’s conclusions support the prospect that onboard CO₂ capture and nuclear propulsion could mitigate competition for sustainable biomass and renewable electricity – all under the right conditions. Onboard CO₂ capture could release maritime from competing for carbon-neutral fuels. Nuclear propulsion is itself carbon-neutral and less exposed

to price swings and supply issues than carbon-neutral fuels.

The report acknowledges that carbon capture would need onboard facilities to remove exhaust CO₂, onshore processing of captured CO₂, temporary storage and offloading facilities, and infrastructure such as pipelines and permanent storage. Obstacles to nuclear include international

regulations, public perception, and technology costs.

Both technologies face barriers for sure. But our studies suggest they could, in the right circumstances, be economical and valuable additions to the flexible toolbox maritime needs to meet mid- and long-term decarbonization targets amid anticipated competition for carbon-neutral fuels. ■

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