

BRITISH PORTS
ASSOCIATION

Advanced nuclear technology use within port environments



Abstract

This paper sets out what advanced nuclear might mean in and around ports. It is intended as a briefing for port leaders, harbour authorities, terminal operators and policymakers. The central conclusion is that ports should treat nuclear as a long-term infrastructure and operating-model question, not simply as a new fuel. The most immediate actions are stakeholder engagement, evidence-building, regulatory engagement and integration of nuclear scenarios into established port safety-management systems and ways of working.

Advanced nuclear technologies are shifting from the theoretical into practical consideration for ports and the maritime sector. For ports, the opportunity is broader than just receiving a nuclear-powered ship, it could include reliable low-carbon electricity for port estates, shore power, industrial heat, hydrogen or synthetic fuel production, resilient microgrids, floating or transportable power units, specialist maintenance services, including new roles in high-value maritime industrial supply chains. Nuclear introduces more breadth and depth on assurance than conventional systems. Safety, security, safeguards, emergency preparedness, licensing, insurance and public confidence must be addressed early, transparently and in a way that fits established port governance rather than creating a dual parallel regime.



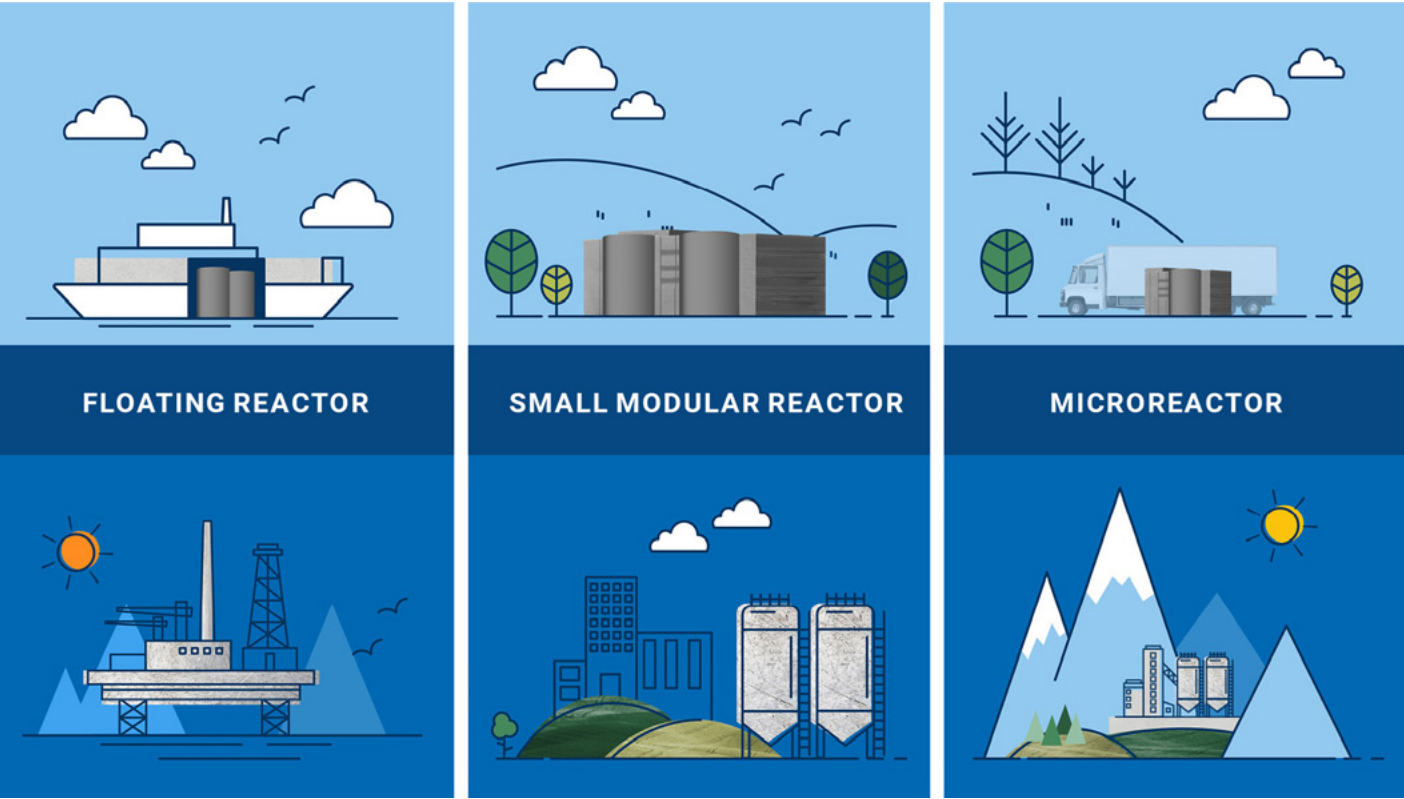
01 Current developments in advanced nuclear technology

1.1 Evolution of maritime-adapted reactors

Modern reactor designs for commercial maritime use differ fundamentally from those traditionally used in nuclear navies. Maritime reactors are based on low enriched fuels, unlike naval reactors, allowing for proportional security requirements and therefore greater commercial application. Modern proposals reduce operational risk and align with commercial shipping's need for reliable, available, and safe systems. They emphasise:

- Passive safety systems
- Low-enriched uranium (LEU) fuels
- Modular construction for rapid assembly and transport
- Refuelling intervals that vary from 1 year to 30 years compared to days or months for conventional ships.





Source: Reimagining emergency preparedness and response for tomorrow’s nuclear fleet, IAEA

1.2 Small Modular Reactors (SMRs)

SMRs are the leading candidate for maritime power and port delivered power. Over 120 designs are under development globally with widespread commercial deployment largely projected for the 2030s, with only a few specifically targeting maritime uses. Proposed advantages include:

- Compact footprints suitable for maritime integration
- Factory fabrication enabling quality control
- Scalable power outputs (5–300 MWe)

SMRs are already in use in China and Russia, and are being developed in the UK, US, South Korea and EU. Designs vary from light-water reactors to molten-salt and lead-cooled fast reactors.

1.3 Microreactors

Microreactors (1–20 MWe) are emerging as a prominent offering delivering more than conventional GW scale power plants. Microreactors are favoured by stationary and mobile military use and the data centre boom. In mid-2026, tech companies including Deployable Energy, who LR supported with a technical qualification, reached “criticality” with their prototype systems. Their small size makes them ideal for:

- Shipboard power production (including for propulsion)
- Port microgrids
- Remote industrial operations
- Remote community power production

Microreactors are often proposed to be transportable so a reactor with limited fuel life can be swapped for a freshly fuelled unit.

1.4 Floating Nuclear Power Plants (FNPPs)

Nearshore or Offshore Power Plants represent one of the more transformative developments. These are compact maritime based units perhaps barge-mounted or hull-integrated capable of supplying energy.

These maritime units can be sited near ports, industrial clusters, or offshore facilities. Many of these proposals promote design and manufacturing features to allow for serial shipyard production to reduce time and cost compared to on-site construction.

02 Why advanced nuclear matters for ports

Ports are becoming increasingly large electrical power consumers and some are exploring their own role in energy production. Electrified cargo-handling equipment, cold storage, shore power, electric fleets, industrial tenants, data centres, hydrogen production and synthetic fuel pathways are all increasing demand for reliable, low-carbon electricity. Small nuclear reactors can provide stable baseload power for ports and reduce reliance on regional grids, depending on power demand, site location, regulations, grid constraints, and cost.

Ports are often located at the intersection of constrained grids, heavy industrial demand, strategic logistics and local air-quality or decarbonisation pressures.

Nuclear offers a possibility to provide for these new or increasing demands in a compact, reliable, low-emission package that is inherently safe.

A useful way for port leaders to frame the opportunity is to consider three overlapping areas:

- **Energy:** reliable low-carbon electricity and heat for port estates, shore power, cold storage, cranes, warehouses, electric fleets, industrial tenants, desalination, production of hydrogen based (synthetic) fuels.
- **Maritime:** safe port calls, inspections, specialist logistics, maintenance and lifecycle services for nuclear-powered vessels.
- **Industry:** shipbuilding, reactor-module integration, workforce development, component fabrication, specialist services, decommissioning and waste-logistics capabilities.

Preparation can begin now through scenario planning, evidence gathering and structured engagement with maritime, nuclear, emergency planning, security and community stakeholders. Ports should not wait until a nuclear-powered vessel requests entry before beginning to understand the issue.

03

What advanced nuclear could look like in a port environment

For port planning purposes, there are three broad use cases, each resulting in different regulatory, commercial and operational obligations.

3.1 Nuclear-powered vessels

For a civil nuclear-powered merchant vessel calling at a port, the port call remains recognisable: the ship arrives, berths, conducts cargo or passenger operations, and departs. Support activities such as resupply or crew changes occur during this time too. The difference is that the assurance, accountability and evidence requirements are expected to increase. A nuclear-powered vessel would need to demonstrate that it is licensed, certified, insured and operated within a defined safety envelope. The port would need arrangements for pre-arrival information, berth selection, traffic management, radiation monitoring, security, emergency preparedness, communications and post-call reporting.

The Port of Rotterdam joint development project assessed a nuclear-powered feeder containership calling at an EU port under normal operating conditions. Its key finding was that the principal barriers are not technical, but relate to regulatory alignment, governance, risk-management integration and public acceptance. The study concluded that nuclear ship port calls can be assessed using safety themes already familiar to ports, provided nuclear-specific considerations are systematically incorporated. See below on how this is being addressed internationally and nationally.

3.2 Floating or transportable nuclear power

The second use case is a floating or transportable nearshore nuclear power unit supplying electricity, heat or fuels from a moored, waterside or nearshore location. Floating nuclear power plants (FNPPs) could be especially relevant where land is constrained, where grid connection is difficult, or where ports need scalable low-carbon power close to demand. The FNPPs may allow ports to deploy reactors where space limits land-based options and where mobility may enable unit relocation to serve different loads over time.

For ports, this creates a different set of questions from a visiting ship. The issue is not simply port-entry control, but hosting, leasing, marine-interface management, site licensing, grid connection, emergency planning, security zones, environmental consent and commercial integration with port and tenant demand.

3.3 Land-based small modular reactors or microreactors

The third use case is a land-based SMR or microreactor located on or near port land. This could support port demand, including shore power, fuels production and local energy resilience. Advanced small reactors typically propose the use of passive safety systems and factory production for safety, cost, and schedule advantages.

For ports, land-based deployment depends strongly on-site suitability. Relevant considerations include available secure land, geotechnical conditions, flooding and storm-surge risk, water availability, nearby hazardous activities, surrounding land use, population density, emergency planning requirements and political or regulatory acceptance. These are not questions ports can answer alone, but they can begin identifying which sites or adjacent industrial areas may warrant future analysis.

04

The port opportunity: from energy consumer to clean-energy hub

Advanced nuclear could give some ports a pathway to become clean-energy hubs. The opportunity is not limited to direct electricity supply: a single 100 MWe-class SMR could, in principle, meet the electricity needs of a medium-sized port and several associated industrial tenants. Potential value pools include:

- **Baseload electricity:** stable power for cargo handling equipment, cold storage, warehouses, port buildings, electric fleets, terminal operations and future shore power.
- **Shore power:** low-carbon electricity for ships at berth, potentially reducing local air emissions and avoiding additional grid strain where local systems are constrained.
- **Industrial heat and decarbonisation:** process heat and electricity for adjacent energy-intensive activities such as petrochemicals, steel fabrication, refrigerated warehousing, ship repair, construction, desalination and other continuous-load industrial operations.
- **Fuel production:** hydrogen and its derivatives using nuclear electricity or heat, supporting wider maritime decarbonisation.

- **System resilience:** microgrid operation, black-start capability, frequency stability and continuity of critical services during grid disruption or extreme weather events.
- **Land and berth value:** long-term leases, dedicated berths, secure zones and new forms of energy infrastructure.
- **Technical and industrial services:** reactor-module fabrication, shipyard integration, nuclear vessel construction, inspection, monitoring, specialist maintenance, nuclear logistics, decommissioning and waste-logistics capabilities.
- **Strategic relevance:** a stronger role for ports in national energy security, industrial, resilience and maritime policy.

The best candidates for port-based nuclear are likely to have large, steady and growing electricity demand, grid constraints, nearby energy-intensive industries, sufficient secure space, manageable site hazards, supportive regulatory or policy environments and strategic resilience needs. Detailed port-specific assessment is essential before any technology match or investment decision can be credible.

05

What changes when a nuclear-powered vessel calls?

A nuclear-powered vessel should not be understood as simply another alternative fuel user. The port call may look familiar, but the evidence, assurance and coordination requirements are different. A practical model can be described as a controlled end-to-end journey:

For shipping, nuclear power would change both vessel performance and port service models. Its very high energy density could support long-distance routes, high utilisation and minimal fuel-storage volume, particularly for larger container ships, tankers and bulk carriers.

The economics would also differ from conventional fuels: higher capital cost and more complex assurance at the outset, offset by predictable long-life energy costs and reduced exposure to fuel-price volatility or carbon pricing. Activities that may look different for a nuclear vessel call are listed below as examples.

- **Pre-arrival:** authorisations, safety documentation, vessel operating status, insurance evidence, port-entry conditions, security plans, berth readiness, weather constraints and emergency contacts.
- **Approach:** traffic management, pilotage, towage strategy, routing, speed controls if required, contingency locations and clear decision rights.
- **Alongside:** protected berth arrangements, access control, radiation monitoring where appropriate, security interfaces, defined operating envelope and controls on simultaneous operations.
- **Port operations:** cargo interface, maintenance restrictions, waste restrictions, shore services, permit-to-work controls, communications protocols and oversight arrangements.
- **Departure:** readiness confirmation, controlled movement, release from berth controls and post-call reporting.

The key principle is that nuclear-specific decisions should be embedded within the port's established marine safety-management system. Ports already manage high-consequence activities involving dangerous goods, hazardous cargoes, bunkering,

simultaneous operations, security zones and emergency response. The challenge is to add the nuclear-specific evidence, competence and regulatory interfaces in a proportionate way.

Nuclear-powered vessels would not require frequent fuel delivery in port, but they would create demand for specialist inspection, radiation monitoring, controlled maintenance, rare refuelling or module-exchange events, and tightly governed waste or material-handling arrangements where permitted. Ports that develop these capabilities early could become high-value technical service hubs rather than conventional fuel suppliers.

The Rotterdam Joint Development Project (JDP) applied the Rotterdam Harbour Master's safety framework and considered themes such as governance, external safety, control zones, terminal readiness, nautical safety, safety of other ships, mooring, bunkering, SIMOPS, port safety operations, risk resilience and emergency response. It provides a useful model for other ports because it shows that nuclear scenarios can be assessed through existing port safety disciplines, while clearly identifying where new guidance or regulatory clarification is needed.



06

Safety, security, safeguards and emergency preparedness

Nuclear introduces a layered operating model. At the base are normal port controls: navigation, cargo handling, berthing, workforce safety, environmental management and emergency arrangements. On top of this sit nuclear-specific controls: radiation monitoring, protected areas, defined operating limits, specialist competence, safety case evidence and additional assurance. Alongside these are security and safeguards controls, including physical protection, cyber security, information control, access management and material accountancy. Finally, emergency preparedness must be capable of integrating maritime and nuclear response arrangements.

For port leaders, the objective should not be to build a duplicate nuclear bureaucracy. It should be to ensure that established port and regional arrangements can handle nuclear scenarios in a coordinated, evidence-based way. This includes:

- Named accountable leaders and clear escalation thresholds;
- Agreed decision rights between harbour authority, port operator, terminal operator, nuclear regulator, maritime regulator, emergency services and government;
- Baseline monitoring and clear ownership of monitoring data;
- Integrated incident command arrangements;
- Tested assumptions on sheltering, evacuation and medical response;
- Exercises covering table-top, command-post and live scenarios;
- Pre-agreed communication plans for workforce, communities, customers and media;
- Cyber-security assessment of ship-shore digital interfaces.

The Rotterdam JDP highlighted that existing emergency planning frameworks are primarily designed for land-based nuclear incidents or transport of radioactive material and provide limited coverage for commercial nuclear ships.

07

Regulatory environment

The regulatory interface is a central challenge for advanced nuclear in ports. A port sits between several regimes: harbour and marine safety, vessel certification, flag and coastal state jurisdiction, nuclear licensing, safeguards, nuclear security, planning, environmental permitting, emergency preparedness, insurance and public policy. There is a need to define the operating envelopes, interfaces and responsibilities across the nuclear and maritime domains.

An international framework exists, intended to support the operation of the NS Savannah and Otto Hahn, that predates modern reactor designs and commercial deployment. SOLAS Chapter VIII requires nuclear ships to carry a safety assessment and provide port and coastal states with information needed to judge safety before entry. The IMO Code of Safety for Nuclear Merchant Ships, Resolution A.491(XII), was adopted in 1981 and is now under review for updating and modernising, with the UK leading the relevant correspondence group. UNCLOS also recognises special precautions for nuclear-powered ships, while IAEA instruments apply to safety, security, safeguards and notification regimes. However, the 1962 Brussels Convention on liability of operators of nuclear ships never entered into force, leaving significant uncertainty around liability and insurance. In August 2026 the

International Atomic Energy Agency launched the ATLAS (Atomic Technologies Licensed for Applications at Sea) Initiative. The intention of this project is to work closely with the IMO in establishing a global safety, security, and regulatory framework for deploying Small Modular Reactors (SMRs) and Floating Nuclear Power Plants (FNPPs) for peaceful use of nuclear technology in the maritime industry.

There is some divergence in national approaches. The UK has placed emphasis on commercial insurability, regulatory leadership and the opportunity to shape international rules. It has also initiated a review of the domestic regulation that adopted the IMO Nuclear Code into British law. Lloyd’s Register formed the MarNuc Consortium so the support the UK government in identifying regulatory change needed to further support advanced nuclear in maritime. South Korea is linking nuclear propulsion to its wider shipbuilding and industrial strategy. Russia continues to operate nuclear icebreakers and floating nuclear power capability, while the United States is developing pathways for advanced reactors and microreactors. This variation reinforces the need for ports to understand both international frameworks and the specific national rules that would apply to any vessel, floating unit or land-based reactor proposal.

08

Liability, insurance and commercial confidence

The Rotterdam JDP found three recurring EU-wide barriers:

- Existing regulations rarely make explicit provision for civil nuclear ships other than military nuclear ships;
- Nuclear safety and maritime safety regimes exist in parallel, with limited integration;
- Ports lack clear guidance on nuclear licensing, insurance and liability for visiting ships.

These challenges are not unique to Rotterdam. They are likely to apply across Europe and internationally, although local governance structures will vary. The practical implication is that national work cannot wait for international harmonisation. International code development can take many years. Ports and national authorities expecting to be early movers will need to influence the development of national or regional approaches in parallel, while feeding lessons back into IMO, IAEA and industry guidance. Classification Societies also have an important role to play in this, including as a convenor able to work across the different regulatory frameworks.



Insurance and liability are not secondary issues; they are central to commercial deployment. A port cannot make confident admissions, leasing, emergency planning or investment decisions without understanding who is responsible for what, what evidence is required, how incidents would be managed, and how liabilities would be allocated.

There is a lack of clarity on how port states will address insurance and liability for nuclear ships, or what may be required from shipowners, operators or local port facilities. A credible framework will need clear allocation of responsibilities, international alignment where possible, access to appropriate insurance or pooling arrangements, harmonised safety expectations and agreed evidence for safe operations. These issues may influence ship design, port controls, emergency arrangements, commercial contracts and investment appetite.

For ports, the immediate requirement is not to solve nuclear liability law alone. It is to ensure that liability and insurance are included early in technology demonstration and stakeholder mapping and are not left until a live project is being negotiated. This should include engagement with insurers, government, nuclear regulators, maritime regulators, shipowners, technology developers, terminal operators and local resilience bodies.

09

Workforce, skills and public confidence

The success of advanced nuclear in ports will depend heavily on people. Port workers, harbour masters, pilots, tug operators, terminal staff, emergency responders, security teams, local authorities and neighbouring communities will all need confidence that risks are understood and governed. Ports will need to consider training and coordination for personnel who may be exposed to radioactive material or involved in emergency response. Workforce development, physical security, cyber security and public perception should therefore be treated as central readiness issues, not peripheral communications tasks.

Public perception should be treated as a core workstream, not an afterthought. The Rotterdam JDP recommends early public engagement because progress can begin locally and independently of technology maturity. Early engagement can reduce uncertainty, support informed discussion and make later regulatory, siting and commercial discussions easier. Nuclear is currently enjoying greater public support due to the geopolitical challenges highlighting energy security needs. This does not mean promotional messaging, for port communities the right approach is likely to be plain-English, evidence-led communication that explains what is being considered, what is not being considered, how safety is regulated, who is accountable, what controls would be in place and how local communities would be involved.



10

A tiered model for port readiness

Not every port needs the same capability. A tiered model allows ports to choose a credible position without over-investing.

Tier 1: Nuclear-aware port	The port can assess requests, engage relevant authorities and manage an exceptional nuclear-related enquiry with external specialist support. It has a basic understanding of the regulatory landscape, relevant stakeholders and decision points.
Tier 2: Nuclear-ready port	The port has identified potential berths or sites, trained relevant teams, mapped emergency and security interfaces, considered monitoring requirements and exercised initial scenarios with regulators and responders.
Tier 3: Nuclear enabled port	The port has deeper capability, defined governance and established commercial service models to support various operations of nuclear ships or FNPPs. 3a: The port can support recurring visits by nuclear-powered vessels that do not require nuclear-specific services. 3b: The port can or provide specialist nuclear inspection, radiation monitoring, maintenance, logistics, workforce, refuelling-support and lifecycle services.
Tier 4: Nuclear energy hub	The port hosts or directly integrates multiple floating, transportable or land-based nuclear generation units into port and industrial energy systems, including power, heat, fuels and resilience services. It is also able to host nuclear ship calls and provide specialised nuclear services. This model enables proportionate planning. A smaller port may aim only to become nuclear-aware. A major energy, industrial or strategic port may explore readiness, service-hub or energy-hub roles over time.

11

No-regret actions for port leaders

Ports do not need to wait for a final reactor design or a live vessel proposal before preparing. No-regret actions may include:

- 1. **Set the ambition.** Decide whether the port wishes to be nuclear-aware, nuclear-ready, nuclear-enabled, or a potential nuclear energy hub.
- 2. **Map stakeholders.** Identify harbour, nuclear, maritime, security, emergency, planning, environmental, workforce, community, insurer, grid and tenant stakeholders.
- 3. **Build the evidence base.** Assess current and projected energy demand, grid constraints, industrial tenants, possible berths, potential sites, navigational constraints and local hazards or security threats.
- 4. **Test operating concepts.** Develop scenarios for a nuclear-powered vessel call, a floating power unit and a land-based SMR or microreactor.
- 5. **Consider commercial models.** Explore whether value lies in energy supply, berth services, technical services, industrial tenants, resilience, or a combination of these.

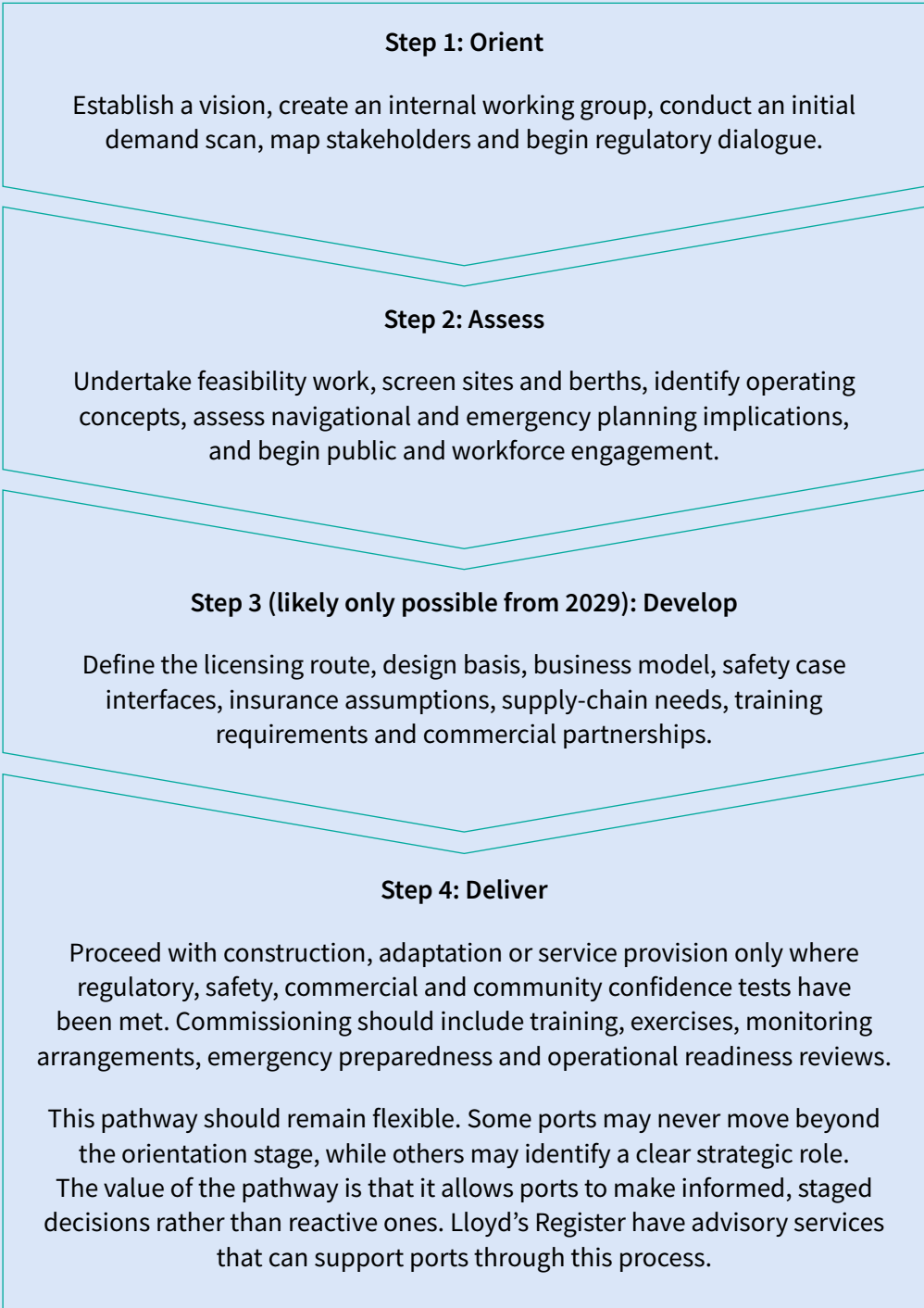
- 6. **Stage decisions.** Use decision gates for strategic fit, regulatory viability, safety and security, commercial case and community confidence.
- 7. **Review existing safety systems.** Map nuclear scenarios against the port’s existing marine safety-management system, emergency plans, security plans and SIMOPS controls.
- 8. **Engage regulators early.** Begin dialogue with maritime and nuclear regulators to understand expectations, evidence requirements and decision pathways.
- 9. **Develop a communications approach.** Prepare clear, non-promotional information for workforce, local authorities, customers and communities.
- 10. **Plan capability.** Identify training, specialist support, monitoring, cyber-security and training/drill requirements.



12

A practical pathway from interest to deployment

A credible development pathway towards maturity should be staged, with evidence increasing before major capital is committed.



Conclusion

Advanced nuclear technology could reshape port environments, maritime operations and industrial energy systems. It offers potential benefits in reliable low-carbon power, shore power, industrial heat, fuel production, vessel propulsion, resilience and high-value maritime services. However, the opportunity is highly site-specific and cannot be separated from safety, security, safeguards, emergency preparedness, licensing, liability, insurance and public confidence.

The key lesson from recent port-focused studies is that the principal barriers are not only technical. They include governance, regulatory alignment, evidence, public acceptance and integration with existing port safety systems. Ports should therefore start with preparation rather than procurement: understand the use cases, map the stakeholders, test scenarios, build the evidence base and engage early with regulators and communities.

Advanced nuclear is not imminent for every port, nor is it a universal solution. But it is strategically significant and relevant to future energy demand such that port leaders should begin structured, proportionate planning in the near-term. The ports that do so will be better placed to make informed decisions, protect public confidence and shape the regulatory and commercial frameworks that will determine whether nuclear has a role in the next generation of maritime infrastructure.



Nuclear Maritime at Lloyd's Register

Lloyd's Register is building a shared pathway to nuclear-powered shipping and offshore energy. With over 260 years of classification authority, our independent assurance provides the confidence insurers, financiers, technology providers, shipowners and port operators need to invest for the future. Through our work with MarNuc, the IMO and the IAEA we are developing the regulatory frameworks to bridge the atomic and maritime worlds, delivering safe, sustainable and innovative maritime nuclear applications for global production and supply chains.



The British Ports Association

The British Ports Association (BPA) represents the interests of UK ports, which collectively handle 86% of the country's maritime trade. As the maritime and energy sectors explore the potential of nuclear technologies, the BPA is working to ensure that the opportunities, challenges and practical implications for ports are properly understood and reflected in future policy and regulation. Working with government, industry and international partners, we support a proportionate regulatory framework that maintains the highest standards of safety and security while enabling innovation, investment and the development of new maritime technologies.

References / source material

- Lloyd's Register, CORE POWER, A.P. Moller-Maersk and Port of Rotterdam, Joint Development Project on the Safety and Regulatory Considerations of a Nuclear-Powered Feeder Ship Calling at the Port of Rotterdam, Jun 2026
- Pacific Northwest National Laboratory, Small Nuclear Reactors for Maritime Ports: A Feasibility Study, PNNL-39328, March 2026
- Lloyd's Register, Advanced Nuclear in and at Ports, presentation to the American Association of Port Authorities, August 2026
- EMSA, ABS, Texas A & M University, Arcsilea, Potential Use of Nuclear Power for Shipping, December 2024
- Qiuwen Wang, Hu Zhang,Puxin Zhu, Using Nuclear Energy for Maritime Decarbonization and Related Environmental Challenges: Existing Regulatory Shortcomings and Improvements, Int J Environ Res Public Health. 2023 Feb 8;20(4):2993



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