NUCLEAR ENERGY IN MARITIME

A Focus Series on **Advanced Nuclear Technology**

ISSUE 1

Where We Stand Today

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Shipowners and operators are navigating a dynamic landscape – balancing near-term needs against **future goals.**

INTRODUCTION

Shipowners and operators face uncertainty about the future of marine fuels and the impacts on their operations as they seek their best options for safe, reliable and economical power that meets evolving requirements for emissions. Most are working through fuel transition strategies that best fit their own near-term needs and regulatory environments. However, many are looking forward to the unique opportunity to leverage advanced nuclear technology in their operations.

Advanced nuclear power offers the potential for safe, operationally efficient, cost-effective, emission-free power at-scale for a wide range of potential uses in the maritime domain. These applications include floating power assets with use cases for grid/microgrid power, remote and emergency power supplies, floating data centers, water desalination, offshore production of future fuels and various other uses. The applications also include propulsion for various types of government and/or commercial ships.

This is the first of a series of publications that will provide a comprehensive exploration of the marinization of nuclear technology, with each issue representing a key step toward commercial applications. The journey begins with an overview of the current state of the field, public perceptions and key stakeholders. Future issues will examine major technical, regulatory and economic challenges. The series will unpack enabling technologies, such as small modular reactors (SMR), state-of-the-art passive safety control systems and advanced nuclear fuels. It will also address safety considerations and shifts in public perception and nonproliferation concerns. Further, the series will highlight the importance of collaboration across academia, industry, and government; outline operational and regulatory pathways; and evaluate the long-term sustainability of maritime nuclear energy through life cycle and economic analysis.

Subsequent issues will assess risk dimensions and mitigation strategies; showcase successful projects and pilot programs; and conclude with a forward-looking roadmap and guidance for enabling nuclear energy at sea.

Make no mistake; the journey ahead for the marine and offshore application of nuclear energy will not be easy or fast. Much like alternative fuels, its potential must be balanced against cost, development and technical hurdles. But as the nuclear energy and maritime industries continue to make progress together, there is great potential for the future of both. Read on as we explore the possibilities of nuclear implementation in this series.

ON THE HORIZON

While nuclear in maritime is gaining momentum and serious interest from shipbuilders, owners, operators, governments, industry and regulatory bodies, critical challenges remain — especially in regulation, nuclear fuel logistics and public perception. The field is transitioning from concept to early demonstration, but its widespread adoption will depend on international policy alignment, economic viability, and trust-building through transparent safety practices and pilot projects.

Nuclear is rapidly gaining traction in the maritime sector, with global momentum — from advanced reactor innovations to cross-sector alliances — driving a bold transition toward zero-emission, high-endurance, future-ready applications.

CURRENT TOPICS AND TRENDS INCLUDE:

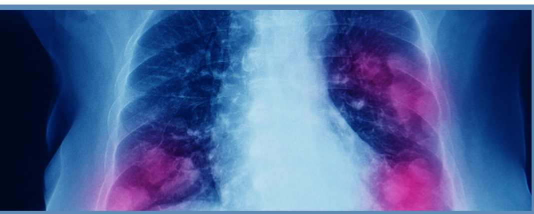
- Commercial Nuclear Propulsion Revival
- National Programs and Strategic Interest
- Emissions Reduction Obligation
- Technological Maturity vs. Commercial Readiness
- Public Perception and Risk Communication
- Regulatory and Policy Bottlenecks
- Emerging Innovation Concepts

The European Maritime Safety Agency (EMSA) commissioned ABS to produce a report on the potential use of nuclear power for shipping, in partnership with Texas A&M University and Arcsilea.

To download the full report, visit **www.emsa.europa.eu**.

WHERE WE STAND TODAY

The maritime industry faces mounting pressure to reduce emissions while maintaining efficiency and economic viability. Nuclear power, a proven and scalable energy source, is increasingly being considered as a solution. This issue sets the foundation for our journey by assessing the current state of nuclear power, maritime, and the merger of nuclear and maritime. By understanding where we stand today, we can better navigate the path forward.



DID YOU KNOW?

Nuclear reactors and spent fuel (so called "nuclear waste") enable many other vitally important applications. Examples include medical radioisotopes for cancer treatment and imaging (Tc99, Ac225), nuclear batteries (Am241) for space exploration and lifesaving heart pace-maker implants.

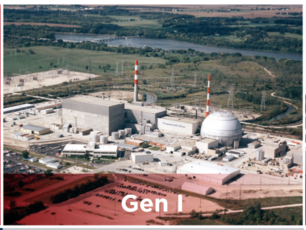
Image sources: NASA; science.nasa.gov (middle), Los Alamos National Laboratory; osrp.lanl.gov (bottom).

Nuclear energy is already one of the safer forms of large-scale energy generation. With a safety record that exceeds that of coal, oil and even hydropower when measured by fatalities per terawatt-hour, historical accidents like Chernobyl and Fukushima are statistical outliers. Decades of safe operation at hundreds of reactors worldwide go largely unnoticed.

Safer, stable, proven. Nuclear energy's track record speaks — if we are willing to listen.

For example, France generates more than 70 percent of its electricity from nuclear energy with a strong safety record. Sweden uses nuclear energy, hydroelectric and other low- or no-emissions options to power its electric grid with mostly zero-carbon sources. The United Arab Emirates' (UAE) Barakah plant is now operational, and China is rapidly expanding its nuclear power capacity. In the United States (U.S.), the Palo Verde Generating Station safely powers millions of homes in the Arizona desert using recycled wastewater.

Advanced Gen IV reactors and modern SMRs are built on this safety trade record, bringing even safer power generation by introducing passive safety features that eliminate the need for external power or operator intervention in emergency scenarios. Many SMRs are designed to be inherently meltdown-proof, using advanced coolants like molten salt or gas, and operate at atmospheric pressure, reducing the risk of pressure-related failures. Shifting public perception from fear to fact is key to developing nuclear energy for maritime applications. A well-informed public can unlock nuclear energy's full potential.

The evolution of nuclear power.	 Gen I	 Gen II	 Gen III/III+	 Gen IV
Technology	Prototype reactors that used manual controls. Low power density and basic systems.	Commercial-scale pressurized/boiling water reactors. Improved materials and automation.	Digital instrumentation and controls. Modular construction using higher burnup fuels. Enhanced thermal efficiency.	Non-traditional coolants and compact cores. Advanced materials, high temperature systems and digital integration.
Safety	Manual shutdown with limited redundancy.	Defense in depth engineered safety systems.	Passive safety systems with extended coping times.	Inherent/intrinsic safety featuring walk-away concepts. Design basis external events (DBEE) resilience.
Economics	High capital cost with low efficiency. Mostly state-funded demonstrations.	Improved economics with standardization, but long build times remain a limiting factor.	Lower operation and maintenance costs. Improved build time with semi-modularization.	Factory fabricated, lowering lifecycle and decommissioning costs. Long refueling intervals.
Regulatory and Licensing Framework	Minimal oversight. Regulatory development was created post-event.	Regulators emerge, such as U.S. Nuclear Regulatory Commission (NRC). Deterministic licensing.	Risk-informed frameworks and design certifications (e.g., Part 52).	Tech-neutral, outcome-based licensing in development (e.g., Part 53).
Fuel Cycle and Sustainability	Once-through cycle with low burnup and no waste management strategies.	Improved enrichment leading to early recycling and longer fuel cycles.	High burnup of about 60 gigawatt-days/metric ton of uranium (GWd/MTU). Some waste minimization.	Advanced fuels. Closed fuel cycles and fast reactors for higher burnup. Early stage commercial recycling.
Operations, Testing and Lessons Learned	Initial testing and operational basics established. Limited liability and material/control issues.	Three Mile Island and Chernobyl drove safety, culture and operator training and design improvements.	Lessons learned from Fukushima. NRC created more coping strategies. Enhanced safety systems.	Theory-driven safety. Small testbeds only with no full-scale operations.
Integration and Modularity	One-off and site-specific — poor scalability.	More standardization but still mostly site-specific.	Semi-modular builds. Grid and load-following integration.	Modular by design with marine/off-grid potential. Hybrid systems integration.

Images courtesy of NRC (I-III) and Canadian Nuclear Laboratories (IV).

DID YOU KNOW?

"Fissionable" and "fissile" are distinct terms in nuclear engineering. While many nuclides are fissionable, only a few subsets are fissile. U235 is the only naturally occurring fissile isotope.

What if, by 2030, SMRs demonstrate **superior safety**, **efficiency** and **cost-effectiveness** compared to other energy sources?

The global maritime industry is under intensifying pressure with tight regulations on emissions.

While hydrogen, biofuels, ammonia, methanol and liquefied natural gas are being explored as alternative fuels, each brings significant challenges in terms of life-cycle emissions, availability and handling complexity.

Technology development, supply chain volatility and infrastructure gaps have limited the adoption of these alternative fuels. Global port infrastructure is largely unprepared to support widespread bunkering of these fuels, and retrofitting fleets comes with high capital costs and uncertain return on investment.

DID YOU KNOW?

The world's first fission reactor occurred naturally in Oklo, Central Africa, where a self-sustaining nuclear reaction took place around 2 billion years ago. This inspired the name of the California-based advanced reactor company Oklo.

Image source: Duke Energy, illumination.duke-energy.com

TODAY — 2030 — 2035 — 2040 — 2045 — 2050

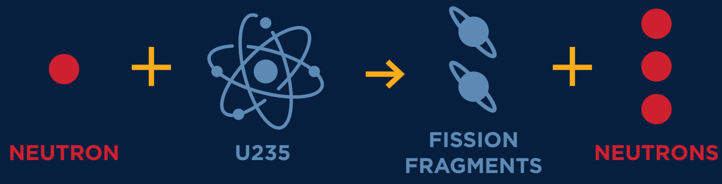
The International Maritime Organization (IMO) is considering nuclear propulsion, including SMRs, as part of its efforts to find alternative fuels and technologies to achieve net-zero emissions by 2050.

This creates a strategic opening for the use of nuclear power in maritime. If SMRs prove to be safer, more cost-effective and logistically simpler than other energy sources by 2030, could the marine and offshore sectors adopt nuclear energy rapidly as one of the main energy sources?

Nuclear energy is slowly becoming a credible solution for maritime emissions reduction, as the industry faces growing pressure to meet the International Maritime Organization's 2050 emission targets. SMRs offer high energy density and zero-emission power well-suited for maritime applications, outperforming other low- or zero-emission power sources. Additionally, SMRs enhance long-term energy security by reducing reliance on volatile fuel supply chains.

DID YOU KNOW?

A single fission event (i.e., U235 fission) generates about 200 mega-electronvolts, which are released from the nuclear binding energy and converted into the projectile kinetic energy of fission fragments. Hence, nuclear power and radioactive buildup directly scales from the number of fissions per second.



Historically, nuclear power in the maritime sector has been both promising and limited. The U.S. NS *Savannah* (classed by ABS) launched in 1959, was a demonstration of peaceful nuclear propulsion, but it faced economic and regulatory hurdles, ultimately being decommissioned in the 1970s. In contrast, Russia (and the former Soviet Union) have successfully deployed and continue to operate nuclear-powered icebreakers in the Arctic, such as the Arktika class, demonstrating nuclear energy's effectiveness in remote, energy-demanding operations. These examples highlight both the technical capability and the economic and policy complexities that have shaped maritime nuclear adoption to date.

Global "firsts" in maritime nuclear systems.

1954 United States' USS *Nautilus* submarine

1959 Soviet Unions' *Lenin* icebreaker

1961 United States' USS *Enterprise* aircraft carrier

1961 United States' USS *Long Beach* cruiser

1962 United States' NS *Savannah* merchant ship

1967 United States' MH-1A *Sturgis* power barge

1969 Germany's NS *Otto Hahn* cargo ship

1972 Japan's *Mutsu* cargo ship

Today, momentum is building again for commercial nuclear applications in the maritime sector. Advanced reactor technologies, including certain types of SMRs, are being developed for integration into marine applications. These systems promise long operational cycles, high energy density and reduced fuel logistics, offering opportunities for global collaboration as regulatory and industry frameworks evolve.

As a leading classification society, ABS is actively engaging in feasibility studies, framework development, Rules, and guidance to support the global energy transition through joint development projects, new technology qualifications and approvals in principle for nuclear systems.

Where others see complexity, ABS aims to **pioneer**, **engage** and **build connections**.

FOOD FOR THOUGHT

- What will it take for public perception to shift in favor of adopting nuclear for maritime applications?
- What if the only viable way for nuclear in maritime is via a power purchase agreement or leasing model?
- Who are the key players for the adoption of nuclear in maritime?
- Who should own the nuclear reactor on a ship? Why? And how?
- Should nuclear propulsion start with containerships, cruise liners or coast guard icebreakers? And why?

NEXT ISSUE

In the next issue, we will address the public perception of nuclear applications, including generational shifts in attitudes and the effects of global sustainability initiatives.

Follow us on social media or subscribe to our newsletters to stay up-to-date on the latest releases.

Want to read more about how ABS is exploring maritime applications for nuclear? Download the nuclear vessel concept publications, developed in partnership with Herbert Engineering.

Available today at www.eagle.org/nuclear.

Join the Nuclear Maritime Conversation

What are your thoughts on nuclear power in maritime? Do you see it as a viable solution for reducing emissions? Join the conversation by sharing your insights, questions or concerns for our upcoming industry roundtable discussions. We welcome your thoughts!

Have questions about nuclear maritime applications? **Let us know.**

www.eagle.org/nuclear

Want to collaborate on nuclear maritime research? **Reach out.**

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