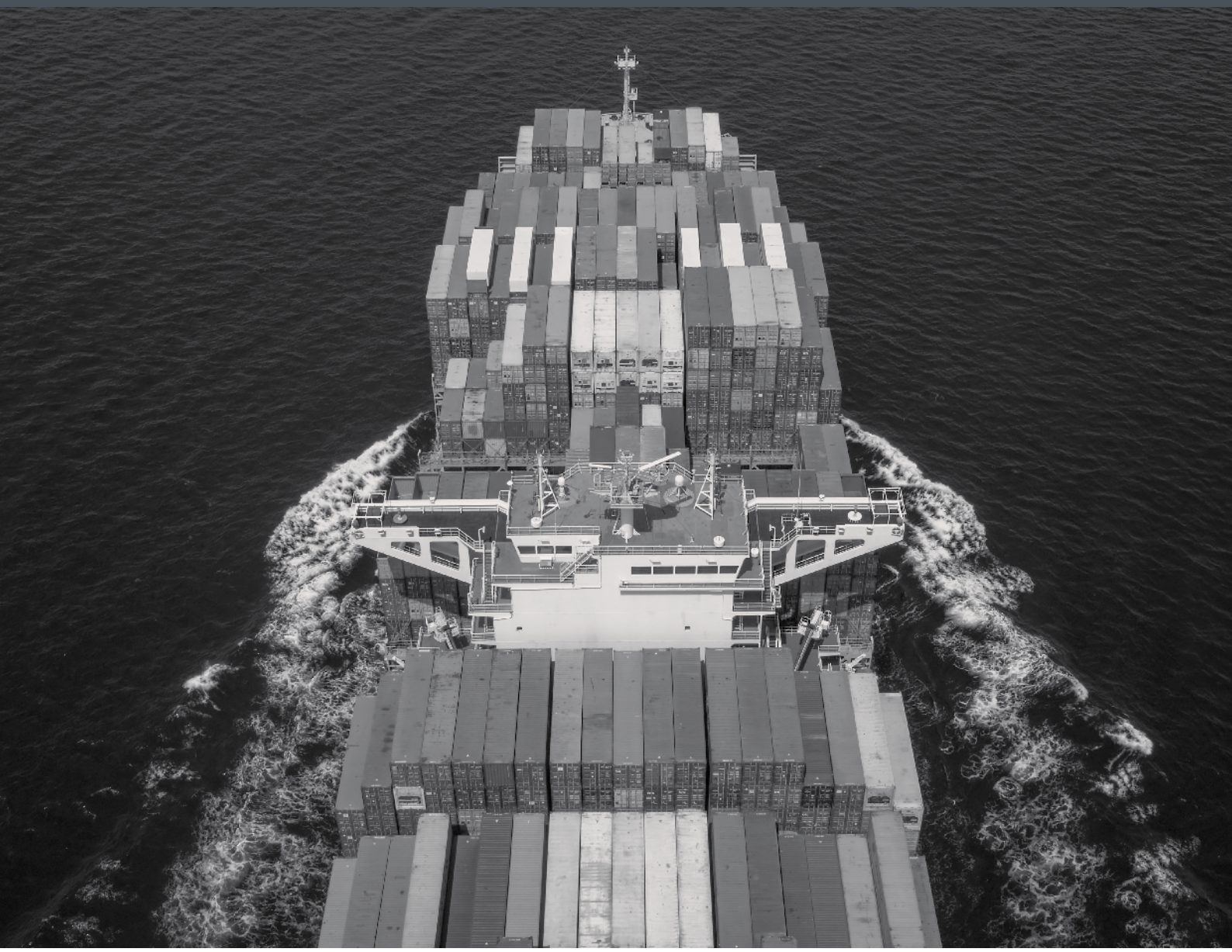


SHIPPING'S NUCLEAR OPTION IN THE MOVE TOWARDS NET ZERO: IS IT VIABLE?

Imagine a ship capable of carrying more cargo than an equivalent conventional sized vessel, yet with zero emissions during a voyage. Surely, if such a vessel existed it would likely gain massive market share very quickly and have a dramatic effect on market dynamics?

This is the near reality as nuclear-powered vessels gain increasing interest, as they would not need to be refuelled for decades and could operate near-continuously for their entire lifespan. So, what's the catch? In this briefing, we look at some of the possible issues surrounding the adoption of nuclear power and how nuclear vessels are currently regulated.

Nuclear is not new technology

In 1954, the world had been living with the threat of nuclear war for nearly a decade. In a bid to overturn the fear of nuclear power, President Dwight D. Eisenhower decided to give nuclear power an overhaul and to try to market its benefits. *"Atoms for Peace"* was a three-stage programme to re-frame nuclear power to appeal to the US population. The stages were intended to focus on: domestic nuclear energy, nuclear medicine and nuclear-powered transportation. The US-built vessel *NS Savannah* was intended to carry both cargo and passengers and entered service in 1962. The vessel's reactor was encased in four feet of concrete, steel and lead.

Other experimental nuclear merchant vessels included a German vessel (*Otto Hahn*) and a Japanese vessel (*Mutsu*) that operated in the 1960s and 1970s. Aside from these examples, production of nuclear vessels on a larger scale did not evolve beyond the experimental stage. However, the push for the shipping industry to decarbonise and forge a path toward net-zero greenhouse gas (**GHG**) emissions has given the discussions a new lease of life. In a world where the move from conventional maritime fuels to other forms of fuel and propulsion are being considered, nuclear propulsion is emerging as a possible clean option.

There is now a growing body of stakeholders in the shipping industry who are actively looking at the use and adoption of nuclear power as part of the wider green initiative and transition to net zero emissions. The UK Government has recognised that nuclear propulsion could be part of the solution against climate change and are now actively pushing technological proposals to achieve the necessary reduction of greenhouse gas emissions from shipping.

New nuclear initiatives

The UK Government's newly named Department for Energy Security and Net Zero (**DESNZ**) launched a competition for up to £20 billion in funding to design and build a small nuclear reactor (**SMR**) project. On 2 October 2023, six companies were selected to advance to the next phase of the competition and invited to bid for Government contracts later this year, with successful companies to be announced in Spring 2024.[1]

In addition to the above, the UK Government also announced a grant funding package across the nuclear industry worth up to £157 million. Grants have been allocated to a variety of projects spanning a wide range of nuclear technologies. The largest grant is £77.1 million available for companies engaged in *"advanced nuclear business development"*.[2] This presumably is aimed at companies developing the next generation and design of SMRs to be constructed within the decade.

Beyond UK initiatives, the classification society American Bureau of Shipping (**ABS**) has published the results of a study carried out with Herbert Engineering Corp. (**HEC**) into the adoption of advanced nuclear reactors onboard a 14,000 TEU containership and 157k DWT Suezmax.[3] They concluded that if the container vessel was powered by two Lead-Cooled Fast Reactors (**LFRs**), this would be sufficient to power the ship for its entire 25-year lifespan. In addition, they found that this would likely increase the container vessel's cargo capacity and operational speed.

The Suezmax vessel study established that powering the vessel using four, 5MW, heat-pipe microreactors, whilst also reducing cargo carrying capacity, could result in an increased operational speed and a requirement to only refuel the vessel once during its 25-year life. The research results also found that both concept vessels would emit zero CO_2.

Other types of reactor are also being developed as alternatives to LFRs. Molten Salt Reactors (**MSRs**) operate at higher temperatures with greater efficiency. The nuclear fuel (Thorium) is suspended in the coolant (molten liquid salt) and the two are placed together in a container. This significantly reduces any risk of a core meltdown. MSRs are not pressurised and contain no water thereby reducing the risk of a 'Fukushima' type explosion. They also produce smaller waste streams and can be refuelled without having to shut down the reactor.

Many stakeholders are already in advanced discussions about the early adoption of nuclear propulsion. Examples include:

- Nine Korean organisations, including H-Line Shipping, Hyundai Merchant Marine (**HMM**), Janggeum Merchant Marine (Sinokor) and Wooyang Merchant Marine, the Korea Atomic Energy Research Institute (**KAERI**), Korea Register of Shipping and the Korea Ship & Offshore Plant Research Institute (**KRISO**), who have signed a memorandum of understanding for the development of MSR powered merchant ships.[4]
- Fortum have signed a memorandum of understanding with Korea Hydro & Nuclear Power Co., Ltd. (**KHNP**), the owner and operator of the South Korean nuclear fleet and a nuclear power technology supplier for cooperation and information exchange regarding future nuclear power plants, new reactor designs as well as safe and efficient operation of existing nuclear power plants.[5]
- Samsung Heavy Industries (**SHI**) has teamed up with a Denmark-based startup focused on nuclear reactor technology Seaborg Technologies and KHNP, an owner and operator of nuclear power plants, in a consortium that aims to develop floating nuclear power plants.[6]
- Korea Shipbuilding & Offshore Engineering (**KSOE**) has unveiled the design of a SMR-powered ship which coincides with the company investing US$30 million (approximately 42.5 billion won)

1 Six companies through to next stage of nuclear technology competition - GOV.UK (www.gov.uk)
2 British nuclear revival to move towards energy independence - GOV.UK (www.gov.uk)
3 Groundbreaking ABS Study Explores Potential of Commercial Nuclear Propulsion - American Bureau of Shipping (cision.com)
4 South Korean partnership to develop SMR-powered ships : New Nuclear - World Nuclear News (world-nuclear-news.org)
5 Fortum and KHNP have signed a Memorandum of Understanding on cooperation on nuclear power | Fortum
6 SHI, KHNP and Seaborg to develop floating nuclear plants - Offshore Energy (offshore-energy.biz)

“There is now a growing body of stakeholders in the shipping industry who are actively looking at the use and adoption of nuclear power as part of the wider green initiative and transition to net zero emissions. ”

in TerraPower, a SMR company established by Microsoft founder Bill Gates.[7]

- The Baltic Shipyard (Baltiysky Zavod) has signed a contract with Atomflot for the construction of a multifunctional nuclear technology service vessel which can load and unload nuclear fuel from reactor units of nuclear icebreakers and floating power units.[8]

Against this backdrop, several issues and questions arise as to how nuclear ships would be regulated and what the legal implications are.

Issue 1: How is nuclear shipping currently regulated?

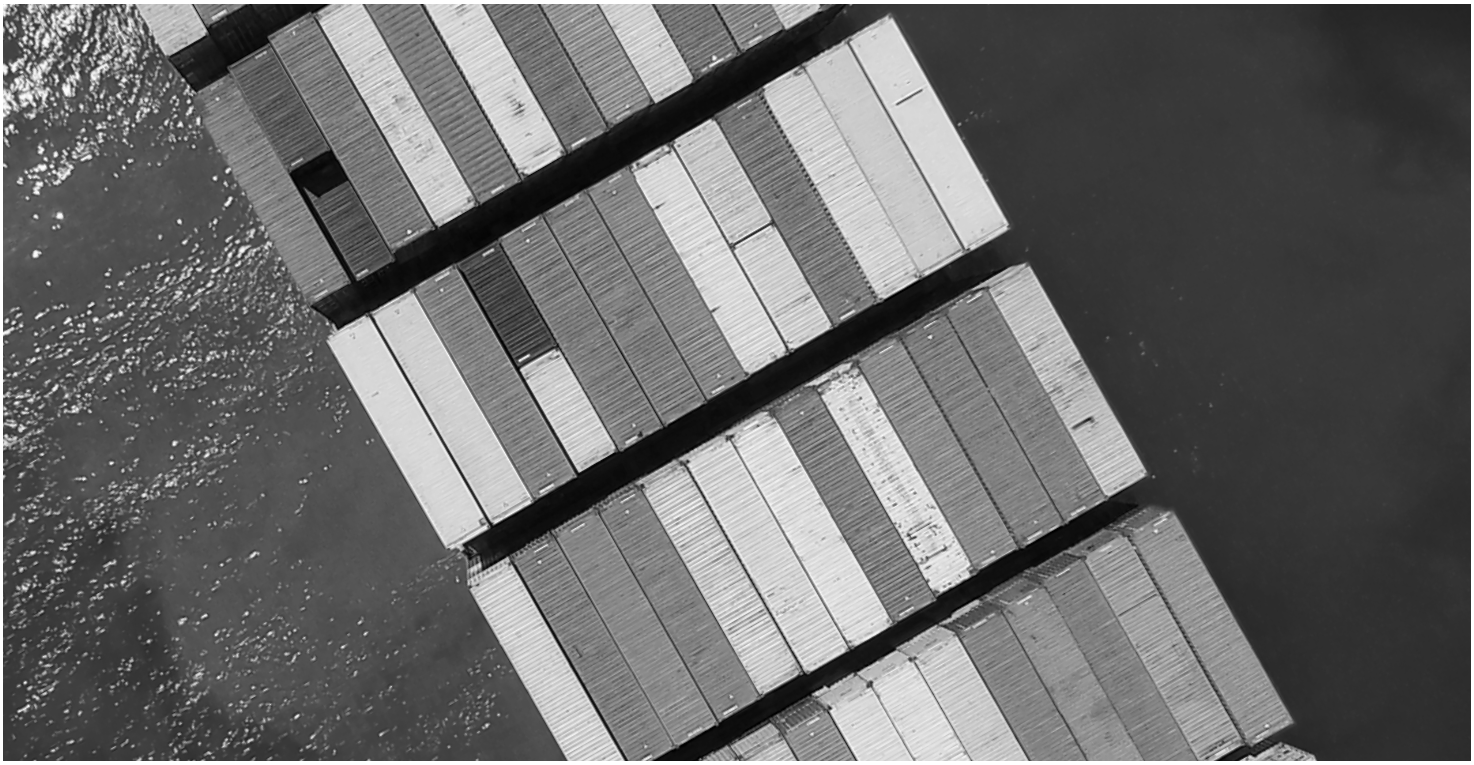
Although nuclear-powered navy vessels have been in use for decades, nuclear merchant vessels very much remain a novelty. Nonetheless, there are existing IMO regulations and guidance on the construction and operation of nuclear vessels, which have recently been supplemented by national legislation in the UK.

Chapter VIII of the International Convention for the Safety of Life at Sea (**SOLAS**) and the Safety Code for Nuclear Ships (res. A.491.XII) (**Nuclear Code**)[9] set out criteria for nuclear vessel design, operation, safety and decommissioning. The Nuclear Code accompanied the 1962 Brussels Convention on the Liability of Operators of Nuclear Ships, but this convention has never entered into force. As a result, the current international regulation of nuclear shipping constitutes non-binding ‘soft law’, and nuclear vessels will be subject to any binding national or regional laws and regulations.

In this regard, the UK has recently taken steps to transpose SOLAS Chapter VIII and the Nuclear Code into binding national legislation by way of the Merchant Shipping (Nuclear Ships) Regulations[10] (the UK Nuclear Ships Regulations) and MGN 679(M) Nuclear Ships[11] (the MGN). Owners and operators of nuclear ships should keep in mind the following regulations of the UK Nuclear Ships Regulations and sections of the MGN:

- The Maritime and Coastguard Agency (**MCA**) must approve a safety assessment and ensure there are no unreasonable radiation or other hazards before construction begins (regulation 7);
- A precondition for MCA approval is also the development of a Quality Assurance Program covering the ship’s lifecycle from design to decommissioning (regulation 28);
- The nuclear ship must carry on board a detailed operating manual including all information necessary for operating the ship in normal operating conditions as well as instructions for appropriate action to be taken in an emergency (regulation 14);
- When a nuclear ship is moored and work is carried out involving ionising radiation, the Radiation (Emergency Preparedness and Public Information) Regulations 2019 must be complied with (section 7.3 MGN);
- A non-UK flagged nuclear ship intending to call at a UK port must provide the port with a safety assessment 12 months before its arrival in UK waters (regulation 13(5));
- Non-compliance with the UK Nuclear Ships Regulations constitutes a criminal offence punishable by a fine or possibly imprisonment (regulation 31).

7 Report: KSOE reveals design of SMR-powered vessel - Offshore Energy (offshore-energy.biz)
8 Contract signed for Russian multifunctional nuclear service vessel : New Nuclear - World Nuclear News (world-nuclear-news.org)
9 A 491 12 (imo.org)
10 The Merchant Shipping (Nuclear Ships) Regulations 2022 (legislation.gov.uk)
11 https://www.gov.uk/government/publications/mgn-679-nuclear-ships/mgn-679-m-nuclear-ships



Another key concern for owners and operators of nuclear ships would be the ability to limit liability in the event of loss or damage arising out of the operation of the ship. The Convention on Limitation of Liability for Maritime Claims 1976 (**LLMC Convention**) explicitly excludes nuclear ships from its scope (under article 3) and so would not offer any protection to shipowners. Further, the Vienna Convention on Civil Liability for Nuclear Damage 1963 applies strict and exclusive liability of the operator of a nuclear installation.[12]

Handling and disposing of nuclear waste, as well as the export of nuclear materials, are also strictly regulated and there are other areas where a nuclear-powered ship may be subject to further regulation compared to traditional fuel oil powered ships.

Finally, port states and flag states will also already have, or will develop, regulations and requirements for nuclear vessels. The UN Convention on the Law of the Sea (**UNCLOS**) explicitly requires nuclear-powered ships and ships carrying nuclear substances to *"carry documents and observe special precautionary measures"* when passing through the territorial seas of port states (see UNCLOS article 23).

Issue 2: How would nuclear shipping be recognised in environmental regulations?

Nuclear shipping could prove an appealing option for complying with new GHG emissions regulations, including the IMO's EEXI and CII regulations and the EU's Fit for 55 measures, including maritime transport's inclusion in the Emissions Trading System Directive (**EU ETS**) and the FuelEU Maritime Regulation (**FuelEU Maritime**). A nuclear ship would be constructed with a reactor that could run for decades without producing any GHG emissions. On the contrary, the nuclear sector is heavily regulated under other environmental regulations and the prospects of nuclear vessels raise concerns of nuclear radiation and contamination to the environment.

Nuclear power has been recognised in the IMO's Guidelines on Life Cycle GHG Intensity of Marine Fuels[13] as a source of electricity/ energy to produce other sustainable maritime fuels such as hydrogen and ammonia. In a similar vein, the EU has included specific nuclear energy activities in the list of environmentally sustainable economic activities under the EU Taxonomy Regulation.[14] Against this backdrop of regulators recognising (to some extent) nuclear as a sustainable method of power generation, the next question is whether nuclear-powered vessels are presently recognised in environmental regulations as a sustainable method of transport.

Considering the IMO's and EU's emissions regulations, it is noteworthy that neither MARPOL's EEXI and CII regulations nor the EU ETS and FuelEU Maritime specifically mention nuclear fuel or propulsion. The IMO has generally abstained from identifying particular compliance methods, so it is likely to be a case for shipowners and operators to test and verify how a nuclear vessel would comply. The IMO Marine Environment Protection Committee could also adopt guidelines in this regard (as it has recently done for use of biofuels in the context of compliance with the CII regulations). The EU, on the other hand, has gone into some detail about possible compliance methods, in particular in FuelEU Maritime. FuelEU Maritime regulates the GHG efficiency of maritime fuels, whereby their carbon factors are calculated. Annex III of the FuelEU Maritime Regulation includes a 'non-exhaustive' table of types of technologies that would be considered 'zero-emission',

12 Vienna Convention on Civil Liability for Nuclear Damage | IAEA
13 https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/annex/MEPC%2080/Annex%2014.pdf
14 https://eur-lex.europa.eu/legal-content/EN/LSU/?uri=CELEX:32020R0852

“The images of Three Mile Island in 1979, Chernobyl in 1986 or Fukushima in 2011 will be prevalent until the public are convinced and reassured that the ‘new’ smaller reactors fitted to nuclear ships are more advanced and operate at lower temperatures, distinguishing them markedly from the commercial reactors of the 1970s, 80s and 90s.”

where nuclear is notably absent. Consideration would also need to be made as to how the GHG efficiency of nuclear propulsion would be assessed on a well to wake basis.

Issue 3: What are the practical requirements and safety concerns?

Although reactors such as MSRs on nuclear vessels are in many aspects safer than conventional nuclear reactors in powerplants, the issue of public perception of the dangers of nuclear technology could pose significant hurdles to the adoption of nuclear vessels in merchant shipping. Further, nuclear vessels will require specially trained crew – with the particular requirements for crew training set out in the UK Nuclear Ships Regulations. These include, at a minimum, that crew receive training in the basic principles of nuclear energy, the structure and performance of a nuclear ship, basic principles of radiation hazards and radiological protection, and on actions to take in emergency situations.

Low-carbon alternative fuels such as ammonia and methanol also require specialised vessels and specially trained crew. Therefore, using a nuclear reactor to fuel a merchant vessel could arguably be viewed as another option from a range of future fuels that will each pose their own requirements and concerns in terms of practicality, affordability and, most importantly, safety. Nonetheless, crew training and manning for a nuclear ship will likely constitute a larger part of operating costs than a conventional ship.

Further questions and concerns arise as to what specific expertise would be required to provide salvage and/or wreck removal services to a nuclear vessel, and how such expertise can be acquired. But this in itself not new – the nuclear submarine *Kursk* was successfully raised from the seabed by a Dutch consortium from Mammoet and Smit Salvage in October 2001. Russia has also announced that it plans to recover four reactors by 2030 – two on the submarine K-159 and two on the K-27.[15]

Looking further into a ship’s lifecycle, repair yards and recycling yards would need the knowledge and equipment to safely repair and decommission a nuclear vessel. The maritime industry can learn from the oil and gas sector and classification societies can ensure that any new ship that is built is designed with its safe decommissioning in mind to ensure that this can be done in a cost-effective manner. The UK Nuclear Ships Regulations requires a nuclear ship to be decommissioned in accordance with the Nuclear Code. At the point where a nuclear ship is no longer fit for navigation, the licensing requirements set out in section 1 of the Nuclear Installations Act 1965 would apply (see section 10 of the MGN).

Ports may also restrict access to nuclear vessels due to safety concerns, which would restrict trade and chartering options. Public perception is likely to be play a big role here. The images of Three Mile Island in 1979, Chernobyl in 1986 or Fukushima in 2011 will be prevalent until the public are convinced and reassured that the ‘new’ smaller reactors fitted to nuclear ships are more advanced and operate at lower temperatures, distinguishing them markedly from the commercial reactors of the 1970s, 80s and 90s.

Issue 4: Can a nuclear ship be adequately insured?

As noted above, operators of nuclear power plants are strictly liable for nuclear damage and in many countries operators are therefore required to take out compulsory third party liability insurance. Most P&I clubs will exclude cover for liability for damage arising from nuclear fuel, nuclear waste or from combustion

 Russia’s ‘slow-motion Chernobyl’ at sea - BBC Future

of nuclear fuel.[16] At present, a merchant nuclear ship cannot be insured on the conventional insurance market and would need to obtain specialty insurance. Lack of insurance options and recognition by commercial insurers would have knock-on effects on the financial viability of nuclear vessels.

Issue 5: Can nuclear shipping work financially?

The issues that the first generation of nuclear merchant vessels like the *NS Savannah* faced in large part boiled down to financial viability. The operating costs outweighed the profits, and these financial concerns remain relevant today. Nuclear vessels require a large upfront cost by way of the purchase of nuclear fuel and the installation of a nuclear reactor (either in a newbuild vessel or possibly retrofitted). Unlike the ammonia or methanol low emission fuel options, there seems to be no viable way to prepare a 'dual-fuel' nuclear vessel that can transition to the alternative means of propulsion when practical.

With standardised SMRs built and installed in shipyards, the hope is that these costs can be reduced. Classification society DNV recently published their industry insight Maritime Impact,[17] which assessed the economic case for nuclear vessels and concluded that they could be financially viable if the price point of reactors reached the lower end of their estimates (around an annual cost of USD35-40 million). Even though the upfront cost will remain high compared to other alternative fuels, the benefit of nuclear propulsion is that running costs remain steady and are not subject to price fluctuations as nuclear vessels can run for years without needing to refuel.

Conclusion: Is nuclear a viable option to achieve net-zero emissions in the maritime sector?

The international community foresaw and adopted regulations for nuclear vessels decades ago, and the recent UK Nuclear Ships Regulations have brought those regulations into the 21st century. As such, the legal framework already exists for the construction and operation of nuclear merchant vessels. While international and EU emissions regulations do not expressly refer to nuclear propulsion, it is a net-zero means of transport that is seriously being tested by the maritime industry. It will therefore be important for regulators to keep up with the appetite that is building commercially for nuclear shipping.

Evidently, merchant nuclear shipping faces an uphill battle in establishing itself as the preferred net-zero option as the maritime industry seeks to decarbonise. However, it is certainly a credible contender alongside other alternative fuel options such as methanol, hydrogen and ammonia. Each option faces its own challenges and, ultimately, all factors would need to be considered to assess where and when the nuclear option makes sense, taking into account concerns as to safety, practical requirements and costs. Such measures will hopefully ensure the future success of the second generation of nuclear vessels.

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16 See, for example, the 2023 Rules for Gard, NorthStandard, Skuld and UK P&I.
17 https://www.dnv.com/expert-story/maritime-impact/can-co2-capture-and-nuclear-get-ships-to-net-zero.html

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