Nuclear Energy in Shipping

A New Technological Revolution in Maritime Transport and Greece's Role

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Conflict of Interest Disclosure

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Introduction

The shipping industry is at critical crossroads: the urgent need to reduce greenhouse gas emissions is driving the search for alternative propulsion technologies. Nuclear energy is emerging as one of the most promising solutions, offering high energy efficiency, lower operating costs, and zero carbon emissions. **Greece**, as the leading maritime power controlling approximately 20% of the global commercial fleet, has a unique opportunity to take a leading role in the transition to nuclear-powered shipping.

Historical Background

The use of nuclear energy in shipping began in the 1950s. Although the technology did not achieve widespread commercial adoption due to high costs and regulatory challenges, it has been successfully used in submarines and surface warships, proving to be a competitive and reliable energy source with long operational autonomy.

Commercial Nuclear Maritime Applications

Floating Nuclear Power Plants

Floating nuclear power plants have been designed to provide energy to remote areas, ports, and industrial facilities. Their applications include:

1. **Electrification of coastal areas, ports, and emergency support during natural disasters**
2. **Use of thermal and electrical energy for the production of green fuels** (hydrogen, ammonia, methanol)
3. **Power supply to desalination plants and data centers**
4. **Energy supply for offshore oil & gas extraction operations**

Nuclear-Powered Commercial Ships

Nuclear-powered commercial vessels have gained renewed interest in recent years due to the International Maritime Organization's (IMO) goal of achieving net-zero emissions in shipping by 2050. These vessels offer several advantages:

- **Increased cruising speed:** Nuclear propulsion enables higher speeds without significantly increasing costs, allowing for more voyages. For example, a 15K CNTR ship with a nuclear reactor can sail at 25 knots instead of 20, reducing travel time and increasing annual trips from 10–12 to 15–17.
- **Reduced equipment weight:** Without fuel tanks and internal combustion engines, more cargo can be transported. For example, a 15K CNTR ship could carry up to 800 additional TEU due to saved space.
- **Lower refueling frequency:** Nuclear ships can operate for 5–7 years without refueling, while new technologies promise up to 20 years of operation.
- **Zero carbon taxes:** Nuclear-powered vessels emit no CO_2, making them a sustainable and reliable solution for decarbonizing shipping.

While nuclear energy may not be suitable for all types of maritime transport, **it appears to be a competitive alternative to internal combustion engines for long-distance shipping**. In this emerging field, countries like the U.S., South Korea, Russia, and China; shipping companies such as Maersk and NYK Line; shipyards like Hyundai KSOE; classification societies including Lloyd's Register and ABS; and tech startups like CORE POWER, Seaborg and Copenhagen Atomics are already actively working toward the transition to a nuclear-powered maritime era.

Technology

A central question is the choice of reactor type and the technological and commercial criteria behind it. Operational experience at sea has been primarily based on **Pressurized Water Reactor (PWR)** technology. New reactor designs currently under development promise even more competitive features, such as longer intervals between refueling and higher operating temperatures. Technologies attracting investment today include **Molten Salt Reactors (MSR) and Lead-cooled Fast Reactors (LFR)**.

Cost and Business Model

Although nuclear energy requires high initial capital investment,lifetime fuel savings can offset the cost, making it competitive against traditional ships- especially for larger vessel types such as ULCCs and ULCVs. Since nuclear energy is considered green, nuclear-powered ships would not be subject to carbon taxes.

At the same time, the business model for nuclear ships may resemble that of Rolls-Royce aircraft engines, with specialized third-party companies responsible for operating and maintaining the reactors.

Regulatory Framework

Licensing nuclear-powered vessels (NPVs) requires coordination between maritime and nuclear regulatory authorities. Discussions have begun to modernize IMO Regulation A.491(XII) (1981), which governs the safety of nuclear ships in international waters. The establishment of the NEMO organization (2024), the IAEA's ATLAS program, and the 2024 ABS guidelines for Floating Nuclear Power Plants demonstrate international mobilization toward a unified regulatory framework.

Safety, Security, and Safeguards

Today, nuclear energy is one of the safest forms of energy production. This high level of safety has been achieved largely thanks to the lessons learned from both minor and major accidents, which placed safety at the core of the nuclear industry. The sector is now governed by advanced and strict regulations and emphasizes early-stage safety integration through a "Safety by Design" approach. Commercial applications of nuclear energy at sea must follow rigorous safety, security, and safeguard protocols. These protocols must account for the maritime environment, including accident or sinking scenarios, and potential threats such as piracy. Additionally, compliance with international safeguards is essential to ensure that nuclear materials are not diverted for military purposes. Waste management remains a critical and complex part of the nuclear fuel cycle. However, it is a challenge that can also be addressed for marine nuclear applications by leveraging the extensive expertise the nuclear industry has already developed in this domain.

Greece's Position

Greece is called upon to develop a modern institutional framework that integrates nuclear energy into its national energy strategy- both on land and at sea. Successful integration will require public awareness campaigns, strategic planning, a suitable regulatory regime, and the development of specialized human capital. The Greek Atomic Energy Commission must be institutionally and operationally strengthened to meet licensing and oversight demands for nuclear applications, aligning with international standards set by authorities such as the U.S. Nuclear Regulatory Commission (NRC).

On the international stage, following the IMO's adoption of the Net Zero Emissions Framework, Greece has the opportunity to play a leading role in shaping regulations for nuclear-powered ships and floating nuclear units. This could be achieved through active participation in the Marine Environment Protection Committee (MEPC). The recent election of a Greek Commissioner for Sustainable Transport to the European Commission, along with progress in port decarbonization projects (e.g., Piraeus and Heraklion), creates strategic advantages. These developments could support the adoption of a European framework for hosting nuclear-powered ships and deploying floating nuclear reactors for port electrification. At the same time, Greece must address the challenges posed by the EU policy requiring ships docked at European ports to use onshore power supply (OPS) starting January 1, 2030- unless they adopt zero-emission technologies. In the long term, marine nuclear power could offer a viable solution.

Geopolitical developments- such as the reindustrialization of the U.S. shipbuilding sector and efforts to reduce dependence on Chinese shipyards- are opening opportunities for the revival of Greece's shipbuilding industry. There is already a noticeable increase in repair activities and shipyard capacity in Greece, which may enable future integration into the global nuclear supply chain.

Introduction

Pericles, in listing Athens' advantages over Sparta, highlights Athens' dominance at sea. "Μέγα τὸ τῆς θαλάσσης κράτος" - "Great is the power of the state that controls the sea" (Thucydides I.143.5). This phrase, which adorns the emblem of the Hellenic Navy, remains deeply relevant to modern Greece. Though geographically small on land, Greece has exercised maritime dominance for millennia in the Mediterranean and, for centuries, across the world's oceans through its commercial fleet. Today, **Greek shipping controls roughly 20% of global commercial fleet capacity, measured in deadweight tonnage (DWT)**.[1]

This maritime dominance must not only be safeguarded but also further strengthened, as it accounts for at least 7% of Greece's GDP and supports approximately 150,000 well-paying jobs directly linked to the shipping sector. [1]

> «Μέγα τὸ τῆς Θαλάσσης κράτος» ("Great is the power of the state that controls the sea" (Thucydides I.143.5)).

In recent years, the maritime industry - along with many related industrial activities - has embarked on a decarbonization trajectory. By 2040, the sector is required to reduce greenhouse gas emissions by 70%.[2] Currently, 7,000 of the world's 65,000 vessels consume over 50% of maritime heavy fuel oil[3]- many of them under Greek ownership.

Despite international pressure for decarbonization, alternative fuels such as ammonia and hydrogen remain costly and require other reliable energy sources for their production. **Nuclear power emerges as a promising - and potentially singular - solution** due to its high energy density and long operational cycles, offering a sustainable long-term path forward. Interest in the development of commercial nuclear-powered vessels and Floating Nuclear Power Plants (FNPPs) has grown substantially in recent years.

This study examines the role of nuclear energy in the maritime industry, focusing on technological applications, cost implications, regulatory frameworks, safety considerations, and its strategic significance for Greece.

[1] **Martinis, Dennis, et al**. "Greek Shipping: Success Factors and Opportunities." McKinsey, 30 July 2024. https://www.mckinsey.com/industries/logistics/our-insights/greek-shipping-success-factors-and-opportunities
[2] MARINE ENVIRONMENT PROTECTION COMMITTEE. "2023 IMO STRATEGY ON REDUCTION OF GHG EMISSIONS FROM SHIPS | ANNEX 1 RESOLUTION MEPC.377(80)." IMO, 7 July 2023. https://wwwcdn.imo.org/localresources/en/MediaCentre/PressBriefings/Documents/Clean%20version%20of%20Annex%201.pdf
[3] **Core Power**. "Maritime Civil Nuclear Propulsion." *CORE POWER*, www.corepower.energy/maritime-applications/nuclear-propulsion

Historical Overview

The use of nuclear energy at sea might sound like a recent innovation, but in reality, humanity has extensive experience in this area, with more than 160 vessels having been powered by over 200 nuclear reactors.

Since the 1950s, nuclear power has been used to fuel submarines and warships across various countries worldwide, proving to be a competitive and reliable energy source thanks to its high autonomy (see Table 1)[4]. More recently, countries like Turkey[5] are preparing to enter the field with the development of nuclear-powered submarines.

Table 1

Total Number of Nuclear-Powered Surface Warships & Submarines in Operation (2023)

Country	Surface Warships & Submarines
Russia	1 Battlecruiser & 21 Submarines
U.S.A	11 Aircraft Carriers & 73 Submarines
United Kingdom	10 Submarines
France	1 Aircraft Carriers & 9 Submarines
China	14 Submarines
India	1 Submarine

The non-military use of nuclear energy in maritime navigation began in 1959, when, as part of the "Atoms for Peace" campaign, the United States- under President Eisenhower- launched the NS Savannah. This first commercial nuclear-powered ship was equipped with a 74 MW reactor and cost a total of $46.9 million. The NS Savannah toured 45 international ports to showcase the safety and potential peaceful applications of nuclear energy. It arrived at the Port of Piraeus on February 2, 1965 (see Image 1), where it was visited by members of the public- including many local school groups from Piraeus and beyond[6].

[4] "Nuclear-Powered Ships." World Nuclear Association, 4 Feb. 2025, world-nuclear.org/information-library/non-power-nuclear-applications/transport/nuclear-powered-ships.
[5] Interview of Admiral Ercument Tatlioglu, Warships International Fleet Review, May 2025, page 37.
[6] "NS SAVANNAH A HISTORIC MILESTONE. ATOMIC ENERGY IN COMMERCIAL SHIPPING" Naftika Chronika, 15 Aug. 1959, Series Number 581/340, page. 15. https://s3-eu-west-1.amazonaws.com/marechron/issues/issues_0775.pdf

ΕΓΕΝΟΝΤΟ ΑΙ ΠΡΟΒΛΕΠΟΜΕΝΑΙ ΠΡΟΣΜΕΤΡΗΣΕΙΣ ΡΑΔΙΕΝΕΡΓΕΙΑΣ ΕΙΣ ΠΕΙΡΑΙΑ ΔΙΑ ΤΟ «ΣΑΒΑΝΝΑ»

Τὸ «ΣΑΒΑΝΝΑ» εἰς τὸν Πειραιᾶ

Τὸ πυρηνοκίνητον σκάφος ρυμουλκεῖται ἐντὸς τοῦ λιμένος. (Σχετικὴ εἰδησεογραφία εἰς τὴν 7ην σελίδα).

Image 1: "NS SAVANNAH A HISTORIC MILESTONE. ATOMIC ENERGY IN COMMERCIAL SHIPPING"[7]

West Germany and Japan also built nuclear-powered commercial ships- the Otto Hahn (1968–1982) and the Mutsu (1972–1996), respectively. The Soviet Union was an early developer of a nuclear-powered icebreaker fleet, beginning with the Lenin in 1959, which ensured year-round navigation under extreme weather conditions. Today, Russia operates the world's only fleet of nuclear-powered icebreakers, consisting of five classes of surface vessels. Additionally, since 1988, Russia operated a nuclear-powered commercial cargo ship, the Sevmorput, which was decommissioned in 2024.

While nuclear-powered commercial vessels did not become widespread in the 20th century, interest in using nuclear energy for ship propulsion and other maritime commercial applications has grown exponentially today. This surge is driven by global policies aimed at reducing carbon emissions and by advancements in nuclear technology.

[7] MLP. The first nuclear-powered commercial ship Savannah at Piraeus Port [1965]. 6 May 2016. To Blog Tou MLP Από Το 2009, https://mlp-blo-g-spot.blogspot.com/2016/05/nssavannah.html.

Commercial Nuclear Applications in the Maritime Sector

The term Commercial Nuclear Applications in the Maritime Sector refers to two broad categories of applications: Floating Nuclear Power Plants (FNPPs) and Nuclear-Powered Merchant Ships

Floating Nuclear Power Plants (FNPPs)

Image 2: The operating floating nuclear power plant Akademik Lomonosov in Russia.[8] © Copyright Rosenergoatom

The advantages of constructing floating nuclear power plants have been recognized for decades. The U.S. Navy's MH-1A Sturgis was a floating nuclear plant that supplied power to the Panama Canal starting in 1967.[9] In 1970, the major U.S. reactor manufacturer Westinghouse, attempted to construct floating nuclear power plants, and in 1972, they even secured a construction permit for eight such units from the U.S. Nuclear Regulatory Commission (NRC)[10]. However, the project failed due to the oil crisis and the growing anti-nuclear sentiment following the 1979 Three Mile Island accident.

The most significant advantages of floating over land-based nuclear power plants are:

1. Mobility by Sea: The station can be transported via sea and used far from its original construction site.
2. Remote Deployment: They can be installed in remote coastal areas and used in offshore applications.
3. Lower Construction Costs: Infrastructure and support systems (Balance of Plant - BoP) can be more cost-effectively built in shipyards, where construction is typically more efficient and less expensive compared to land-based plants.
4. Direct Access to Cooling Water: Immediate access to seawater provides a reliable and abundant cooling source, essential for the safe operation of nuclear plants.

[8] "Over 5 Years, Akademik Lomonosov Prevented 390,000 Tons of Greenhouse Gas Emissions." AKADEMIK LOMONOSOV, 13 Sept. 2024, fnpp.info/latest-news/over-5-years-akademik-lomonosov-prevented-390000-tons-of-greenhouse-gas-emissions.
[9] **Honerlah, Hans B, and Brian P. Hearty**. "WM'02 Conference, February 24-28, 2002, Tucson, AZ." https://archivedproceedings.econference.io/wmsym/2002/Proceedings/44/168.pdf
[10] **Touran, Nick**. "Offshore Nuclear Power Plants – That Time We Almost Built 8 GW-Scale Floating Reactors." What Is Nuclear?, 29 Dec. 2020, whatisnuclear.com/offshore-nuclear-plants.html.

Interest in floating nuclear power plants has recently surged, potentially due to their applications:

A. Power supply for coastal regions, ports, or disaster relief operations. Currently, 36 ports worldwide are equipped with at least one cruise ship berth connected to onshore power. An additional 23 ports have such projects funded, while 16 have already begun implementation.[11] Projections indicate that by 2035, the power demand for the Port of Los Angeles and the Port of Long Beach could reach between 400.4 and 446.1 MW. By 2040, this demand may rise to between 452.3 and 475.2 MW, depending on operational scenarios.[12]

B. Production of green fuels by utilizing both thermal and electrical energy for desalination and electrolysis to produce hydrogen. This hydrogen can then be used to generate synthetic fuels, such as ammonia and methanol. The volume of green fuels needed to replace fossil fuels for the global fleet is estimated to exceed 500 million tonnes per annum (mtpa), which would require approximately 80% of today's total renewable electricity production.[13]

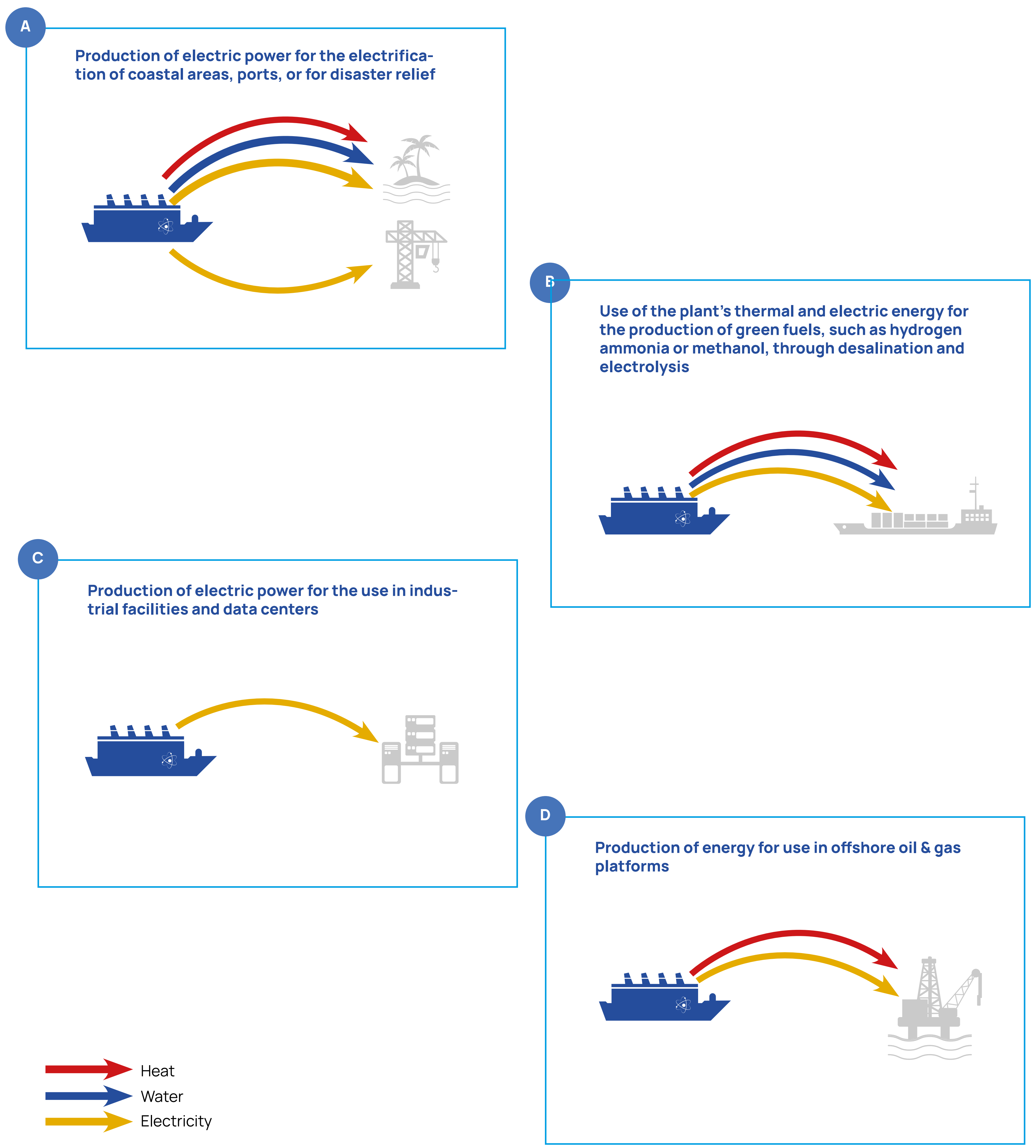
C. Power supply for energy-intensive facilities such as desalination plants and data centers. Currently, data centers consume about 1–2%[14] of global electricity production, and their projected global power demand by 2030 is estimated to reach 300 GW.[15] The economic size of this sector is expected to reach $0.5 trillion by that time.[16] Simultaneously, energy demand for desalination is forecasted to reach 345 TWh by 2040, compared to just 40 TWh in 2014.[17]

D. Power generation for offshore resource extraction (e.g., fossil fuel operations). To meet global carbon reduction targets, the oil and gas sector must cut its emissions by at least 3.4 gigatonnes of CO_2 equivalent ($GtCO_2e$) per year by 2050.[18] Nuclear energy- especially floating nuclear power plants that can be deployed near offshore oil and gas operations- presents an attractive solution. These plants can provide both electricity and heat for industrial processes, capturing the interest of energy companies worldwide.[19]

[11] Ports with at least one cruise birth with Onshore Power Supply (OPS). 1 Oct. 2024. Cruise Lines International Association, https://cruising.org/en/environmental-sustainability.
[12] **Villa, Natasha**. "Electrification of California Ports Technical Memorandum." Pacific Merchant Shipping Association, 11 June 2024, www.pmsaship.com/maritime-insights-blog/electrification-of-california-ports-technical-memorandum.
[13] "Floating Nuclear: The Route to Economic e-Fuels." CORE POWER. https://www.corepower.energy/fact-sheets.
[14] IEA. "Data Centres & Networks." IEA, 11 July 2023, www.iea.org/energy-system/buildings/data-centres-and-data-transmission-networks.
[15] **Srivathsan, Bhargs, et al.** "AI Power: Expanding Data Center Capacity to Meet Growing Demand." McKinsey, 29 Oct. 2024. https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/ai-power-expanding-data-center-capacity-to-meet-growing-demand
[16] "Global Data Centre Market Confident about AI Fuelled Growth, despite Power Supply Concerns." DLA Piper, 26 Nov. 2024, www.dlapiper.com/en/news/2024/11/global-data-centre-market-confident-about-ai-fuelled-growth.
[17] "The Desalination of Seawater through Nuclear Energy, an Option for the Future." Foro Nuclear, 22 Mar. 2023, www.foronuclear.org/en/updates/in-depth/the-desalination-of-seawater-through-nuclear-energy-an-option-for-the-future/.
[18] Beck, Chantal, et al. "The Future Is Now: How Oil and Gas Companies Can Decarbonize." McKinsey & Company, McKinsey & Company, 7 Jan. 2020, www.mckinsey.com/industries/oil-and-gas/our-insights/the-future-is-now-how-oil-and-gas-companies-can-decarbonize
[19] "Viaro Partners with Newcleo to Decarbonise Oil and Gas Assets." *World Nuclear News*, 5 Mar. 2024, www.world-nuclear-news.org/Articles/Viaro-partners-with-Newcleo-to-decarbonise-oil-and

Image 3

Commercial Uses of Floating Nuclear Power Plants



Today, Russia, continuing its tradition, has been successfully operating a Floating Nuclear Power Plant (FNPP) since 2019, providing electricity and heating to the city of Pevek in Siberia (see Figure 2). At the same time, Russia is constructing additional units with the possibility of selling them to other client states as part of its nuclear diplomacy efforts.[20]

The global market for floating nuclear power plants is potentially broad, ranging from data centers, ports, and offshore gas and oil extraction applications, to remote areas that require clean water, heating, and energy. In 2023, the U.S. Department of Energy (DOE), in collaboration with the Idaho National Laboratory, the American Bureau of Shipping (ABS), and the National Reactor Innovation Center, published a study estimating the United States' needs for small modular reactors (SMRs) by 2050 , as summarized in Table 2.

Table 2

Projects for Demand of Commercial Applications of Nuclear Energy in the Maritime Sector by 2050

Application	Estimated demand by 2050
Port Electrification	**3** to **5** ports
Production of Synthetic Green Fuels (Coastal)	**35** to **70** million tons of hydrogen produced
Floating Nuclear Powered, Data Centers	**2** to **9** data centers.
Production of Synthetic Green Fuels (Offshore)	**2.5** to **5** million tons of hydrogen produced
Floating Nuclear Desalination Plants	**2** to **6** floating desalination plants
Floating Nuclear Power Plants for Coastal Area Electrification	**1** to **2** GW total capacity installed
Nuclear Powered Commercial Ships	**178** to **439** nuclear powered merchant ships

Steps toward the development of floating nuclear reactors are already underway: Westinghouse, fifty years after founding Offshore Power Systems, has signed a partnership agreement with CORE POWER- a company focused on developing marine nuclear energy systems- for the design of floating nuclear power stations using its new eVinci microreactor.[22] Recently, Allseas, a global leader in offshore pipeline installation and subsea construction, announced[23] plans to design and develop a Small Modular Reactor (SMR) for use in both maritime and land-based applications.

[20] "Guinea Signs Floating Nuclear Power Plants MOU with Russia." World Nuclear News, 7 June 2024, www.world-nuclear-news.org/Articles/Guinea-and-Russia-sign-MoU-for-floating-nuclear-po#:~:text=The%20Republic%20of%20Guinea%20and,electricity%20to%20the%20African%20country.

[21] **Idaho National Laboratory**. Accelerating Commercial Maritime Demonstration Projects for Advanced Nuclear Reactor Technologies: Road Map for the Development of Commercial Maritime Applications of Advanced Nuclear Technology. U.S. Department of Energy, Jan. 2023. https://inldigitallibrary.inl.gov/sites/STI/STI/Sort_145957.pdf

[22] Westinghouse Electric Company. "Westinghouse and CORE POWER Partner for Floating Nuclear Power Plants Using eVinci™ Microreactors." Westinghouse Electric Company, 25 Nov. 2024, https://info.westinghousenuclear.com/news/westinghouse-and-core-power-partner-for-floating-nuclear-power-plants-using-evinci-microreactors "

[23] Allseas Aims for Rapid SMR Deployment." World Nuclear News, 6 June 2024, www.world-nuclear-news.org/Articles/Allseas-aims-for-rapid-SMR-deployment.

Nuclear-Powered Commercial Ships

Nuclear-powered commercial ships have come to the forefront in recent years due to the International Maritime Organization's (IMO) requirements for zero emissions in shipping by 2050. Beyond environmental benefits, nuclear propulsion offers several highly competitive advantages, which is why the world's most powerful countries use it for their naval fleets.

The most important advantages of nuclear propulsion are:

Sailing Speed: Nuclear technology provides a virtually abundant energy source. Nuclear reactors operate most efficiently near their maximum power output, which does not significantly increase operating costs- unlike internal combustion engines, whose operational costs rise dramatically with speed. This competitive advantage can transform maritime trade since higher speeds enable the transport of more cargo in less time, ultimately increasing profits for shipping companies. Recent calculations by HD Korea Shipbuilding & Offshore Engineering (HD KSOE), based on a 15,000 TEU container ship (15K CNTR) with a 90 MWth reactor compared to a ship with an LNG dual-fuel internal combustion engine, showed propulsion speeds increasing by 5 knots (from 20 to 25 knots). This reduces the duration of a typical voyage from 54–70 days to 40–56 days, allowing 15–17 voyages per year versus the current 10–12.[24]

Lower Equipment Weight: Compared to traditional cargo ships or tankers, a nuclear-powered ship does not require fuel tanks or an internal combustion main engine. The size and weight of a nuclear power plant mainly come from supporting systems like steam turbines and shielding, rather than the reactor itself, depending on the nuclear technology, fuel enrichment, and power output. With appropriate design and technology choices, nuclear-powered ships are expected to carry more cargo by leveraging this volume and weight gain. Although the main criteria for choosing nuclear technology for SMRs will be discussed in the Technology chapter, it is worth noting that in the 15K CNTR example, the absence of fuel tanks is estimated to increase payload capacity by 800 TEU. [24]

[24] **Sangmin Park on behalf of Hyundai KSOE** (2025, February 12), Maritime SMR: Nuclear Powered Ship Concept & SMR Business Strategy, New Nuclear in Maritime Summit, Houston, TX, USA. https://www.youtube.com/watch?v=boUcgnuYZrk&t=19s&ab_channel=COREPOWER

Refueling Frequency: Depending on the nuclear technology, fuel type, and initial loading, a nuclear ship can operate for many years without service interruptions for refueling. For instance, Russian Arktika-class icebreakers are refueled only every 5 to 7 years. This represents a significant operational advantage compared to conventional ships, drastically reducing operating costs. Emerging liquid nuclear fuel technologies enable "online refueling" during reactor operation and promise up to 20 years of continuous operation before refueling.

On the other hand, nuclear fuel refueling is a relatively time-consuming process, lasting approximately 6 to 8 weeks, and can only be performed by specially licensed personnel at equipped and certified shipyards capable of handling fresh and spent fuel. Refueling can be coordinated with other dockside activities such as inspections and maintenance to minimize operational downtime.

Zero Carbon Dioxide Emissions: Nuclear energy is a zero-emission energy source. It is considered green and sustainable by international organizations, including the EU, the US, and the UN. The European Commission has classified nuclear energy as a "green" and sustainable energy source[25] as part of its strategy to reduce pollution and greenhouse gas emissions, provided it meets strict safety and environmental protection standards. In the US, nuclear energy enjoys bipartisan support as part of the transition to clean energy, with tax incentives[26] promoting its further development. According to the UN's Intergovernmental Panel on Climate Change (IPCC), nuclear energy contributes to the Sustainable Development Goals (SDGs) by helping reduce carbon emissions.

While nuclear power may not be the appropriate solution for all types of maritime trade, it appears to be a competitive alternative to internal combustion engines in long-distance shipping-particularly if international zero-emission targets are upheld.

As a result, major shipping companies worldwide have started to seriously consider nuclear propulsion, investing in research programs and nuclear technology startups.

Countries like the US, South Korea, Russia, and China- as well as shipping companies like Maersk[27] and NYK Line, shipyards such as Hyundai KSOE[28], classification societies like Lloyd's Register and ABS, and tech startups like CORE POWER and Seaborg- are already actively working toward ushering in the new era of maritime nuclear energy. In December 2023, China announced the development of a nuclear cargo ship using a Molten Salt Reactor (MSR)[29]. CORE POWER is also partnering with TerraPower to develop the Molten Chloride Fast Reactor (MCFR) and with Westinghouse to adapt the eVinci microreactor for marine use, as part of a broad initiative known as the LIBERTY Program.[30] Finally, newcleo announced plans to use its developing Lead-cooled Fast Reactor (LFR) in marine nuclear systems, while companies like Seaborg, Nano Nuclear, and NewProship are also advancing marine nuclear technology.

[25] **EUROPEAN COMMISSION.** "COMMISSION DELEGATED REGULATION (EU) 2022/1214 of 9 March 2022." Publications Office of the European Union, 15 July 2022. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022R1214

[26] **United States, Congress**, Inflation Reduction Act of 2022 (IRA): Provisions Related to Climate Change, Congressional Research Service, 2022. 2022 Congress bill. https://www.congress.gov/bill/117th-congress/house-bill/5376/text

[27] **Lloyd's Register**. "LR and CORE POWER to Conduct Next-Generation Nuclear Container Ship Regulatory Study." Lloyd's Register, 15 Aug. 2024, https://www.lr.org/en/knowledge/press-room/press-listing/press-release/2024/lr-and-core-power-to-conduct-next-generation-nuclear-container-ship-regulatory-study/.

[28] **World Nuclear News**. "Korean Shipbuilder Joins Maritime SMR Project." World Nuclear News, 7 Feb. 2024, https://www.world-nuclear-news.org/articles/korean-shipbuilder-joins-maritime-smr-project.

[29] **The Maritime Executive**. "CSSC Designs Containership Using Molten Salt Nuclear Reactor." *The Maritime Executive*, 5 Dec. 2023, https://maritime-executive.com/article/china-present-design-for-containership-using-molten-salt-nuclear-reactor.

[30] **Core Power**. *CORE POWER Launches Liberty Maritime Civil Nuclear Program at Houston Summit*. Core Power, 27 Feb. 2024, https://www.corepower.energy/news/core-power-launches-liberty-maritime-civil-nuclear-program-at-houston-summit.

Technology

The current design of commercial nuclear ships is moving towards electric ships (see Figure 6), where nuclear energy is converted into electricity, just as it is done today in nuclear power plants. This electricity is then used to cover all the ship's energy demands, including propulsion.

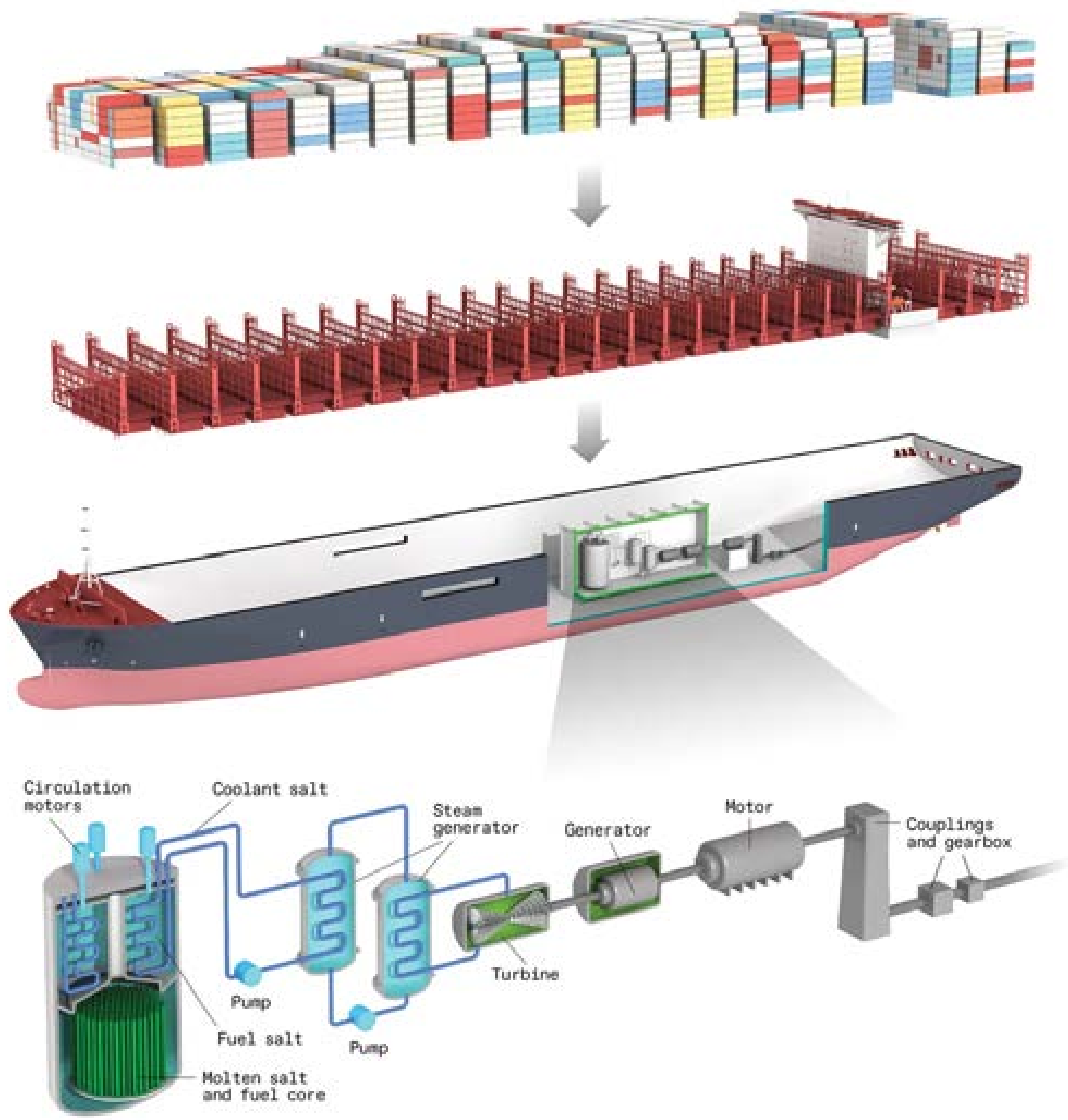


Image 6a: Artistic renderings of a nuclear container ship featuring molten salt reactors (Molten Salt Reactor - MSR) [31]

[31] **Ackerman, Evan**. "The Case for Nuclear Cargo Ships." IEEE Spectrum, 12 Jan. 2024, https://spectrum.ieee.org/nuclear-powered-cargo-ship.

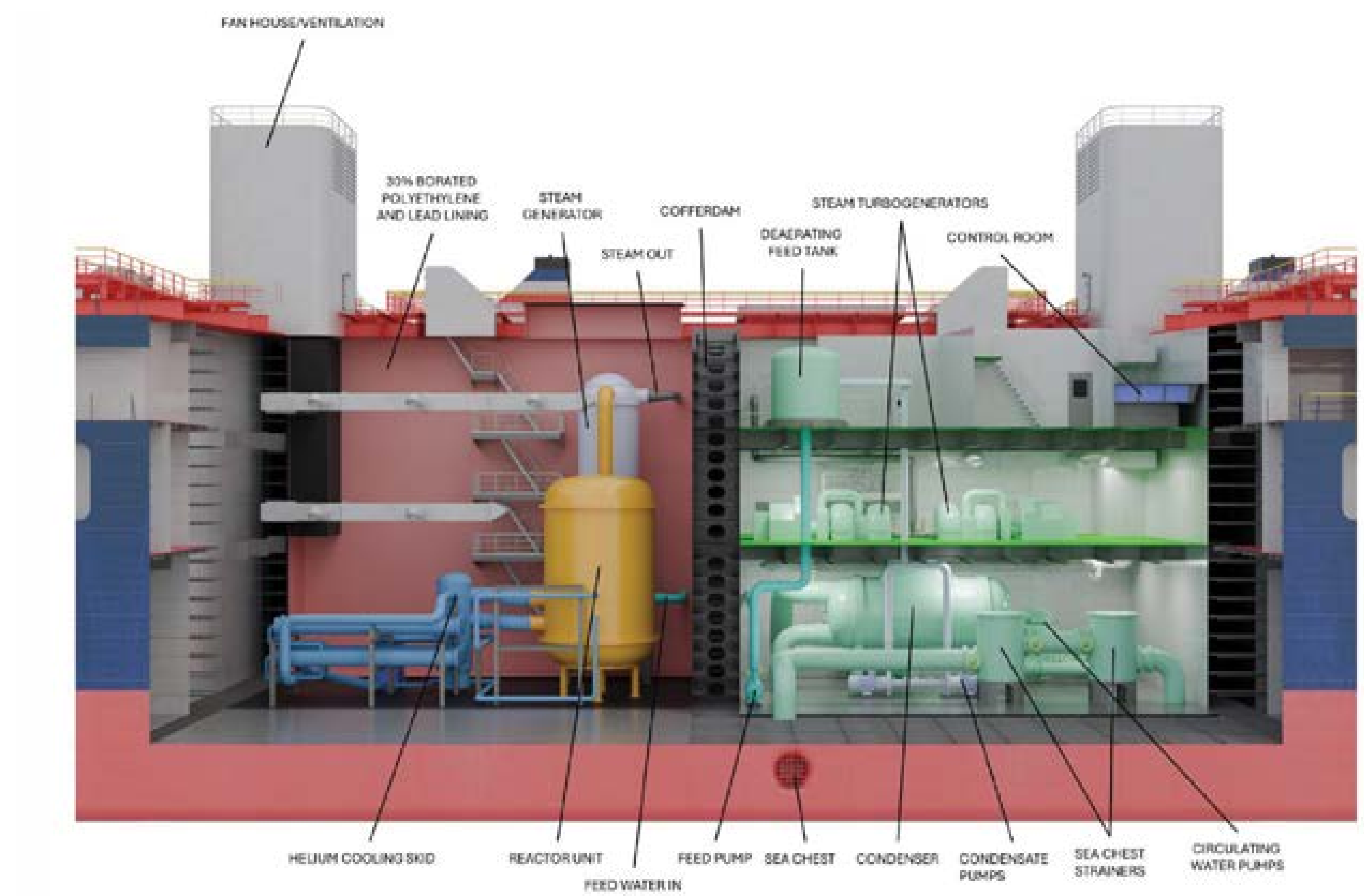


Image 6b: Artistic rendering of an air-cooled high-temperature reactor on the bottom (Copyright of the American Bureau of Shipping - ABS).[32] These illustrations are not technical drawings; **the depicted dimensions and systems should not be considered as design information.**

Operational experience with reactors at sea has been gained primarily through **Pressurized Water Reactor (PWR)** technology. The naval forces of various countries have the capability to use highly enriched fuel, which allows the reactor to be small in size, with high power output and low refueling frequency. The same conditions do not apply to commercial versions of this technology, which are restricted to using low-enriched fuel and require refueling. Such business challenges, combined with the lack of a unified regulatory and insurance framework, have so far prevented the widespread use of PWRs in commercial shipping despite their successful use in military navies (with the exception of Russia, which resolves economic and regulatory issues within its borders and operates a fleet of nuclear-powered icebreakers).

Some of the new reactor technologies currently under development promise technological characteristics that appear to be ideal alternatives for maritime use, such as high temperatures, low refueling frequency, reduced equipment size, enhanced safety, and a reduced number of required operators. Table 3 briefly lists some of the reactor types and their commercial maturity.[33]

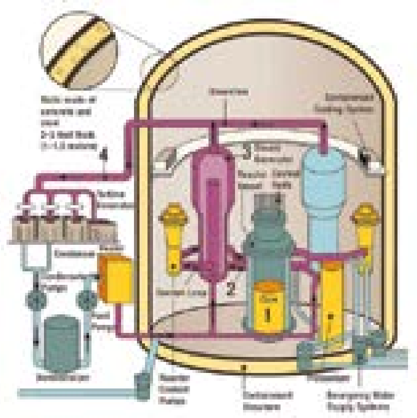
[32] **American Bureau of Shipping (ABS), and Herbert Engineering Corp. (HEC).** "PATHWAYS TO A LOW CARBON FUTURE FLOATING NUCLEAR POWER PLANT." American Bureau of Shipping (ABS), 2024.
[33] **International Atomic Energy Agency.** "Advanced Reactor Information System." International Atomic Energy Agency, https://aris.iaea.org/.

Table 3a

Main Reactor Types and the Commercial Readiness

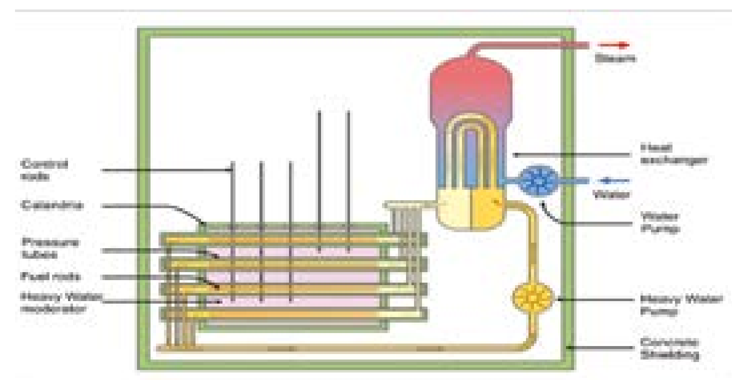
Mature and tested technologies

Pressurised Light Water Reactor (PWR)



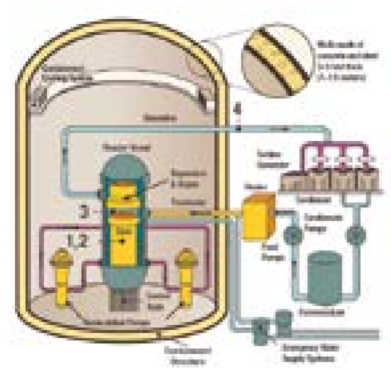
Reactor that uses pressurized light water as both moderator and coolant. Typically uses U-235 enriched at 3%-5% (LEU).

CANada Deuterium Uranium (CANDU)



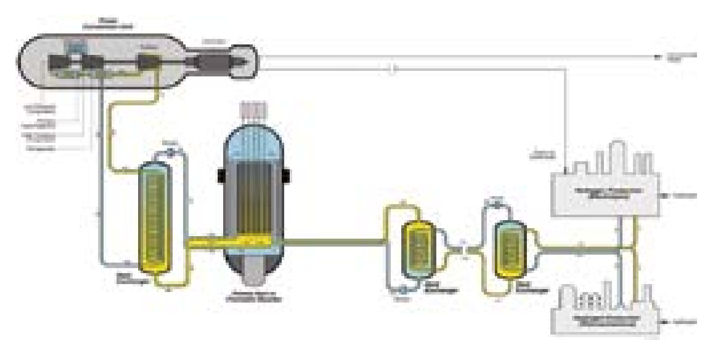
Reactor that uses pressurized heavy water (deutrium oxide) as both moderator and coolant. Uses natural uranium without the need for enrichment.

Boiling Water Reactor (BWR)



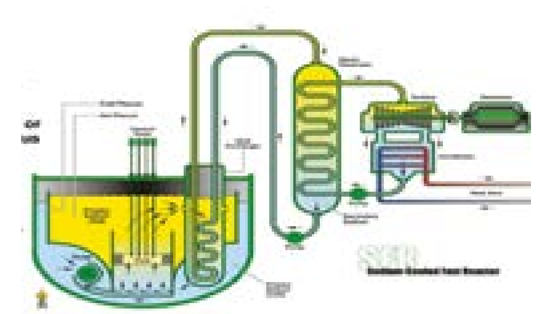
Reactor using water as moderator and coolant, which boils in the core; steam drives the turbine directly. Typically uses U-235 enriched at 3%-5% (LEU).

High Temperature Gas Reactor (HTGR/AGR)



Reactor using helium as coolant and graphite as moderator. Typically uses U-235 enriched at 3%-5% (LEU).

Sodium cooled Fast Reactor (SFR)



Reactor using liquid sodium as coolant, without moderator (fast reactor). Typically uses U-235 enriched at 5%-20% (HALEU).

Commercial Readiness

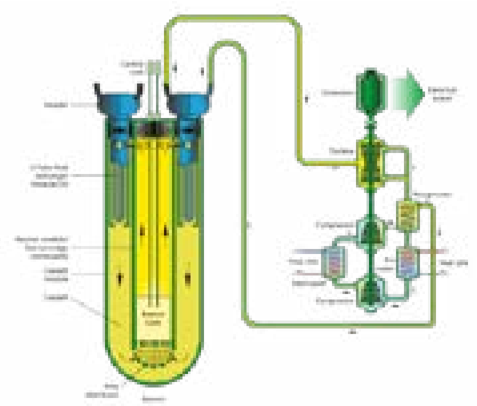
- Mature Technology with wide industrial use
- Tested technology with existing use industrial applications
- Technology under development in research environments, potentially with pilot testing
- Technology at theoretical stage with little to none operating hours

Table 3b

Main Reactor Types and the Commercial Readiness

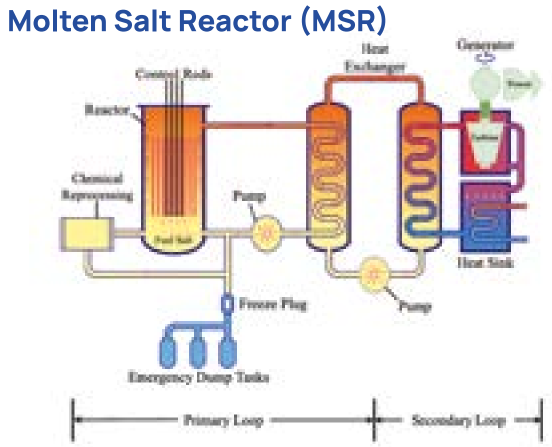
Technologies under development and in theoretical stage

Lead cooled Fast Reactor (LFR)



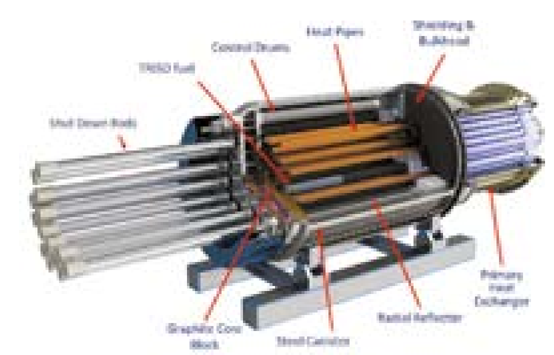
Reactor using liquid lead as coolant, without moderator (fast reactor). Typically uses U-235 enriched at 5%-20% (HALEU).

Molten Salt Reactor (MSR)



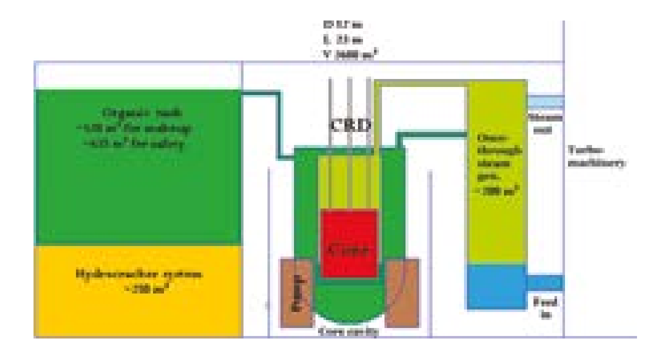
Liquid fuel reactor using molden flouoride or chloride salts as both coolant and fuel. Thermal MSRs use graphite as moderator. Designs under development use U-235 enriched at 5%-20% (HALEU).

Heat Pipe Reactor (HPR)



Reactor using heat pipes as coolants and graphite as a moderator. Designs under development use U-235 enriched at 3%-5% (LEU).

Organic Cooled Reactor



Reactor using organic hydrocarbons as moderator and coolant. Designs under development use U-235 enriched at 3%-5% (LEU).

Commercial Readiness

- Mature Technology with wide industrial use
- Tested technology with existing use industrial applications
- Technology under development in research environments, potentially with pilot testing
- Technology at theoretical stage with little to none operating hours

Technological Suitability Criteria

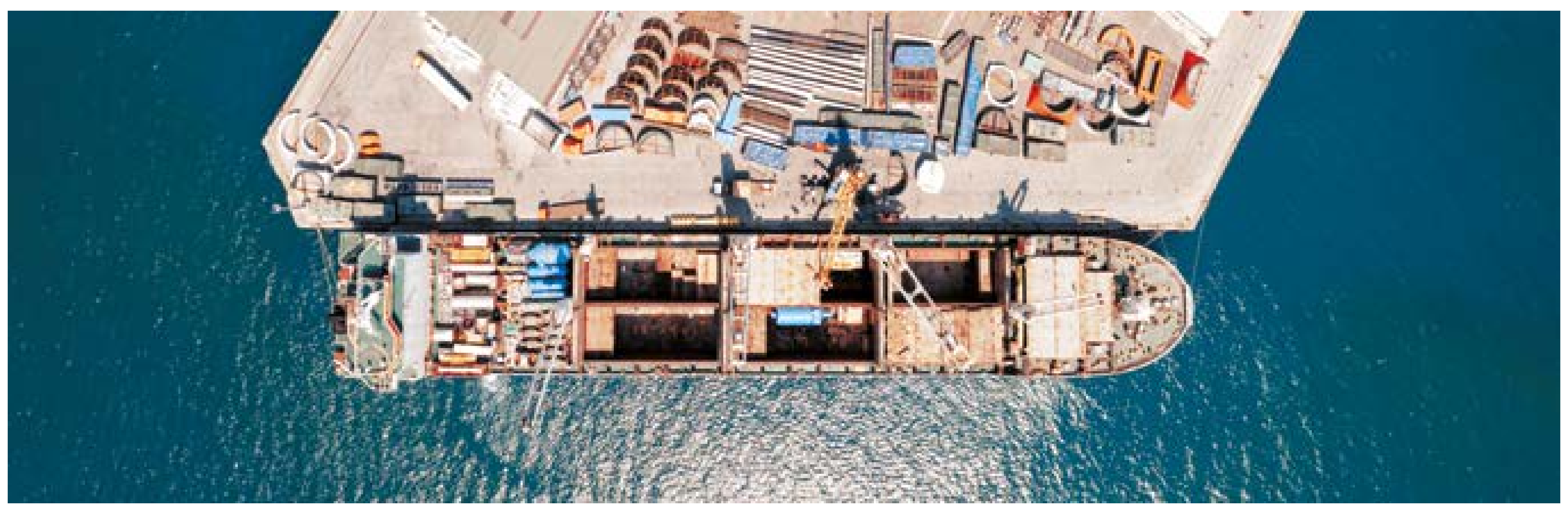
One of the key questions for the future of nuclear power at sea is the selection of an appropriate reactor type. The fundamental technological suitability criteria of a reactor are: (1) **availability**: fuel cycle, refueling and maintenance frequency, (2) **power output**, (3) **size**, (4) **emergency planning zones and commercial insurance**, (5) **maximum operating temperature**, (6) **number of required operators and crew**, and (7) **suitability for the marine environment, accelerations, and criticality safety**.

Availability: Fuel Cycle, Refueling and Maintenance Frequency

High availability and continuous operation are essential criteria both for trade and for the provision of electricity. The frequency of refueling and maintenance, as well as scheduled downtime, must align with the high demands of maritime commerce. Drydocking of a ship, during which refueling and maintenance of nuclear systems could take place in a suitably licensed shipyard, usually occurs every 5 years.

A current PWR requires refueling approximately every 2 years, with the refueling period (during which the reactor is shut down) lasting up to 2 months. Some evolutionary PWRs (Generation III+) are being designed to extend the refueling frequency to 4–5 years. The level of required safety and protection during refueling, as well as the handling of fresh and spent fuel, means such refueling can only be done at nuclear-licensed shipyard facilities, not at any regular port.

As mentioned, advanced reactors (Generation IV), currently under development, promise longer fuel cycles and lower refueling frequencies.



Power Output

The required power depends on the specific type of commercial nuclear maritime application (propulsion, electricity generation, desalination, etc.) and ranges from tens to hundreds of MWe depending on the application. Small Modular Reactors (SMRs) is a term used over the last decade by the nuclear industry to describe new developing technologies with power outputs of up to ~300 MWe, which ideally will be suitable for mass and serial construction, aiming to reduce overall production cost.

Most of the existing and developing nuclear technologies listed in Table 2 can be designed within SMR power output levels, meeting the criteria for the required power of an NPCS. In cases where higher power is needed, multiple SMRs can be installed for a given application.

Size

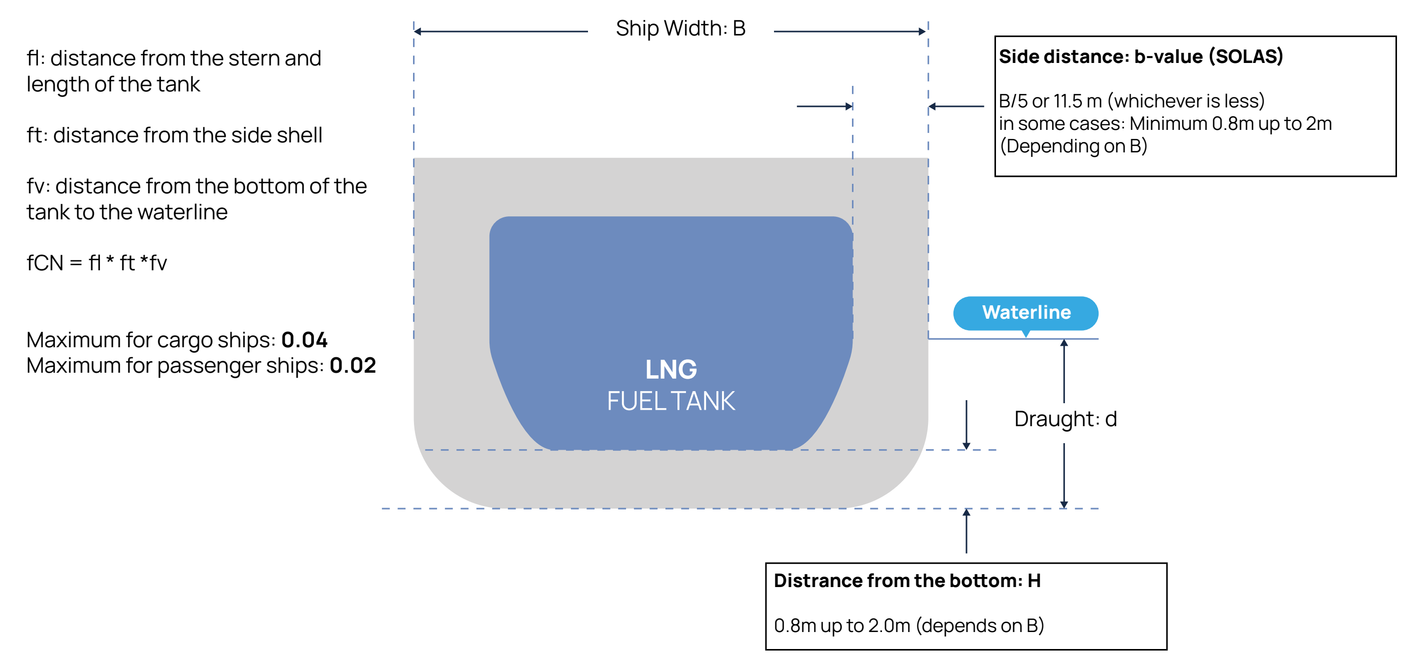
Nuclear installations at sea are limited in size, primarily by the physical and design constraints of the ship or platform on which they are installed, as well as by safety regulations concerning physical protection from collisions. The protected space must be at least one-fifth of the total width and length of the ship on each side.

For example, on a ship with a beam of 25 meters, the nuclear installation's dimension perpendicular to the ship's axis cannot, by regulation, exceed 15 meters, including structural components.[34] Similar physical and construction limitations apply to the height of the nuclear installation, as a double bottom is also required.

The figure illustrates the main features of a protective structure for a liquefied natural gas (LNG) tank, based on the provisions of the International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code).[35]

Image 7

Depiction of LNG tank size limits based on regulations for collision protection



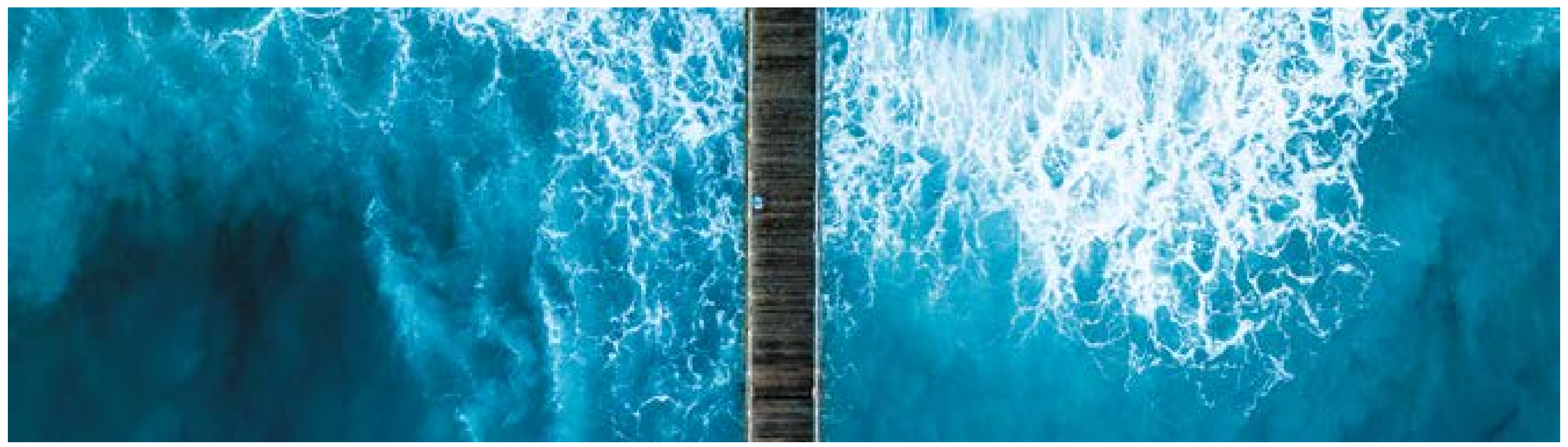
At first glance, Generation IV reactors operating at low pressures are expected to be smaller in size than existing technologies.[36] However, this conclusion is not always accurate, as one must also consider the additional support systems these reactors require for operation. For example, reactors that use salts either as coolant or as fuel require noble gas circulation and salt purification systems for their operation, which add to the overall size of the nuclear plant. Looking back at Figure 6, the MSR building appears "deceptively" small, as many essential support systems are omitted from the depiction—a common feature in concept illustrations of nuclear ships. Examples of developing small-sized reactors include Heat Pipe Reactors (HPR), Lead cooled Fast Reactors (LFR), and Gen III+ Pressure Water Reactor (PWRs).

[34] **International Maritime Organization**. Code of Safety for Nuclear Merchant Ships. Resolution A.491(XII), adopted on 19 Nov. 1981, https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/AssemblyDocuments/A.491(12).pdf
[35] **Würsig, Gerd**. The Safety Principles for the Use of Low Flashpoint Fuels in Shipping. Springer Nature Switzerland : Imprint: Springer, 2025. https://link.springer.com/book/10.1007/978-3-031-64174-9
[36] **Rogoway, Tyler**. "This Is the World's Fastest Production Submarine's Crazy Molten Metal Cooled Reactor." TWZ, 19 Apr. 2020, www.twz.com/33074/this-is-the-worlds-fastest-production-submarines-crazy-molten-metal-cooled-reactor.

Emergency Planning Zones and Commercial Insurance

Nuclear power plants have Emergency Planning Zones (EPZ) spanning several kilometers, within which the population and government authorities are prepared to take protective actions or evacuate in the event of an accident.

For nuclear-powered ships operating in densely populated ports and canals, establishing safety zones will be complex—especially if these zones span several kilometers. However, for floating nuclear power plants, this is less of a concern, since insurance and emergency planning can follow the standards set for land-based nuclear facilities, as was the case with Russia's floating power plant mentioned earlier.



The size of the EPZ varies by country and is determined during licensing based on the potential radiation exposure of the surrounding population in the event of an accident.

Emerging fourth-generation reactors, which operate at low pressures and offer enhanced passive safety, aim for operating licenses with emergency planning zones limited to the site boundary- offering a practical solution for the deployment and commercial insurability of nuclear ships.

Despite regulatory differences, all currently operating nuclear technologies, including PWRs, are extremely safe- something that will be discussed further in the Safety chapter. In fact, the Nuscale PWR station has already received approval from the NRC for a reduced EPZ.[37]

Maximum Operating Temperature

Many potential applications of Nuclear-Powered Floating Energy Nodes (NPFENs)- such as desalination, electrolysis, and ammonia synthesis- require high-quality heat at elevated temperatures to achieve high efficiency and optimal process performance. PWRs operate at temperatures around 300 °C, which limits their use in such applications. In contrast, advanced reactors like MSRs, HTGRs, and HPRs can exceed 700 °C, providing the necessary heat for more efficient and economically viable operation of these industrial processes.

[37] NuScale Power. "NuScale's EPZ Boundary Methodology Validated by the NRC Advisory Committee on Reactor Safeguards." NuScale Power, 20 Oct. 2022, https://www.nuscalepower.com/press-releases/2022/nuscales-epz-boundary-methodology-validated-by-the-nrc-advisory-committee-on-reactor-safeguards

Number of Required Operators and Personnel

The operational cost of human resources in shipping is usually the second highest after fuel. The number of required operators is certainly an important criterion in selecting the appropriate nuclear technology.

With current data, a commercial nuclear maritime application will require the following general roles for its nuclear component: a) Senior Reactor Operator, b) Reactor Operator, c) Material Control & Accounting (MC&A) Personnel, d) Security Personnel.The number of personnel for each role depends on the size and type of the NPFEN and the corresponding shifts.

The new generation reactors we mentioned promise a significantly reduced number of operators compared to current technologies, due to the advanced passive operation and safety systems of the reactor, and increased automation. It should also be noted that these technologies have not yet received operating licenses. It is very likely that nuclear regulatory authorities will require a larger number of operators and fewer automations when the time for licensing arrives, due to the lack of relevant industry experience.

The emerging technology with the lowest expected number of operators is the Westinghouse eVinci Heat Pipe Reactor (HPR),[38] which aims to have only one operator per reactor due to its passive design and advanced control systems.[39] By passive design here we mean the design of a station with passive systems that do not require external intervention for their correct operation, which is based on natural phenomena such as the natural circulation of coolant due to temperature differences.

Marine Environment

Operating a nuclear power plant at sea requires the ability to withstand conditions such as dynamic loads from waves, torques, vibrations, inclinations, and oscillations, as well as a greater likelihood of water exposure and new risks associated with maritime systems and operations.

Regarding acceleration and station motion due to waves, most nuclear technologies can handle these through proper engineering. Today's nuclear plants are already designed to endure strong seismic activity, so these design demands are not unfamiliar to the industry. However, this criterion is less favorable for newer technologies that rely entirely on natural circulation of the coolant or fuel, as that circulation could be disrupted by the reactor's motion.[40]

As for possible exposure to water, technologies that use materials with undesirable chemical reactions when in contact with water- such as sodium-cooled reactors- will be harder to adopt and may require additional physical barriers in their design. Nevertheless, managing the unique risks of the marine environment and maintaining the strict level of nuclear safety required is a given and a prerequisite for licensing any future marine nuclear power installation.

[38] **Westinghouse Electric Company**. "eVinci™ Microreactor." Westinghouse Electric Company, https://westinghousenuclear.com/energy-systems/evinci-microreactor/
[39] **Westinghouse Electric Company**. "Westinghouse eVinci™ Control System Achieves Major U.S. Licensing Milestone." *Westinghouse Electric Company*, 4 Dec. 2024, https://info.westinghousenuclear.com/news/westinghouse-evinci-control-system-achieves-major-us-licensing-milestone
[40] Evaluation of the Molten Salt Reactor technology for the application of Floating Nuclear Power Plants, I. Kourasis et. al. IAEA SMR CONFERENCE 2024

Cost and Business Model

Nuclear energy has a different operational model from fossil fuels and internal combustion engines.

Cost

Nuclear energy requires high capital expenditures. The reactor and fuel are assets worth hundreds of millions that require special management during transport, licensing, and operation, as well as significant costs for their decommissioning, management of nuclear waste, and spent fuel.

Given the high capital cost, the question naturally arises whether this technology is economically competitive compared to existing technologies. To answer this question accurately would require a detailed comparison for specific ships and technologies.

Although such a comparison far exceeds the scope of this text and the information we currently know about future technologies, we provide an estimate of the general viability of such an undertaking. Below (Table 4) are indicative annual fuel costs for various types of container, bulker, and tanker ships assuming the current HSFO price of $450-500 per ton (05/03/2025) (the cheapest fuel widely used in shipping) and operation for 275 days per year.

Table 4

Table of estimated fuel consumption, annual and lifetime fuel costs per type of ship.

Actual daily consumption rates vary depending on engine type, speed and loading conditions.

Ship Type	Ship Capacity	Daily fuel consumption	Estimated Annual Fuel Cost	Estimated Lifetime Fuel Cost (25-Year Operation)
Capesize	100.000 – 200.000 DWT	30-45 mt / day	$4-6M	$90-150M
Chinamax / VLOC	200.000 – 400.000 DWT	40-50 mt / day	$5-7M	$120-170M
Aframax	45.000–79.999 DWT	30-50 mt/day	$4-7M	$90-170M
Suezmax	80.000–159.999 DWT	45-60 mt/day	$6-8M	$140-200M
VLCC (Very Large Crude Carrier)	160.000–319.999 DWT	60-100 mt/day	$7-14M	$180-240M
ULCC (Ultra Large Crude Carrier)	320.000–549.999 DWT	100-150 mt/day	$12-20M	$310-515M
ULCV (Ultra Large Container Vessel)	14.501 and higher TEU	200-400 mt/day	$25-55M	$600-1.300M

Actual daily consumption rates vary depending on the type of engine, speed, and loading condition. However, the above calculations are consistent with the average annual fuel consumption per ship type, as calculated in a very recent article.[41] If carbon emission taxes are added to the cost of fossil fuels, then a significant margin for savings emerges through the use of nuclear reactors for certain types of ships. This exact estimation was confirmed by the research conducted by the Maritime Nuclear Applications Group,[42] concluding that nuclear ships could not only be viable but also competitive. Regarding the operating costs of conventional (fossil-fueled) ships, the study offsets the cost of fossil fuel with the carbon emission tax, estimating that nuclear ships would have lower operational costs- with a difference ranging from $95M to $445M over the period 2035–2055, in the scenarios assuming competitive nuclear technology.

Nevertheless, these forecasts and calculations are accompanied by considerable uncertainty, and their main utility is to assess the general viability of this proposal based on the data currently available. The total capital cost of a nuclear propulsion plant cannot be determined with certainty, as such plants are not currently in commercial use. Initial estimates suggest that the capital cost for a new nuclear-powered container ship of 24,000 TEU would start at $280 million, with operational costs around $11.5 million per year[43]. Operational costs also include decommissioning costs,[44] which range from 10% to 20% of the initial capital cost, while the insurance cost for a land-based nuclear plant is about $1–1.5 million per year[45]. For ships, commercial insurance costs are expected to be higher.

The estimated capital cost of a nuclear propulsion vessel, which constitutes the largest share of the total cost of ownership of a ship, is solely offset by differences in fossil fuel costs, exluding the costs of carbon taxes.

Business Model

The ownership and operation of a nuclear propulsion plant can only be undertaken by a certified owner and operator (Licensed Nuclear Owner and Operator). Certification is granted under strict regulations by the relevant nuclear regulatory authority and requires specialized personnel with nuclear expertise, infrastructure and plans for the management of nuclear fuel and waste, as well as long-term financial guarantees. Currently, no shipping company meets these criteria. Therefore, the business model for the first nuclear-powered ships will need to include existing certified nuclear operators.

These specific characteristics of nuclear energy make it necessary to establish a different business model for its private use in shipping- one that will likely resemble the Rolls-Royce "Power by the Hour" model used in aviation engines. Under this model, the reactor owner and operator would handle certification, construction, fuel supply, maintenance, and overall management of the reactor, while charging the client/shipowner for its use. Within this framework, shipowners could lease or co-own the vessel while maintaining full operational control. However, questions regarding sub-chartering and the resale of a ship under this model remain unresolved.

Additionally, the insurance providers in the nuclear sector currently lack a common framework with the maritime industry, although discussions toward collaboration have begun, in anticipation of the first modern applications.

At present, the nuclear fuel market is the greatest variable in the economics of Small Modular Reactors (SMRs) and micro-reactors. The cost of nuclear fuel depends primarily on the enrichment level of uranium-235. The new SMRs and micro-reactors under develop-

[41] Evaluation of the Molten Salt Reactor technology for the application of Floating Nuclear Power Plants, I. Kourasis et. al. IAEA SMR CONFERENCE 2024
[42] **New Energies Coalition**, The role of nuclear in shipping decarbonization, April 2025, page 14. https://www.newenergies-coalition.com/static/f76f704347f93b44f1b2000ecba8421d/NewEnergiesCoalition-Nuclear_in_shipping.pdf
[43] **Dowling**, M. et al. Configurations of Commercial Advanced Nuclear-Maritime Applications, doi:10.2172 2318529.
[44] **De, Pabitra** L. Costs of Decommissioning Nuclear Power Plants: A Report on Recent International Estimates. IAEA Bulletin, vol. 32, no. 3, 1990, pp. 39–42. https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull32-3/32304783942.pdf
[45] **U.S. Nuclear Regulatory Commission**. Nuclear Insurance and Disaster Relief. NRC, 26 Mar. 2024, https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/nuclear-insurance.html

ment plan to use High-Assay Low-Enriched Uranium (HALEU), enriched to 19.75%. Currently, the main global supplier of HALEU is the Russian state-owned company TENEX. As a result, there is a shortage of this fuel in the West, as it is currently produced in small quantities by the U.S. and China. As we will see below, the U.S. aims to rapidly develop new enrichment capabilities, along with methods of down-blending (mixing already enriched uranium with natural uranium) to support future HALEU production. Thus, the current situation is expected to improve in the coming years due to the development of a HALEU supply chain in the West, the anticipated easing of U.S.–Russia geopolitical tensions, and technological advances that may reduce enrichment requirements. Pressurized water reactors (PWRs), for instance, are designed for low-enriched uranium, for which there is already a well-established supply chain in the West.

Regulatory Framework

The licensing of Nuclear-Powered Commercial Vessles requires coordination between nuclear and maritime regulatory authorities. This process is still in its early stages.

For the commercial use of nuclear energy in the maritime sector to be realized, the following regulatory frameworks must be implemented in parallel: a) international and national maritime regulatory frameworks, b) international and national nuclear energy regulatory frameworks, c) classification society regulations, and d) port authority regulations.

Such an implementation requires harmonized regulatory standards, which have not yet been fully established or applied. Many countries have legislation and/or bilateral agreements allowing nuclear-powered military vessels to navigate their waters (Greece is among them), but not for nuclear-powered commercial vessels in their ports or waters. It is likely that the first nuclear-powered commercial ships will operate between specific countries that have established nuclear industries and experienced regulators, based on bilateral agreements. In any case, these ships will be subject to international regulations by the International Maritime Organization (IMO).

International Framework

Today, the United Nations Convention on the Law of the Sea (UNCLOS) is widely recognized as the general legal framework within which activities in the oceans and seas must be conducted. The ship safety requirements related to commercial nuclear shipping are supported by the IMO's Safety of Life at Sea Convention (SOLAS). In the 1960s and '70s, Chapter VIII of SOLAS was used to support the few commercial nuclear ships of the time (NS Savannah, Otto Hahn, Mutsu). IMO Resolution A491(XII) "Safety Regulations for Nuclear Merchant Ships" from 1981 is essentially outdated in terms of nuclear technology, international nuclear safety practices, risk analysis, and IMO's own rules. At the 108th session of the Maritime Safety Committee (MSC 108), the World Nuclear Transport Institute (WNTI) submitted a detailed 350-page study titled "Gap Analysis of the Safety Code for Nuclear Merchant Ships (Resolution A.491(XII) November 1981) in Relation to Current International Safety Standards,"[46] calling for the modernization of Resolution A491(XII) so that it can coexist with regulatory practices and modern technologies. The code update is expected to be discussed at the upcoming MSC 110.[47]

In 2013, the International Atomic Energy Agency (IAEA) published a comprehensive review report regarding the framework for Floating Nuclear Power Plants (FNPP). The report emphasized the importance of developing SMR reactors, particularly for FNPP units that remain stationed in their country of origin. Nevertheless, significant unresolved regulatory questions arise for FNPPs that may operate in a country other than their manufacturing country or in international waters.

The IMO nuclear fuel code, known as the INF Code, takes into account the requirements of the IAEA and is mandatory for ships carrying packaged nuclear fuel, high-level radioactive waste, or plutonium. The provisions of this code are interconnected with the IMO International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC) and the International Maritime

[46] **World Nuclear Transport Institute**. "WNTI Gap Analysis of the Code of Safety for Nuclear Merchant Ships." World Nuclear Transport Institute, 2 May 2024, https://www.wnti.co.uk/news/wnti-gap-analysis-of-the-code-of-safety-for-nuclear-merchant-ships/.
Full document can be accessed here: https://www.corepower.energy/library/gapanalysisa491
[47] **Core Power**. Nuclear at IMO MSC 108. Core Power, 24 May 2023, https://www.corepower.energy/news/nuclear-at-imo-msc-108.

Dangerous Goods (IMDG) regulations. Specifically, section 2.7 of the IMDG Code reflects the provisions of the IAEA requirements for Class 7 radioactive materials. However, currently only radioactive materials packaged as cargo are considered- a framework that does not cover power-generating reactors.

In April 2024, the Nuclear Energy for Maritime Organization (NEMO) was founded, with the aim of becoming a non-governmental organization affiliated with both the IAEA and IMO, to support the renewal and establishment of a unified regulatory framework for Nuclear-Powered Merchant Ships. Notable NEMO members from the nuclear and maritime industries include Westinghouse, BWX Technologies, HD KSOE, the American Bureau of Shipping, Bureau Veritas, and Lloyd's Register.[48] At the same time, the IAEA, through its ATLAS program (Atomic Technology Licensed for Applications at Sea), officially launching in 2025, aims to create an international regulatory framework for nuclear applications in maritime navigation.[49]

Regulatory Framework of the Classification Society

TIn October 2024, the American Bureau of Shipping (ABS) issued the first modern class society regulatory guidelines for floating nuclear power plants- a significant step toward the implementation of Comercial Nuclear Maritime Applications.[50]

ABS's guidelines for nuclear power systems for marine and offshore applications were developed to improve the design, construction, and inspection of vessels equipped with nuclear power systems. They define ABS's requirements for the mandatory Power Service (Nuclear) notation for nuclear energy production, not limited to propulsion. The term "vessel" includes ships, barges, offshore units, and installations. According to ABS, it is the responsibility of the nuclear regulatory authority to license the reactor, structures, systems, and nuclear safety components. Therefore, cooperation is recommended with other regulatory bodies, including those of the intended Port Authority, Flag State, and Nuclear Energy Regulatory Authority.

The regulation is primarily based on IMO Resolution A.491(XII) and aims to achieve parallel implementation of the various regulatory frameworks mentioned above through an interface document for each station. Depending on the case, this document will describe and delineate the maritime and nuclear systems of the station, the interfaces between them, and the responsibilities of the different regulatory bodies for their inspection and approval. This method enables each nuclear or maritime regulatory authority to enforce its regulations with a clear division of responsibilities. This, of course, assumes that the Comercial Nuclear Maritime Applications Flag State will, in each case, recognize an established nuclear regulatory authority willing to issue such a license.

It is acknowledged that when IMO Resolution A.491(XII) is updated or new internationally recognized standards are developed, the registration requirements will be updated accordingly.

[48] **Nuclear Energy Maritime Organization**. "Nuclear Energy Maritime Organization." *Nuclear Energy Maritime Organization*, https://www.nemo.ngo/
[49] **CORE POWER**. "IAEA Prepares to Set Sail with ATLAS Project." *CORE POWER*, 5 Sept. 2024, https://www.corepower.energy/news/iaea-to-launch-atlas-project-on-new-nuclear-for-maritime.
[50] **American Bureau of Shipping**, Requirements for Nuclear Power Systems for Marine and Offshore Applications. Oct. 2024. https://ww2.eagle.org/content/dam/eagle/rules-and-guides/current/special_service/346-requirements-for-nuclear-power-systems-for-marine-and-offshore-applications-2024/346-nuclear-power-systems-reqts-oct24.pdf

Image 9

Diagram of Systems Subdivision of a Nuclear Powered Vesseled, according to ABS Regulations

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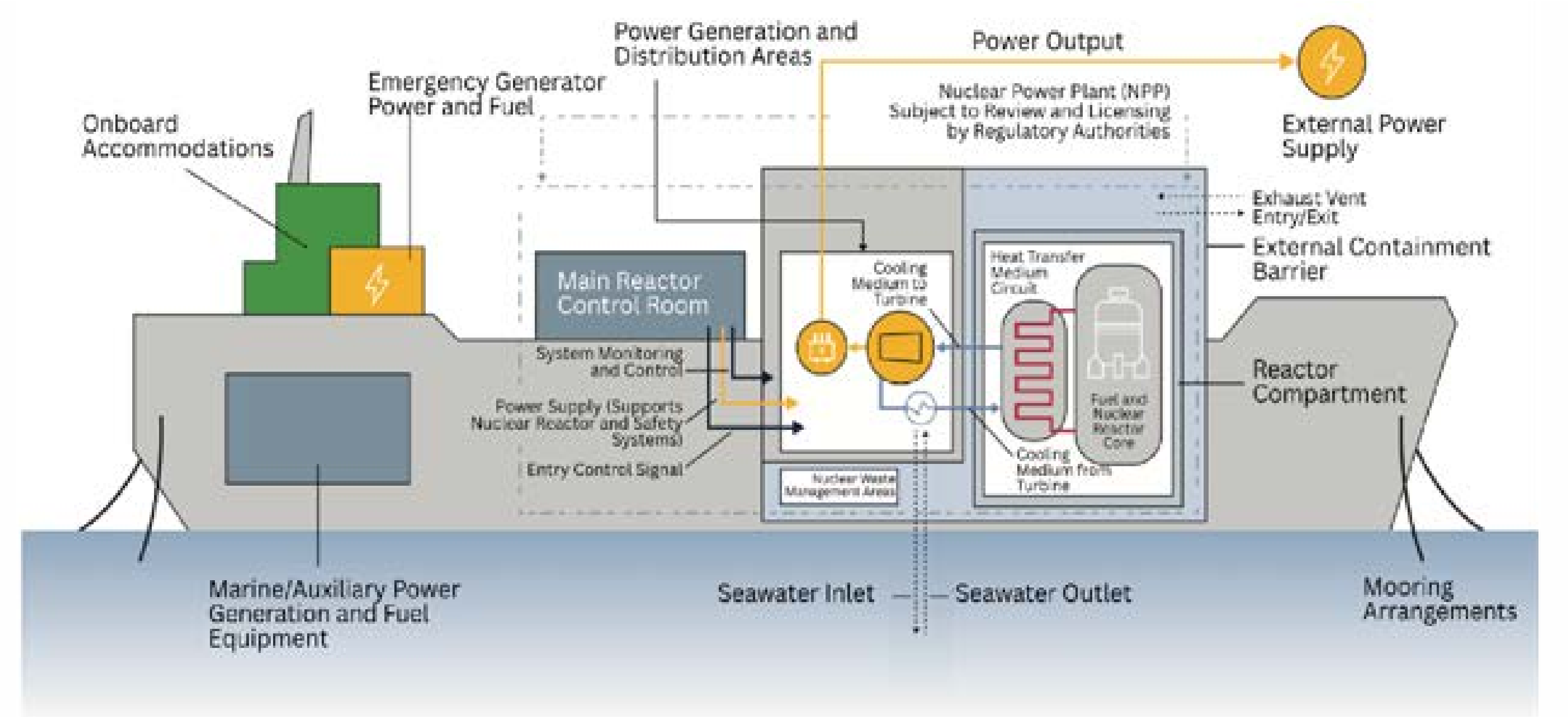


One core assumption of the regulation is that the nuclear regulatory authority will accept the division of the station into nuclear and non-nuclear facilities (Figure 9) and will recognize the "interface document" not only as a necessary but also as a sufficient condition for nuclear licensing. This is by no means a given for nuclear regulatory bodies. From the perspective of the nuclear industry, this kind of "Separation" (Separation of Nuclear Facility and Adjacent Facility) has only recently begun to be implemented in the licensing of next-generation nuclear power plant designs- primarily to reduce construction costs- and it requires specialized design to be achieved.

In conclusion, although a unified regulatory framework for the licensing of commercial nuclear maritime applications is currently lacking, developments at both the international and national levels are encouraging for the future of comercial nuclear marine applications. In practice, this points to the gradual formation of a new regulatory framework that will foster technological cooperation, knowledge exchange, and the alignment of interests.

Safety, Security, Safeguards, and Nuclear Waste

Safety

Today, nuclear energy is one of the safest forms of energy production, with a mortality rate comparable to that of renewable energy sources. [51] The nuclear industry has achieved this exceptional level of safety due to strict regulation, lessons learned from accidents, and the emphasis placed on safety early in the design process (Safety by Design).

For any nuclear power plant to be licensed today, it must demonstrably comply with the three fundamental principles of nuclear safety,[52] both during normal operation and in potential accident conditions, to minimize the risk to humans and the environment:

1. **Control of reactivity,**
2. **Cooling of the nuclear fuel,**
3. **Containment of radioactive materials and radiation shielding.**

Another key design principle for nuclear power plants is the redundancy of defense systems (Defense in Depth). For example, leakage prevention in an accident is ensured by dozens of independent systems/barriers, each capable of preventing it on its own. Even the fuel itself and its physical properties are designed with safety in mind to avoid leakage during accidents (Accident Tolerant Fuel).[53]

Regarding floating nuclear power plants (FNPPs), nuclear safety must be combined with maritime safety. To achieve this, modern probabilistic risk assessment methods should be followed, including the hazards of both nuclear and maritime operations. A notable example of such an application is the qualitative risk analysis method HAZID (Hazard Identification), which was conducted based on a nuclear cruise ship design by the European Maritime Safety Agency (EMSA) in its report.[54] In this area, there is also long-standing expertise from naval nuclear propulsion specialists from military systems, who now work in the commercial industry and contribute their insights to such exercises.

From the perspective of nuclear safety, for a floating nuclear power plant (FNPP) to be licensed, the three nuclear safety principles we mentioned must be upheld even in accident scenarios such as collision and sinking. Encouraging in these cases are the physical properties of water, which simultaneously serves as an excellent medium for cooling and radiation shielding. However, water is also a neutron moderator, which can increase the reactor's criticality. Today, the cores designed for use in FNPPs must be capable of remaining subcritical (meaning the fission chain reaction cannot sustain itself) even in accident conditions, including exposure to water. Such an example was recently presented at the IAEA conference.[55]

Regarding environmental risk, FNPPs must be designed so that the containment barriers for radioactive materials remain functional in collision and sinking events. Currently, nine nuclear submarines are sunken at sea. Among the radioactive isotopes that could leak, Cs-137 and Sr-90 can be absorbed by marine fauna. Due to their natural dilution in the vast amounts of seawater, the final risk to the environment and humans can be significantly reduced, depending, of course, on the sinking location. For example, even in the case

[51] **Paul Scherrer Institute,** Swiss Federal Office of Energy, Severe Accidents in the Energy Sector
[52] **International Atomic Energy Agency.** Fundamental Safety Principles. IAEA Safety Standards Series No. SF-1, International Atomic Energy Agency, 2006. https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1273_web.pdf
[53] **U.S. Nuclear Regulatory Commission.** NuScale DCA - Chapter 13.6 SE with No Open Items. U.S. Nuclear Regulatory Commission, 2019. https://www.nrc.gov/docs/ML1918/ML19182A241.pdf
[54] **European Maritime Safety Agency.** Potential Use of Nuclear Power for Shipping. EMSA, Apr. 2024. https://www.emsa.europa.eu/publications/item/5366-potential-use-of-nuclear-power-for-shipping.html#:~:text=Therefore%2C%20nuclear%20power%20for%20shipping,liability%20and%20also%20insurance%20regime.
[55] **Kourasis, Ioannis, Jake Miles, and Mamdouh El-Shanawany**. "Evaluation of the Molten Salt Reactor Technology for the Application of Floating Nuclear Power Plants." International Conference on Small Modular Reactors and their Applications, 21 Oct. 2024, International Atomic Energy Agency (IAEA). https://scholar.google.com/citations?view_op=view_citation&hl=en&user=RVCM8ocAAAAJ&citation_for_view=RVCM8ocAAAAJ:9yKSN-GCB0IC

of a complete leak of Cs-137 from the sunken submarine K-159 in the Barents Sea, radioactivity levels in seafood would remain within safe consumption limits.[56] [57] The dilution of isotopes in water, which reduces their impact on the environment and humans, depends on factors such as depth and ocean currents. In any case, for any FNPP to be licensed, it must comply with the strict regulations of environmental protection authorities. For example, the floating nuclear power station currently operating in Russia is designed with five independent physical barriers for radioactive materials in the event of an accident or sinking, and five independent safety levels, adhering to the high safety standards of the global nuclear industry. [58]

As mentioned in the introduction, nuclear energy has a very good operational record at sea. By following modern risk analysis techniques, adopted by both the nuclear and maritime industries, the safety of FNPPs is ensured from their design stage. After all, a very high safety level is a prerequisite for licensing any nuclear application in the West.

Security

Security is essential for all nuclear and maritime facilities. The protection of a station takes many forms, such as physical security and cybersecurity. In the nuclear industry, the strategy and design of security begin with the identification of design basis threats, and protective measures are implemented to prevent, detect, and respond to intentional malicious acts. States play a central role in this process.[59]

For commercial nuclear marine applications the list of potential threats includes sea-related risks such as piracy, terrorist attacks, and the construction of a radioactive bomb (dirty bomb) by organizations like the Houthis. The security measures for FNPPs must be suitably adapted to these different threats. For example, an FNPP with a molten salt reactor may have at least eight independent physical security barriers to block and prevent access to radioactive materials.[60] Another deterrent against such threats is the selection of

[56] **Thorstad, Eva B.,** et al. *The Salmon Project in Vefsna: A Collaborative Project Between Research and Management.* Report from the Institute of Marine Research, no. 24-2017, Institute of Marine Research, 2017, https://www.hi.no/resources/publikasjoner/rapport-fra-havforskningen/2017/rapport_24-2017_lakseprosjekt_endelig.pdf.
[57] **Nilsen, Thomas.** *Ill-Fated Russian Sub Shouldn't Contaminate Fisheries*, Norwegian Researchers Say. Bellona, 6 May 2015, https://bellona.org/news/nuclear-issues/2015-05-ill-fated-russian-sub-shouldnt-contaminate-fisheries-norwegian-researchers-say.
[58] **Alekhin, Mikhail.** *Overview of the Russian Approach to the Licensing of MMRs*. OECD Nuclear Energy Agency, Multinational Design Evaluation Programme (MDEP) Workshop on Licensing and Waste Management of Small Modular Reactors, 2024, https://www.oecd-nea.org/mdep/events/LWSMMRWS_2024/presentations/S1_MFPU_Alekhin.pdf.
[59] **International Atomic Energy Agency.** Objective and Essential Elements of a State's Nuclear Security Regime. IAEA Nuclear Security Series No. 20, International Atomic Energy Agency, 2013. https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1590_web.pdf
[60] **CORE POWER**. "Power Hour #4: New Nuclear Security for Maritime." CORE POWER, https://www.corepower.energy/library/powerhour-4.

routes and locations with lower risk. Floating nuclear plants can be installed in protected areas with available state coast guard protection, and nuclear vessels will initially operate on routes with lower piracy risk.

Designers of new technologies apply a strategy of Safety by Design, meaning that the technologies have built-in protections within their construction. For instance, the security computer systems of NuScale's SMR are physically and energetically separated from each other and are not connected to other station networks, preventing the spread of any cyberattack. Similar strategies are followed by FNPP designers. Beyond the designers, national states have the first and final say in developing the protection plan for nuclear facilities within their borders, as well as in identifying threats. The owner and operator of the station cooperate with the state and the relevant authorities to implement the protection plan.

Safeguards

Nuclear Safeguards are a set of legal agreements, regulations, and activities carried out by the International Atomic Energy Agency (IAEA) to ensure that a country does not use its nuclear program for the production of nuclear weapons.[61] For nuclear power plants, this practically means strict control, monitoring, and measurement of the plant's nuclear materials by the IAEA, through mechanisms such as regular inspections by agency officials, seals, and camera surveillance. Unlike protection (security), which refers to threats from third parties, safeguards relate to state actions, ensuring that fissile products like plutonium are not removed from the plant for use in military defense programs.

Countries subject to strict safeguards are those party to the Non-Proliferation Treaty (NPT) and do not possess nuclear weapons (Non-Nuclear Weapon States - NNWS). Nuclear-armed states (USA, Russia, China, France, UK) are not subject to these strict safeguards since they already have nuclear arsenals.

Nuclear-powered maritime vessels under the control of non-nuclear-weapon states will need to comply with nuclear safeguards. Any state hosting comercial nuclear maritime Systems, such as floating nuclear power plants in its national waters, must follow the same safeguards regulations and legal agreements as it would for a land-based station. The future framework for implementing safeguards for Nuclear-Powered Maritime Systems is currently being developed by the international community through NEMO working groups, including experts from the IAEA. In March 2025, the first joint NEMO–IAEA conference on NPMS safeguards was held, with the participation of Deputy Director General Massimo Aparo.[62]

Nuclear Waste

The management of nuclear waste in general is a critical and complex stage in the nuclear fuel cycle, but public fear of it is disproportionate to the actual risk, especially compared to waste from other industries. As Admiral Rickover, the father of nuclear technology, said, "We respect even low amounts of radioactivity." International regulatory authorities strictly control every stage- from transportation and temporary storage to permanent geological disposal- with continuous inspections and environmental measurements. The result is that the actual risk to the public remains negligible, while the benefits of nuclear energy for energy security and emissions reduction are enormous. According to a report by the National Research Council, to date, there has been no health damage caused by the contents of used fuel transport or storage packages — a safety record superior to any other category of hazardous cargo.[63]

[61] **Greek Atomic Energy Commission** (EEAE). *Nuclear Safeguards*. EEAE, https://eeae.gr/πυρηνική-ασφάλεια/πυρηνικές-διασφαλίσεις-safeguards.
[62] **Nuclear Energy Maritime Organization (NEMO) and International Atomic Energy Agency (IAEA).** *Safeguards by Design Workshop*. 18–19 Mar. 2025, London, United Kingdom.
[63] https://nap.nationalacademies.org/read/11320/chapter/13?utm *Safe Transport of Spent Nuclear Fuel and High-Level Waste: International Experience National Academies of Sciences, Engineering, and Medicine.*

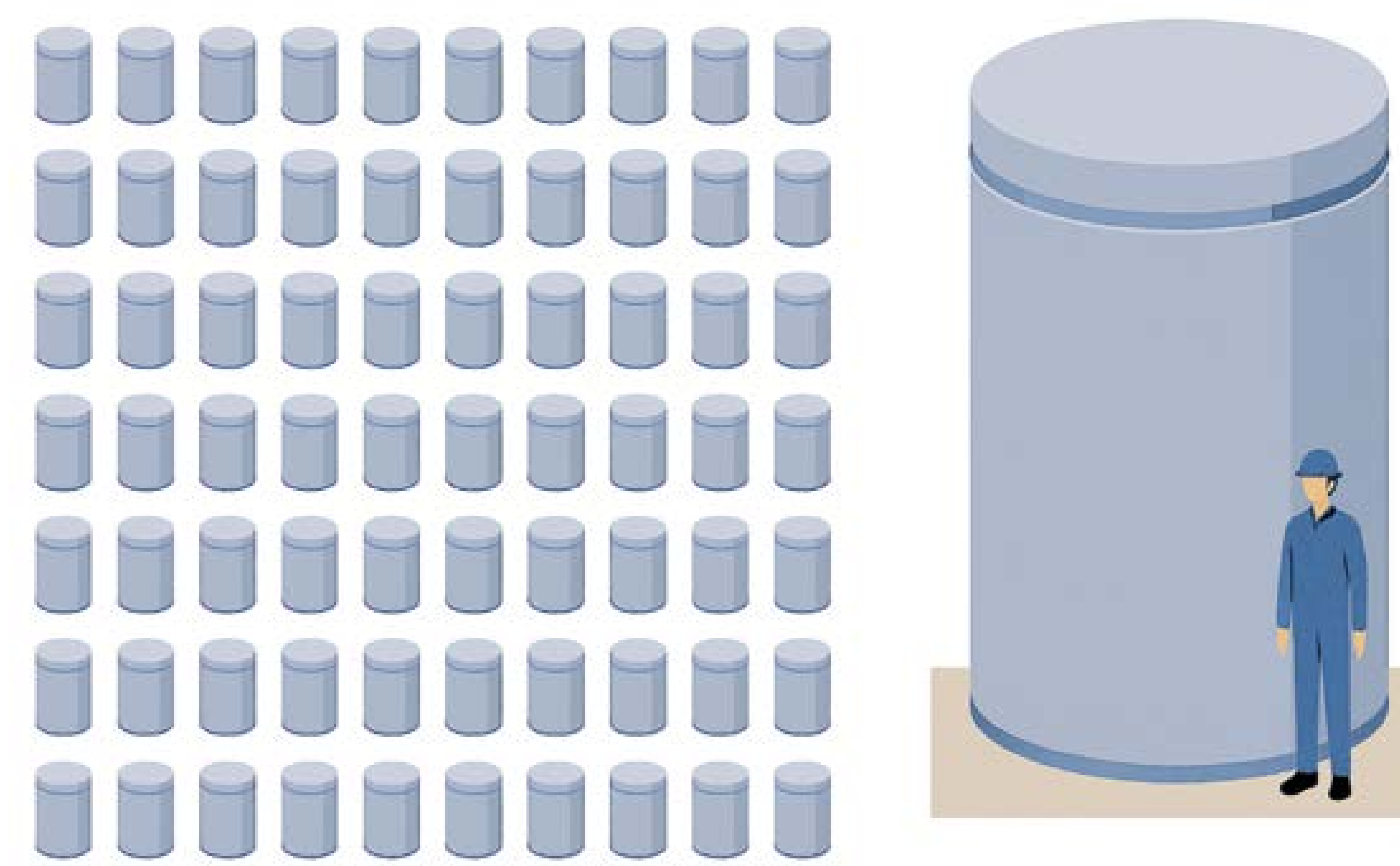
The annual used nuclear fuel produced in the U.S. has a total volume equivalent to half an Olympic-sized swimming pool and has powered 70 million households. Producing the same amount of energy with fossil fuels would emit 400 million tons of carbon dioxide.In Figure 10, we see the storage of the entire used nuclear fuel of a U.S. nuclear power plant that produced 5 TWh per year for 25 years. This energy is enough to cover over 8 years of the entire electrical consumption of the population of Athens. [64]

Thanks to their high internal shielding, radiation levels just 10 meters from this stored fuel are at background radiation levels (environmental). [65]

Worldwide, approximately 15 million shipments of radioactive material are transported every year over distances of many millions of kilometers, without a single case of health or environmental damage caused by radiation. [66]

Image 10:

Visualization of Storage of Spent Fuel in the United States



[64] 2,600,000 residents × 4,700 kWh/resident/year = 12,220,000,000 kWh/year ≈ 12.22 TWh/year enerdata.net
[65] Gao, Yuan, et al. Radiation Dose Rate Distributions of Dry Fuel Casks Estimated with MAVRIC Based on Detailed Geometry and Continuous-Energy Models. Nuclear Engineering Program, University of Florida, 100 Rhines Hall, Gainesville, FL 32611, https://www.osti.gov/servlets/purl/1525310.
[66] International Atomic Energy Agency. Transporting Radioactive Materials. IAEA, https://www.iaea.org/topics/transporting-radioactive-materials.

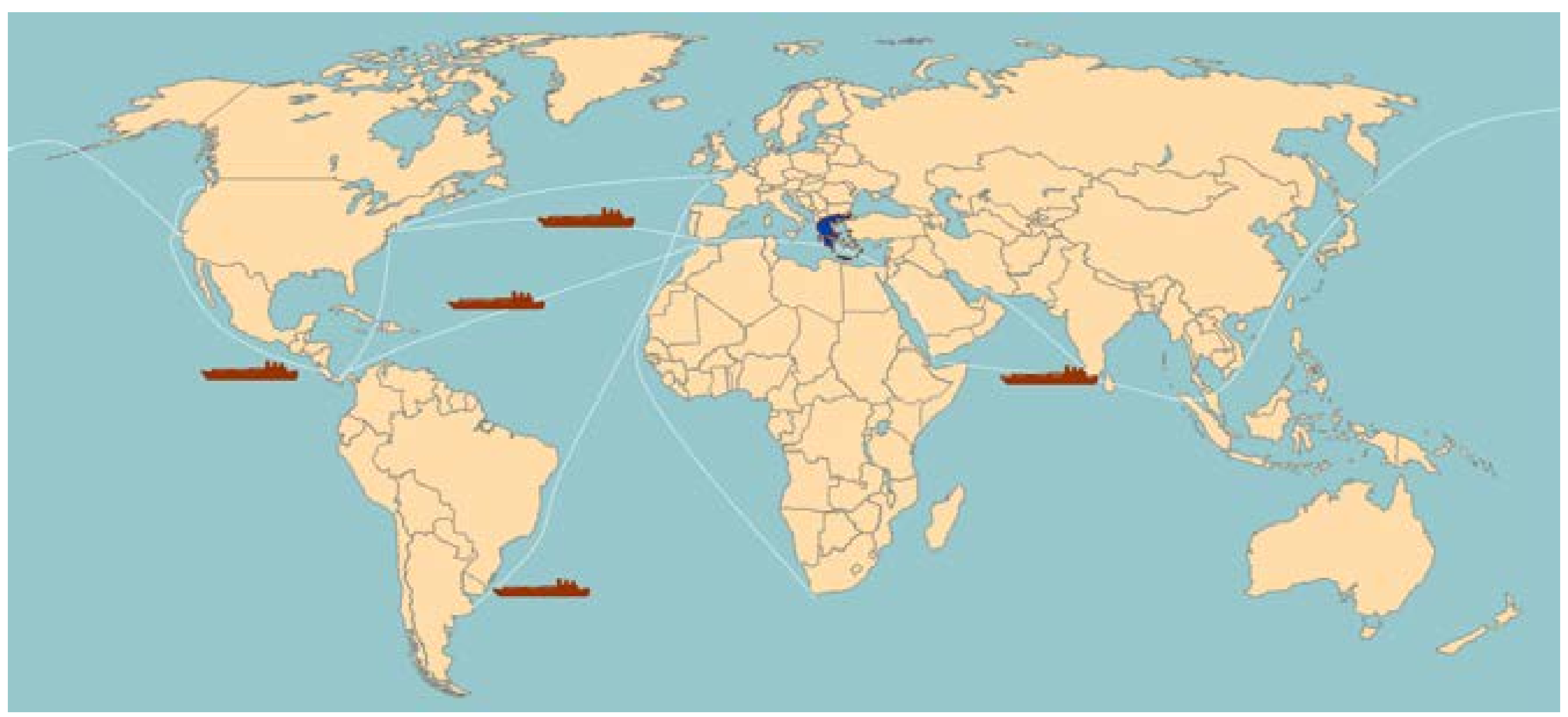
Greece’s Position

Nuclear Energy and National Energy Strategy

In a rapidly changing world, Greece is called to protect its vital interests in the maritime industry by adopting a modern national legal framework that addresses the challenges posed by new energy sources, including nuclear energy, while at the same time playing a decisive role in shaping new global rules for their regulation.

The integration of nuclear energy into Greece’s energy mix requires several fundamental steps. These include raising public and policymaker awareness, developing a strategic plan that defines the uses of nuclear energy, suitable sites, and appropriate technologies, shaping a clear regulatory framework that covers applications on land and at sea, and preparing the workforce. These actions should be part of a comprehensive National Nuclear Energy Program, which can be developed based on the existing and applicable IAEA guidelines.

Successful integration of nuclear energy into the Greek energy mix primarily requires the support of both society and political leadership. It is critical to launch organized educational campaigns so that citizens are adequately informed and actively participate in decision-making on issues related to safety, environmental benefits, and the economic prospects offered by nuclear energy both on land and at sea. At the same time, forming broad political consensus is vital to ensure the stability and continuity of such an initiative. Simultaneously, the creation of a strong political and regulatory framework is required. For Greece, the political aspect will likely be incorporated into the National Energy and Climate Plan (NECP), which defines the country’s long-term energy and climate policy goals. According to Presidential Decree 67/2022, the Greek Atomic Energy Commission (EEAE), which was effectively re-established under Law 1733/1987, falls under the Ministry of Development and Investments and serves as the regulatory authority responsible, among other things, for the control, regulation, and supervision of the nuclear energy sector, nuclear technology, and its applications. Within this framework, further institutional deepening and specialization of the EEAE’s responsibilities are necessary, along with its reinforcement in expertise and personnel following the standards of the U.S. Nuclear Regulatory Commission (NRC) or equivalent European authorities. This is aimed at future licensing management, overseeing development, effective supervision of nuclear power plant operations, and supporting the broader nuclear energy sector on land and at sea.



Another critical factor is the education and development of the specialized workforce.

Our country has experience in the successful operation and decommissioning of the research reactor at N.C.S.R. “Demokritos,” as well as the operation of a subcritical graphite reactor in the Nuclear Technology Department of the National Technical University of Athens (NTUA). These two nuclear energy research centers in our country should be strengthened so that they can properly handle the education of future nuclear engineers, technicians, and operators. The training of the merchant navy should also include a basic introduction to the principles of nuclear energy so that our seafarers can serve on nuclear-powered vessels (although, as we discussed, reactor operation will be carried out by specially trained operators who will not necessarily be naval personnel).

The strength of Greek shipping and the leading role of our country are based on people and our maritime expertise. The goal should be to attract new human resources and provide the necessary technical knowledge, tools, and skills to Greeks. This includes their ability to effectively utilize modern technologies, including nuclear technology.

Greece’s Role in a Rapidly Changing International Environment

Nuclear energy is gaining ground globally. In just the first half of 2025, European countries such as Belgium, Germany, and Denmark—traditionally opposed to nuclear power—have shown signs of revising their energy policies. Newly elected German Chancellor Friedrich Merz, in a joint article[67] with Emmanuel Macron, announced his intention for a historic shift in Germany’s energy strategy, based on the principle of technological neutrality, aiming for Germany and Europe to regain part of their competitiveness and energy sovereignty. In early May 2025, the Belgian federal parliament voted to repeal the 2003 law mandating the gradual phase-out of nuclear energy. At the same time, the Danish parliament approved the commissioning of a study on the potential use of nuclear energy, which had been banned for the past 40 years. In the United States, the new administration under President Trump loudly declared its intention to triple the country’s nuclear power capacity- from 100 GW to 400 GW- by signing four executive orders[68] at the end of May 2025. The West’s turn toward nuclear energy comes in the wake of the ongoing conflict with Russia and the growing realization that competition in new energy-intensive technologies, such as Artificial Intelligence and Data Centers, will likely be determined by the long-term availability of abundant and affordable energy.

In the maritime sector, in April 2025, the International Maritime Organization (IMO) took a major step by approving a draft regulation that establishes the Net-Zero Framework[69] - a legally binding system combining mandatory emissions caps and greenhouse gas pricing in the global shipping sector. The measures, which include global standards for marine fuels and a pricing mechanism for emissions, will apply to large vessels over 5,000 gross tons, which are responsible for 85% of CO_2 emissions. The framework is expected to be formally adopted in October 2025 and enter into force in 2027, introducing fuel intensity targets and a system of compliance units and financial incentives to reward low-emission vessels.

Despite the IMO’s concrete commitment, the organization and national European nuclear regulatory authorities have not yet co-developed a unified licensing framework for nuclear-powered ships. New initiatives, such as NEMO and the IAEA’s ATLAS program, aim to shape a harmonized regulatory framework. In fact, the personal interest of IAEA Director General Rafael Mariano Grossi in the de-

[67] **Macron, Emmanuel,** and **Friedrich Merz.** “A Franco-German ‘Reset’ for Europe.” Le Figaro, 7 May 2025, https://www.lefigaro.fr/en/a-franco-german-reset-for-europe-20250507
[68] Executive Orders of the President of the USA, May 23rd 2025: REINVIGORATING THE NUCLEAR INDUSTRIAL BASE
https://www.whitehouse.gov/presidential-actions/2025/05/reinvigorating-the-nuclear-industrial-base/
REFORMING NUCLEAR REACTOR TESTING AT THE DEPARTMENT OF ENERGY
https://www.whitehouse.gov/presidential-actions/2025/05/reforming-nuclear-reactor-testing-at-the-department-of-energy/
ORDERING THE REFORM OF THE NUCLEAR REGULATORY COMMISSION
https://www.whitehouse.gov/presidential-actions/2025/05/ordering-the-reform-of-the-nuclear-regulatory-commission/
DEPLOYING ADVANCED NUCLEAR REACTOR TECHNOLOGIES FOR NATIONAL SECURITY
https://www.whitehouse.gov/presidential-actions/2025/05/deploying-advanced-nuclear-reactor-technologies-for-national-security/
[69] **International Maritime Organization.** “IMO Approves Net-Zero Regulations.” IMO, 24 May 2024,
https://www.imo.org/en/MediaCentre/PressBriefings/pages/IMO-approves-netzero-regulations.aspx.

carbonization of shipping and the leading role that Greece could play in this effort was discussed during his recent meeting with the Greek Prime Minister in Athens.[70] Indeed, due to Greece's role in the IMO and its effectively mediating position between the IMO and the EU on matters of decarbonization, the country could play a pivotal role in these negotiations- including those concerning nuclear shipping- by setting the parameters within which such a discussion should move in the Marine Environment Protection Committee (MEPC). The regulatory framework of Greek ports must also be adapted to accommodate nuclear commercial vessels, just as it must adapt to all new fuel types. Nuclear-powered ships are not new to Greek waters, considering the frequent presence of American and French nuclear aircraft carriers in the country.

At the same time, the fortunate circumstance of a Greek being recently appointed as the EU Commissioner for Sustainable Transport and Tourism- responsible for developing the EU's industrial maritime strategy and its strategy for ports- creates a particularly favorable framework for Greece to promote the formation of a European framework for the seamless reception of nuclear-powered ships in EU ports. This includes the use of floating nuclear reactors to provide clean energy, at least to cruise ship ports of call. It is worth noting

[70] Paphitis, Elena Becatoros and Demetris Nellas. "UN Atomic Agency Sees Big Role for Nuclear Power in Shipping as Climate Pressures Grow." AP News, 10 June 2024, https://apnews.com/article/greece-nuclear-shipping-grossi-4dd6cc70e28b9f00446390696d106d58

that the energy consumption of a cruise ship docked in port is equivalent to that of a small city, and this energy is mostly supplied by the cruise ship's engines, thus burdening the port environment. The European Commission is requiring a 31% reduction in emissions by 2040[71] and an 80% reduction by 2050 for ships over 5,000 GT that approach European ports, along with a mandate for shore-side power supply or the use of alternative zero-emission technologies starting January 1, 2030. Two of the ports on the path to decarbonization are the ports of Piraeus and Heraklion (Crete), where projects to provide cleaner electricity from shore have already been funded.

Such a policy is in full alignment with the European Commission's recent "Clean Industrial Deal,"[72] which, for the first time, seeks to strengthen and accelerate the licensing and approval processes for Small Modular Reactors (SMRs), mobilize private capital for nuclear energy, and modernize regulatory frameworks to facilitate investment in nuclear technologies- ensuring a resilient and competitive European nuclear industry.

These initiatives of the EU for designing a new industrial policy do not take place in a vacuum. The tariff war waged by the US, which currently targets mainly China, is expected to have adverse effects on global trade but also creates opportunities for Western countries. One of the industrial sectors expected to be strengthened in the West in the coming years is the shipbuilding sector.

The recent executive order regarding the "Restoration of U.S. Maritime Dominance,"[73] as well as the "Shipbuilding and Port Infrastructure Act for the Prosperity and Security of America,"[74] introduced for voting in Congress by the previous U.S. administration, aim to rebuild the commercial shipbuilding capacity of the United States and to strengthen the maritime workforce. The simultaneous expressed intent to impose tariffs on ships built in China (64% of new ships were built in China in 2023) every time they dock at a U.S. port clearly shows the U.S. determination not only to strengthen the U.S.-owned shipbuilding industry but also to prevent U.S. allies from constructing ships at Chinese shipyards. It is notable that 77% of new orders for tankers, 73% of orders for bulk carriers, and 75% of orders for containerships have been placed at Chinese shipyards (2024).[75]

U.S. policy has not only economic but also security motives, as the use of nuclear propulsion in shipping and the construction of nuclear reactors in shipbuilding environments- which is gaining ground internationally (due to drastic reductions in cost and construction time)- constitute part of Western know-how that cannot be exported and must remain strictly within Western countries. Thus, the titanic effort of "reshoring" the shipbuilding industry by the U.S. is expected to strengthen regional Western countries that have specific security characteristics and can undertake part of the nuclear industrial production chain.

The expected diffusion of shipbuilding activity from China to the United States and other Western countries also concerns Greece. Although our country went through a fifteen-year period during which shipbuilding activity was declining (in 2000, 1,575 ships were brought in for repair, while in 2013 only 339 according to ELSTAT data presented in Naftika Chronika[76]), the trend reversed during the crisis, with approximately 651 ships brought in for repair in 2023. A similar increase can be seen not only in the number but also in the total capacity of ships repaired in Greek shipyards, since from 16 million grt (gross register tonnage) in the early 2000s, capacity decreased by 75% to 4 million grt in 2016, and then recovered in the following years to about 8 million grt. This recovery coincides in time with the above geopolitical developments and the declared goal of the domestic shipbuilding industry[77] to become a leading power in the construction of floating and offshore energy solutions, which may also include its participation in the global nuclear supply chain.

[71] **European Commission**. *Decarbonising Maritime Transport – FuelEU Maritime*. European Union, 2023, https://transport.ec.europa.eu/transport-modes/maritime/decarbonising-maritime-transport-fueleu-maritime_en
[72] **European Commission,** "Clean Industrial Deal." European Commission, 26 Feb. 2025, https://commission.europa.eu/topics/eu-competitiveness/clean-industrial-deal_en
[73] RESTORING AMERICA'S MARITIME DOMINANCE, Executive Order of the President of the USA, April 9th 2025 https://www.whitehouse.gov/presidential-actions/2025/04/restoring-americas-maritime-dominance/
[74] **U.S. House of Representatives.** H.R.10493 – Nuclear Industrial Reinvigoration Act of 2024. 118th Congress, 2nd Session, introduced 12 April 2024. Congress.gov, https://www.congress.gov/bill/118th-congress/house-bill/10493/text
[75] S. Hatzigrigoris, The future of shipbuilding will be shaped by greek technology, automation and digitalization, Ναυτικά Χρονικά, Μάρτιος 2025, σελίδες 144-146.
[76] M. Charitos, Greek shipyards: From decline to revival, Naftika Chronika, March 2025, pages 102-104.
[77] Varvitsiotis, Miltiadis, P. Xenokostas, and A. Bayoumi. "Interviews." Naftika Chronika, March 2025, pp. 107–125.

Nuclear energy emerges as a sustainable path for the transition of the maritime industry to clean and high-performance propulsion. Floating nuclear power plants and nuclear-powered commercial vessels are steadily gaining ground as practical solutions for decarbonization and energy security. However, challenges remain related to regulation, fuel availability, and social acceptance. The successful implementation of these technologies will require close cooperation between governments, industrial stakeholders, and international organizations.

Greece can and should play a leading role in shaping this new international framework.

δεον, το [δέon]

That which is binding, needful, right, proper.

“μᾶλλον τοῦ δέοντος”, Xenophon, *Memorabilia*, 4.3.8

“παρόντων τὰ δέοντα μάλιστ᾽ εἰπεῖν”, Thucydides, *The Peloponnesian War*, 1.22

“Πρὸ τοῦ δέοντος”, before it be needful, Sophocles, *Philoctetes*, 891

“ἐν δέοντι”, in good time, Euripides, *Medea*, 1277

Deon Policy Institute is the first and only non-partisan Hellenic Diaspora think tank. Their mission is to organize and transform the Hellenic Diaspora into a catalyst for the progress and prosperity of Greece. Deon Policy Institute was co-founded by young Greek expats who saw an opportunity to bridge the gap between the Hellenic Diaspora and Greek Policy Makers. Their network consists of diaspora experts, academics and seasoned professionals, who develop evidence-based policy, leveraging knowledge and best practices from abroad.

Source: “δέον”. Henry George Liddell. Robert Scott. A Greek-English Lexicon. Oxford. Clarendon Press. 1940.

OUR STORY

The financial crisis in Greece had a detrimental social and economic effect on the country, causing 500,000 people to emigrate seeking better opportunities. The diaspora still maintains a strong connection with the country - a bond if you will. So, while others see a Greece that is losing talent to other countries, we saw an opportunity:

Organize and transform the Hellenic diaspora into a catalyst for the progress and prosperity of Greece.

Deon Policy Institute was founded by a group of Greek academics, entrepreneurs and young professionals who wanted to leverage their expertise to support Greece in its recovery and modernization path.

Deon seeks to foster a sense of unity and shared purpose among all Greeks in the diaspora. And we welcome you to join us.

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Empowering Progress and Prosperity for Greece

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