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Ocean Power: Floating Nuclear Power Plants under the Law of the Sea

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Abstract

States Parties to the United Nations Convention on the Law of the Sea are responsible for exploring uses of the ocean that may reduce carbon emissions and the resulting deleterious effects on the marine environment. Nuclear energy is a component of many States' planning for a low-carbon energy future, yet conventional land-based nuclear reactors have been beset by high costs, lack of access to cooling water, and safety concerns for population centres on land. A floating nuclear power plant (FNPP) is a marine low-carbon energy solution, particularly but not exclusively for use at remote islands and Arctic territories, offers access to nuclear energy, if the marine environmental risks can be controlled. This article explores whether the law of the sea provides a framework for the legally certain and environmentally sound development and deployment of this technology. The law of sea is supplemented by international nuclear energy law.

Keywords

LOSC – law of the sea – nuclear energy law – floating nuclear power plant

1 Introduction

States Parties are bound by Part XII of the 1982 United Nations Convention on the Law of the Sea (LOSC)[1] to protect the marine environment from pollution. The International Tribunal for the Law of the Sea (ITLOS), in its 2024 advisory opinion on the implications of climate change for the LOSC, has found that carbon emissions have deleterious effects on that environment, including sea level rise and ocean acidification.[2] It follows that States Parties must, under Article 194 of the LOSC, prevent carbon emissions from any sources, be they marine or land based. There must therefore be a transition to low-carbon energy, and this transition may utilise the ocean to generate such energy. A floating nuclear power plant (FNPP) is an example of a marine low-carbon energy form and technology to this effect. There is an obligation on States to consider, and potentially improve on, the applicable law of the sea and nuclear energy law to enable deployment of this technology in legally certain and environmentally sound ways.

FNPP design and functionalities significantly differ from traditional nuclear reactors, which has consequences for their evaluation under international law. Historic and contemporary FNPPs are characterised by the mooring of a chain of a barge on the sea, with nuclear reactors integrated into their construction. In alternative designs, a FNPP resembles more traditional platforms such as oil rigs or other spar platforms.

FNPP technology has advantages over land-based nuclear power because of cost-effectiveness and its flexibility. Traditional land-based nuclear power plants are the most familiar form of nuclear energy generation. However, these reactors have faced considerable criticism due to their high capital investment needs and lengthy construction timelines, as well as the intricate waste disposal processes.[3] A FNPP has the potential to resolve the investment issues because it can be constructed in modular form in port and then be deployed away from

1 United Nations Convention on the Law of the Sea (Montego Bay, 10 December 1982, in force 16 November 1994) 1834 *UNTS* 397 [LOSC].

2 *Request for an Advisory Opinion submitted by the Commission of Small Island States on Climate Change and International Law*, Advisory Opinion of 21 May 2024, ITLOS Case No. 31, available at https://www.itlos.org/en/main/cases/list-of-cases/request-for-an-advisory-opinion-submitted-by-the-commission-of-small-island-states-on-climate-change-and-international-law-request-for-advisory-opinion-submitted-to-the-tribunal/; accessed 4 May 2024.

3 International Atomic Energy Agency (IAEA), 'Floating Nuclear Power Plants: Benefits and Challenges Discussed at IAEA Symposium' (21 November 2023) available at https://www.iaea.org/newscenter/news/floating-nuclear-power-plants-benefits-and-challenges-discussed-at-iaea-symposium; accessed 4 May 2024.

population centres. A crucial benefit is that a FNPP can rely on the abundance of seawater for cooling needs without the additional infrastructure or water procurement usually required by land-based nuclear plants. This natural heat sink holds the potential to sustain optimal temperatures, preventing the risk of overheating and averting potential accidents or equipment malfunctions.[4] These advantages will mean that more States gain access nuclear power. In particular, FNPPs could fulfil the electricity demands of remote regions, such as islands and the Arctic, where establishing land-based electrical infrastructure and distribution networks is impractical.

However, and at the same time, deployment of FNPPs raises important environmental concerns regarding the potential disruption of marine ecosystems, including altered spawning and migration patterns of fish, as well as the destruction of clam beds and other shellfish harvesting areas. [5] In the event of an accident, the reactor core could breach the barge and enter the hydrosphere, leading to the contamination of thousands of cubic miles of ocean with radioactive material.[6] The potential effects of radioactive release on human health are significant and widely acknowledged, as exposure to internal radiation can shorten life, increase the risk of cancer, and cause reproductive mutations.[7] Given that FNPPs may traverse long distances before reaching their destination, they are susceptible to extreme weather conditions, increasing the risk of accidents during towing operations.[8] Under Article 192 of the LOSC, States must protect the marine environment from these risks. This entails that important substantive and procedural obligations are met regarding environmental impacts assessment and consultation before the technology can be used at scale.

This article explores the international law issues associated with FNPPs, while the international regulatory bodies, including the International Maritime Organization (IMO), and the International Atomic Energy Agency (IAEA) are

4 World Economic Forum, 'Could We Build Nuclear Power Plants That Float on the Sea?' (26 June 2015) available at https://www.weforum.org/agenda/2015/06/could-we-build-nuclear-power-plants-that-float-on-the-sea/; accessed 5 May 2024.

5 CP Goodyear, CC Coutant and JR Trabalka, *Sources of Potential Biological Damage from Once-through Cooling Systems of Nuclear Power Plants* (Oak Ridge National Laboratory, Oak Ridge, TN, 1 July 1974) available at https://www.osti.gov/biblio/4272708; accessed 4 May 2024.

6 *Ibid*.

7 JB Moore, 'The Environmentalist and Radioactive Waste' (1972) *49 Chicago-Kent Law Review 55*.

8 The International Maritime Organization (IMO) has issued guidelines for towed ships and other floating platforms, urging adherence to the regulations and safety standards. See 'Guidelines on the Safety of Towed Ships and Other Floating Objects Including Installations, Structures and Platforms at Sea, IMO Res A.765(18) (adopted 4 November 1993).

trying to ascertain the exact nature of a FNPP.[9] The focus of this article rests on the law of the sea laid down in the LOSC complemented by IMO conventions, including the International Convention for the Safety of Life at Sea (SOLAS)[10] and the International Convention for the Prevention of Pollution from Ships (MARPOL),[11] and implementing codes,[12] as well as nuclear energy instruments. It does not consider maritime law or investment law.

The article is structured into five parts. The first introduces the concept of a FNPP. With some FNPPs proposed to operate off moored barges, Part 2 turns to the classification of a FNPP under the law of the sea as a 'ship' or 'vessel' and sets out the consequences. The LOSC and SOLAS do not define the terms 'ship' or 'vessel', making it difficult to determine whether a FNPP can be accommodated within their scope. While noting that the LOSC could be interpreted broadly to include FNPPs, SOLAS explicitly excludes 'non-self-propelled' vessels from its scope.[13] The International Maritime Dangerous Goods (IMDG) Code,[14] International Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High-level Radioactive Wastes (INF Code),[15] and the Polar Code[16] that draw on the convention would also not be applicable. Several other treaties define a ship broadly and could accommodate FNPPs.[17] Part 3

9 DJ Steding, 'Russian Floating Nuclear Reactors: Lacunae in Current International Environmental and Maritime Law and the Need for Proactive International Cooperation in the Development of Sustainable Energy Sources' (2004) 13 *Pacific Rim Law and Policy Journal* 711–742.

10 International Convention for the Safety of Life at Sea (London, 1 November 1974, in force 25 May 1980, 1184 *UNTS* 278 [SOLAS].

11 International Convention for the Prevention of Pollution from Ships (London, 2 November 1973, not in force) 1340 *UNTS* 61, as amended by the Protocol of 1978 relating thereto (London, 17 February 1978, in force 2 October 1983) 1340 *UNTS* 61 [MARPOL].

12 Examples are the International Maritime Dangerous Goods (IMDG) Code 2002 (IMO Res MSC.122(75) (adopted 24 May 2002, in force 1 January 2004)), the International Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on Board Ships (INF) Code 2001 (IMO Res MSC.88(71) (adopted 27 May 1999, in force 1 January 2001)), and the International Code for Ships Operating in Polar Waters (Polar) Code which draws its existence from SOLAS and MARPOL (International Code of Safety for Ships Operating in Polar Waters, IMO Res MSC.385(94) (21 November 2014) and IMO Res MEPC.264 (15 May 2015) (both in force 1 January 2017); Amendments to the International Convention on the Safety of Life at Sea, 1974, IMO Res MSC.386(94) (21 November 2014, in force 1 January 2017); Amendments to MARPOL Annexes I, II, IV and V, IMO Res MEPC.265(68) (15 May 2014, in force 1 January 2017) [Polar Code].

13 SOLAS (n 10), Regulation 3(iii).

14 IMDG Code (n 12).

15 INF Code (n 12).

16 Polar Code (n 12).

17 For example, MARPOL (n 11); London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (London, 29 December 1972, in force

explores whether a FNPP can be alternatively classified as an artificial island, installation, or structure, and what the legal consequences are of that classification. Part 4 turns to the marine environmental protection obligations. Part 5 reviews applicable nuclear energy law. The technology is constantly evolving, and future FNPP designs or regulations may alter some of the conclusions reached here.

2 The Concept of FNPPS

International bodies are yet to reach a consensus definition of a FNPP. The IAEA in a 2013 publication defined a transportable nuclear power plant (TNPP) as a 'factory-manufactured, movable nuclear power plant that, when fuelled, can produce final energy products such as electricity and heat'.[18] The TNPP design has sub-categories which include FNPPS. Unlike conventional land-based plants which require on-site construction, an FNPP is built from start to finish in shipyards, using the same expert construction technology as on nuclear icebreakers and naval ships.[19] After undergoing the required testing, they are subsequently transported to the operation site.

The first FNPP in the world was constructed by the United States in the 1960s. The *Sturgis* was a conversion from the Liberty ship *Charles H. Cugle*, which entailed the removal of the propulsion plant and replacing the midsection of the original vessel, making it a barge.[20] Thereafter, it was towed to its operating location at the Panama Canal Zone.[21] The barge included the nuclear reactor and the components for the primary and secondary cooling systems as well as the electrical equipment required for the reactor to operate. The reactor operated at an overall capacity factor of 0.54 for a period of nine years. The Russian *Akademik Lomonosov* stands as the only operational FNPP worldwide illustrating some technical aspects of a FNPP. Nikitin and Andreyev described

30 August 1975, 1046 *UNTS* 120, and 1996 Protocol thereto (adopted 7 November 1996, in force 24 March 2006) [2006] ATS 11) [London Convention]; Convention for the Suppression of Unlawful Acts against the Safety of Maritime Navigation 1988 (Rome, 10 March 1988, in force 1 March 1992) 1678 *UNTS* 201.

18 IAEA, *Legal and Institutional Issues of Transportable Nuclear Power Plants: A Preliminary Study*, IAEA Nuclear Energy Series No. NG-T-3.5 (IAEA, Vienna, 2013).

19 Nuclear Energy Agency, *Small Modular Reactors: Challenges and Opportunities* (OECD Publishing, Pars, 2021).

20 HB Honerlah and BP Hearty, 'Characterization of the Nuclear Barge Sturgis' (WM'02 Conference, Tucson, AZ, 24–26 February 2002) available at http://www.archivedproceedings.econference.io/wmsym/2002/Proceedings/44/168.pdf; accessed 4 May 2024.

21 K-H Lee, M-G Kim, JI Lee and P-S Lee, 'Recent Advances in Ocean Nuclear Power Plants' (2015) 8 *Energies* 11470.

the Russian FNPP as resting on a 'flush-deck, flat-bottomed, non-self-propelled vessel of the berth-connected type'.[22] The *Akademik Lomonosov* has living quarters, work areas, service systems, automatic control systems, power systems, a bar, a gym, and a swimming pool for approximately 70 personnel on board. Each of the two KLT-40 reactors on board generates 35 megawatts of power, with an estimated capacity to supply electricity to a city of approximately 100,000 residents. The reactors have an operational lifespan of around twelve years. The construction cost of the *Akademik Lomonosov* was estimated to be approximately USD574 million upon completion.[23] Safety features of the FNPP include anti-flooding systems and anti-collision protection. Additional auxiliary structures on board include two steam turbine plants for electricity generation and heat production as part of the co-generation system.[24] There are also examples of various FNPP undergoing development.[25]

A fundamental characteristic of FNPPs is that they are non-self-propelled vessels, meaning they lack a propulsion system for independent movement. Rosatom contends that the absence of a propulsion system mitigates risks associated with failures of self-propulsion systems and mobility-related emergencies.[26] The transportation phase requires careful planning and execution to navigate several transportation modes, including roads, railways, and waterways. Upon arrival at their deployment site, which may be a port, FNPPs require specialised maritime infrastructure to facilitate mooring and operation. This includes the establishment of berths, which serve as dedicated docking areas for the FNPPs to secure themselves.

In addition to berths, docking facilities are essential components of the maritime infrastructure needed for FNPP deployment. These facilities provide access to support vessels, crew transfers, and logistical operations associated with the maintenance and servicing of the FNNP. Coastal protections are also part of the maritime infrastructure surrounding FNPP deployment locations.

22 A Nikitin and L Andreyev, 'Floating Nuclear Power Plants' (2011) 1 *Bellona* 6, 22.

23 P Lobner, 'Russia's Akademik Lomonosov – The First Modern Floating Nuclear Power Plant (FNPP)' (15 May 2021) 9, available at https://www.lynceans.org/wp-content/uploads/2021/05/Russia-Akademik-Lomonosov-FNPP-converted.pdf; accessed 4 May 2024.

24 *Ibid*.

25 For example, the Long Operating Cycle Simplified BWR (LSBWR) design of Toshiba Corp., Japan (100-300 MW(e)); the CNEA/INV AP CAREM-25 design from Argentina (27 MW(e)); the SMART (System-Integrated Modular Advanced Reactor) of the Republic of South Korea (90 MW(e)); Mitsubishi's (Japan) Integrated Modular Water Reactor (IMR) (300 MW(e)); and Russia's KLT-40S heat and power floating reactor unit (75 MW(e)).

26 Rosatom, 'Akademik Lomonosov Floating Nuclear Power Plant: Get the Facts' available at https://www.fnpp.info/get-the-facts; accessed 4 May 2024.

These protections may include seawalls, breakwaters, or other engineered structures designed to shield the FNPP and surrounding areas from adverse marine conditions, such as waves, currents, and storm surges.[27]

A third technical aspect of FNPP is the integration of storage facilities intended to accommodate both fresh and spent fuel assemblies. Fresh fuel is typically loaded into the reactor at the outset of its operation. As the reactor functions, spent fuel accumulates until it reaches the end of its operational lifespan, at which point it is towed back for refuelling. This represents a significant departure from traditional land-based reactors, where storage facilities are housed in separate structures. One advantage of the FNPP setup is that it reduces the frequency of transporting radioactive substances, thereby minimising the risks of radioactive release into the environment. Globally, an estimated 18–38 million radioactive packages are shipped annually, primarily for use by conventional nuclear power plants, contributing to potential environmental hazards.[28]

Finally, the electricity generated from the FNPP is transmitted ashore. The process of generating and transmitting electricity from a FNPP begins when enriched uranium undergoes nuclear fission. This reaction generates immense heat, which is transferred to the primary coolant system. The heated coolant then moves to the steam generators, where it converts water into steam. This high-pressure steam drives the steam turbines, causing them to spin and activate the attached turbogenerators, thereby generating electricity. Once generated, electricity is ready for transmission. Transmitting the electricity to the shore requires sophisticated infrastructure. High-voltage cables are laid on the seabed, connecting the FNPP to the onshore electrical grid. These cables are designed to endure the harsh marine environment, ensuring efficient and reliable transmission of electrical power. Upon reaching the shore, the electricity is routed through transformers, which step down the voltage to levels suitable for distribution to end-users. This transformation process is crucial, as it reduces the risk of electrical loss and makes the electricity safe for use in homes, businesses, and other applications. Aside from electricity, a FNPP also provides heat for district heating networks. A heat substation is constructed onshore to facilitate this transfer. It contains pumps for the intermediate

27 M Fialkoff, 'A New Offering for the Seaman Status Labyrinth–Seaman Status for Nuclear Reactor Operators on Floating Nuclear Power Plants' (2023) 47 *Tulane Maritime Law Journal* 3.

28 RA O'Sullivan, 'International Consensus for the Safe Transport of Radioactive Material: An Experience to Imitate Over the Past Decades, a Strong Record of Safety Has Been Built' (March 1988) 3 *IAEA Bulletin* 31, available at https://www.iaea.org/sites/default/files/30302543134.pdf; accessed 4 May 2024.

circuit, hot water circulator pumps, and water heaters of the FNNP. This substation ensures that the heat generated by the FNPP is effectively transferred to the onshore district heating system, providing a reliable source of heat for residential and commercial use.

The entry point into the legal analysis depends on the categorisation of a FNPP as either a vessel/ship or as an installation/structure. How a FNPP is categorised has consequences for the legal framework that law of the sea applies provides for the development and deployment of FNPP on the ocean.

3 A FNPP as a Ship or Vessel

For vessels and ships, the LOSC provides for freedom of navigation. But can a FNPP be classified as a 'ship' or 'vessel'? The LOSC does not define the terms 'ship' or 'vessel'. Historically, this absence of a definition was a deliberate choice. In 1955, the International Law Commission (ILC) deleted the proposed definition of a 'ship' from the drafts of the predecessor convention on the grounds that it would be too restrictive and could give rise to numerous conflicts.[29] Ironically, the very problem the ILC sought to avert seems to have materialised. With recent technological advancements, the lack of a clear definition for a 'ship' or 'vessel' in the LOSC represents a significant gap. The absence of a definition creates challenges in applying the well-established rights, duties, obligations of the Convention and related instruments to the FNPP. The clarification of the legal status of a FNPP as a ship or vessel rather than a mere object being towed is significant to determine applicable law, safety, environmental protection, and liability obligations, which are all crucial given the unique risks associated with nuclear technology in the maritime environment.

An Annex VII Arbitral was seized of the definitional issue in *The Arctic Sunrise Case*.[30] It did not positively define a 'ship' or 'vessel', but rather defined what may not be a 'ship' or 'vessel'. In the case, the *Arctic Sunrise* protested the development of oil in the Arctic, with particular reference to the *Prirazlomnoye* oilfield within the jurisdiction of Russia. The ship, along with those on board, was

29 A ship was defined as 'a device capable of traversing the sea, but not the air space, with the equipment and crew appropriate for the purpose for which it is used'. *Yearbook of the International Law Commission*, 1950, Vol. II (United Nations, New York, 1957) 38.

30 *The Arctic Sunrise Arbitration* (*Netherlands* v. *Russia*), Award on the Merits, 14 August 2015, PCA Case No. 2014-02, available at https://pca-cpa.org/en/cases/21/; accessed 9 October 2024; H Jessen, 'The Legal Understanding of the Terms "Ship" And "Vessel" Under the United Nations Convention on the Law of the Sea (UNCLOS)' (2021) 1 *Ascomare Yearbook on the Law of the Sea* 231.

arrested by the Russian authorities, after which the persons on board were charged with 'piracy'. A crucial aspect of the definition in Article 101 of the LOSC is that piracy must be directed 'against another ship'. The Tribunal held that the *Prirazlomnaya* was not a ship but a 'fixed platform'. This determination leaves open whether self-propulsion is a characteristic of a ship or not.

Some scholars contend that an FNPP can still be categorised as a ship or vessel.[31] Steding argues that the essential features in the definition of a vessel put forth by Professor Walker for the ILC align with the characteristics of a FNPP.[32] These features, which a FNPP such as the *Akademik Lomonosov* display, are the criteria of a barge designed to be portable and transportable in a marine environment, and that when moored and generating power, the barge serves as a floating—not fixed—platform for the reactors.[33] It remains, however, that the ILC definition relied upon never was accepted for the LOSC. The Law of the Sea Committee of the American Branch of the International Law Association has defined a ship as a 'self-propelled sea-going vessel used in international seaborne trade for the transport of goods, passengers, or both'.[34] This definition was influenced by the UN Convention on Conditions for Registration of Ships, which has not entered into force.[35] This would exclude FNPPs that are non-self-propelled barges towed by tugboats. In terms of State practice, it should be highlighted that the Russian authority has affirmed that the *Akademik Lomonosov* meets the construction standard of a ship notwithstanding its lack of self-propulsion.[36]

There is thus ground to assume that a FNPP can be classified as a ship or a vessel and to proceed with the analysis of the applicable law.

4 Freedom of Navigation and Its Limits

One of the most important features of a ship or vessel is that it is a means of 'navigation'. Additionally, related international instruments, such as the INF Code and IMDG Code, have strict specifications for the kind of vessel that can be used for the transportation of radioactive materials and packaging

31 Steding (n 9), at pp. 711–712.

32 See AE Kramer, 'The Nuclear Power Plant of the Future May be Floating Near Russia' (*The New York Times*, 2018); Honerlah and Hearty (n 20).

33 Steding (n 9), at pp. 711–712.

34 *Ibid*.

35 United Nations Convention on Conditions for Registration of Ships (Geneva, 7 February 1986, not in force) UNCTAD Doc TD/RS/CONF/19/Add.1 (7 August 1985).

36 Rosatom (n 26).

requirements (Chapter 1).[37] This may mean that the general freedom of navigation enjoyed by ships is limited when it comes to a FNPP.

Article 17 of the LOSC establishes the right of 'innocent passage' for all vessels traversing the territorial waters of coastal States. An 'innocent passage' is defined as a passage that does not jeopardise the 'peace, good order, or security of the coastal State'.[38] However, a precise definition for the phrase 'peace, good order, or security' does not exist. Coastal States may assert that the passage of FNPPs carrying spent or fresh nuclear fuel, with the potential to affect the marine environment and ecosystems through potential radioactive discharge or nuclear leakage, cannot be considered innocent. Similarly, a neighbouring State can also lay claims of potential transboundary effects against a coastal State that deploys FNPP in its territorial waters. Some critics have highlighted that the 'non-self-propelled' nature of FNPPs, thus requiring towage, presents additional environmental risks, especially in adverse weather conditions, including threats of terrorist attacks, maritime accidents, severe mechanical failures, explosions, or nuclear leaks during FNPP transportation.[39]

Nonetheless, several LOSC provisions indicate that a coastal State cannot unreasonably deny a vessel its right of innocent passage. For example, Article 19(2) outlines factors considered prejudicial to 'peace, good order, or security'. However, controversy arises with Article 19(2)(h), allowing a coastal State to deny a vessel innocent passage due to 'wilful and serious pollution'. Determining 'serious' pollution is problematic, particularly given the often invisible and long-lasting effects of radioactive pollution. Also, what constitutes 'wilful' pollution presents challenges, as it usually refers to motivation. Historically, radioactive releases have mostly been accidental and hardly 'wilful'. According to Roscini, 'wilfulness' refers not to the consequence of the conduct but to the conduct itself.[40] This suggests that FNPP passage should not be hampered solely based on potential environmental impacts but on actual harm caused by their operations. This poses a dilemma regarding the principle mandating precautionary measures to protect the marine environment, which is binding on all States under Part XII of the LOSC.[41] The LOSC limits the powers that a coastal State exercises over its territorial waters by providing that coastal States can only suspend 'temporarily' and not completely

37 INF Code (n 12), Chapter 1; IMDG Code (n 12), Part 1.

38 LOSC (n 1), Article 19.

39 See Iran's Note No. 641/1206 of 3 May 1995 addressed to the Embassy of the French Republic in Tehran' in UN, *Law of the Sea Bulletin* No. 221 (1996) 37.

40 M Roscini, 'The Navigational Rights of Nuclear Ships' (2002) 15 *Leiden Journal of International Law* 251.

41 ITLOS Advisory Opinion (n 2).

prevent the innocent passage of a vessel. Furthermore, the suspension of such passage would only take place where there is a security threat, and in those circumstances, such suspension must be duly published.[42]

Articles 22 and 23 explicitly address vessels transporting nuclear material, which makes those provisions the most applicable in this context. Article 23 reaffirms the principle of innocent passage for vessels navigating through the territorial sea and carrying nuclear materials and other hazardous substances. The only requirement for such passage is that the ship has appropriate 'documents' and 'observe special precautionary measures established for such ships by international agreements'. There is no reference to any specific 'special precautionary measures' and 'international agreements' in that provision. However, it is inferred that these agreements would encompass regulations set forth by international regulatory bodies such as IMO and the IAEA. Article 22 allows coastal States to designate specific sea lanes for nuclear-powered vessels and those carrying hazardous substances, including FNPPs and the towing of FNPPs, which raises concerns about safety standards. Given that FNPPs are towed by other vessels, increasing the risk of accidents, should safety standards for FNPPs be distinct and more stringent compared to those for self-propelled vessels?

The exclusive economic zone (EEZ) is an area not more than 200 nautical miles from the baselines from which the breadth of the territorial sea is measured.[43] Within the EEZ, all States have the right of navigation subject to the relevant provisions of the LOSC and other internationally lawful uses of the sea.[44] Coastal States are empowered to enact laws and regulations for the EEZ, provided such rules are 'compatible with the Convention and other international laws'.[45] If coastal States deploy FNPPs in the EEZ, this may require closing the areas where the FNPP is deployed to avoid collision with other vessels and to also provide it with the appropriate security from terrorist attacks. The process also ensures that there is a level of coordination in navigation.

Transport of FNPPs to date has not exceeded the national jurisdiction of a State. However, there are prospects for future international deployment of FNPPs which may involve traversing the high seas.[46] Every State has the

42 LOSC (n 1), Article 25.

43 *Ibid*., Article 57.

44 *Ibid*., Article 58(1).

45 *Ibid*., Article 58(3).

46 The rapid advancement of technology suggests that few possibilities can be dismissed, including the deployment of FNPPs in deeper waters like the high seas. First, FNPPs have been considered for their prospects in supporting sustainable maritime operations, such as deep-sea mining, ocean research, and offshore industries. An important feature of

freedom of using the high seas, including the freedom of navigation, as long as it is exercised under the conditions laid down in the LOSC and by other rules of international law.[47] Under Article 90 of the LOSC, when exercising the freedom of navigation on the high seas, a State sailing a ship must fly its flag. A question may arise in the international deployment of FNPPs, particularly when a supplier State is delivering a FNPP to the recipient's State. During transit, whose flag would be flown—that of the supplier State, the recipient State, or both? Also, in the event of damage occurring during transport on the high seas, who bears liability? Article 92 of the Convention addresses part of this puzzle by stating that a ship may not change its flag during a voyage or while in a port of call, except in cases of genuine ownership transfer or registry change. Typically, the supplier State would fly the flag of the FNPP during transit. However, this status may change if the parties agree to transfer ownership of the FNPP during transit. In such a scenario, the recipient State assumes ownership and bears the associated obligations and liabilities until the FNPP reaches its destination. Alternatively, the supplier and recipient State may agree to transfer ownership of the FNPP while it is still in the possession of the supplier State, allowing the recipient State to fly its flag during transit until it reaches its destination or place of deployment. In this case, the responsibilities and liabilities of the FNPP would rest with the recipient State. A more pragmatic approach might be that the supplier State commits to the delivery of the FNPP to the recipient State and fly its flag accordingly. In that situation, the supplier State takes responsibility in the event of any damage. However, once the FNPP is delivered and ownership is transferred to the recipient State, the supplier State would no longer bear liability for the FNPP. The allocation of flag usage and associated responsibilities during the international transit and deployment of FNPPs hinges on agreements between the supplier and recipient States regarding ownership, transfer, and flag usage, as guided by the provisions of the LOSC and relevant international law.

FNPPs is their flexibility and mobility, allowing them to be deployed for temporary or evolving projects where permanent infrastructure is impractical or too costly. This positions FNPPs as an ideal solution for nations seeking to address immediate or short-term energy needs, with the option to hire them for swift deployment as required. Also, the high seas offer a neutral space for States with limited access to coastal areas or those involved in contested maritime zones to tap into emerging nuclear technologies to meet their energy needs and achieve climate goals.

47 LOSC (n 1), Article 87(1).

5 Safety of Life at Sea

SOLAS promotes the safety of lives at sea. Like the LOSC, SOLAS does not define a ship or vessel, leading to similar definitional challenges explored above. SOLAS only applies to 'ships engaged on international voyages'.[48] This implies that FNPPs like the *Akademik Lomonosov*, deployed within the territorial waters of Russia, fall outside the scope of this treaty. If a FNPP is deployed internationally, Regulation 3 of SOLAS provides a list of ships exempted under the treaty, including ships 'not propelled by mechanical means'. This exemption means that SOLAS would not apply to a non-self-propelled FNPP deployed internationally.

Some scholars have advocated for an expansive interpretation to include FNPPs under SOLAS.[49] They argue that SOLAS is to be interpreted in accordance with the Vienna Convention on the Law of Treaties (VCLT), which mandates interpretation be conducted in 'good faith'.[50] They assert that FNPPs such as the *Akademik Lomonosov*, although not self-propelled by mechanical means, are propelled by mechanical means with the assistance of multiple tugboats.[51] This approach to interpretation raises significant concerns. First, for a FNPP to qualify as having 'propulsion', it would necessitate the presence of other vessels as FNPPs are immobile without tugboats and less manoeuvrable than conventional ships. Furthermore, according to the VCLT, treaty interpretation must align with the ordinary meaning of treaty terms, within the context of the treaty and its objectives and purposes. While there may be valid arguments for a broader interpretation under Article 59 of the LOSC to accommodate a FNPP, the same cannot be said of SOLAS. Unlike the LOSC, SOLAS explicitly excludes ships 'not propelled by mechanical means' from its scope.[52] By contrast, if any future FNPP development is designed to be self-propelled and deployed internationally, SOLAS will apply.

Three crucial instruments for the regulation of ships that have become integral components of SOLAS are the INF Code, the IMDG Code, and the Polar Code. Given that SOLAS does not apply to FNPPs, it follows that the Codes will not apply. If future FNPP developments include self-propulsion and SOLAS is

48 SOLAS (n 10), Chapter 1, Part A, Regulation 1(a).

49 See, for example, E Molinari, 'A New Vessel on the Block: How the Law of the Sea Applies to Floating Nuclear Power Plants' (Master's Thesis, UiT, The Arctic University of Norway, JUR 3910, 2020) 36.

50 Vienna Convention on the Law of Treaties (Vienna, 23 May 1969, in force 27 January 1980) 1155 *UNTS* 331, Article 31.

51 Molinari (n 49), at p. 33.

52 SOLAS (n 10), Chapter I, Regulation 3.

applicable, the issue that may arise would be the integration of spent nuclear fuel (SNF) storage in a FNPP. The INF Code addresses various cargoes specifically for the carriage of irradiated nuclear fuel (INF), which may exclude SNF.[53] Furthermore, in meeting the requirement for proper storage of dangerous goods to avoid any harm, the IMDG Code provides that the goods must be in 'packaged form'.[54] It remains unclear whether the SNF accumulated on a FNPP is stored in a manner that meets the definition of 'packaged form'. The Polar Code, just like the IMDG and the INF Codes, is also referred to in the SOLAS Convention through Chapter XIV. Regulation 2 of SOLAS states that the Polar Code applies to all ships operating in polar waters. It applies to ships certified in accordance with SOLAS, meaning that ships without mechanical means of propulsion are excluded.[55] FNPPs without self-propulsion are therefore not included in the mandatory parts of the Polar Code.

6 The International Convention for the Prevention of Pollution from Ships

MARPOL covers the prevention of pollution of the marine environment by ships from operational or accidental causes. Unlike the LOSC and SOLAS, MARPOL does define a 'ship'. Under Article 2(4), a ship is 'any type of vessel operating in the maritime environment, encompassing hydrofoil boats, air-cushion vehicles, submarines, floating craft, and fixed platforms'. FNPPs may well fall within this expansive definition, given the use of terms like 'vessel of any type' and 'floating craft' and even fixed platforms, presumably to maximise the protection of the marine environment from any pollution. However, it is still uncertain whether FNPPs can be classified as vessels due to their non-navigational design. As affirmed by Justice Breyer in *Lozman* v. *City of Riviera Beach*,[56] not every floating structure is a vessel. Furthermore, the fact that a FNPP does not supply power during transportation like most nuclear-powered ships, as well as the extended periods of permanent mooring at the sites until required for refuelling, defueling, or decommissioning procedures, further distinguish them from traditional vessels or ships. However, Annex III of MARPOL sets additional standards for applicability, as also outlined in Regulation 1 of SOLAS. Like the SOLAS Convention, MAROL Annex III

53 INF Code (n 12), Chapter 1.
54 IMDG Code (n 12), Regulation 1(3).
55 SOLAS (n 12), Chapter XIV, Regulation 2.
56 Lozman v. City of Riviera Beach, 568 U.S. 115 (2013).

Regulation 1 references the IMDG Code to define 'harmful substances' and 'packaged form'. In this context, 'harmful substances' align with those listed as IMDG Class 7 goods. The question is whether the SNF accumulated on FNPP will be stored in a manner that qualifies as 'packaged form'. These additional standards cast doubt on the applicability of MARPOL.

7 FNPPs as an Artificial Island, Installation or Structure

This part will discuss the classification of a FNPP as an artificial island, installation, or structure. The concepts of artificial islands, installations, and structures within the LOSC have been the subject of intense scrutiny for several years due to the lack of definition for these terms within the law of the sea. Under the LOSC, the terms are sometimes used together or interchangeably, suggesting that their meanings are not different by a wide margin.[57] Nevertheless, efforts have been made to define the terms in isolation. For instance, an artificial island could be gleaned through the definition of an 'island'. LOSC defines an 'island' as 'a naturally formed area of land, surrounded by water, which is above water at high tide'.[58] From this definition, it can be inferred that it is only the absence of the characteristic of natural formation that differentiates an artificial and a non-artificial island. Fitzpatrick defined artificial islands and installations as 'man-made, surrounded by water from all sides, above water at high tide, supposed to stay at a specific geographical location for a certain period, and which are stationary in their normal mode of operation at sea'.[59] Under Fitzpatrick's definition, artificial islands and installations are the same. While some scholars agree that an artificial island should meet certain criteria, which include non-natural formation, exposure of the water surface at high tide, and stability on the seabed, they however suggest that a technology would qualify as an artificial island, installation, or structure, depending on its positioning and certain characteristics.[60] They argue that artificial islands are normally associated with fixed structures of a permanent nature. On the other hand, installations or platforms, especially when of floating nature can be anchored to the seabed and their nature is considered more temporary

57 See LOSC (n 1), Articles 60, 80, 87(1)(d).

58 *Ibid*., Article 121(1).

59 C Fitzpatrick, 'Legal Issues of Ocean Cities' (19 March 2009) available at http://2100.org/w_oceancitieslegal.html; accessed 7 May 2024.

60 R Churchill, V Lowe and A Sander, *The Law of the Sea* (Manchester University Press, Manchester, 1999) 50–51.

nature. Thus, if the design technology of a FNPP involves permanent fixation on the seabed, it may be considered an 'artificial island'. On the other hand, if the design incorporates non-permanent fixation methods, such as breakwaters, the FNPP may fall under the classification of 'installations and structures'.[61] Professor Noyes' argument rests on a FNPP being equated to an installation or structure.[62]

While the classification of a FNPP as a 'ship' or 'vessel' primarily revolves around the right of navigation, the conversation shifts to jurisdiction when classified as an 'artificial island', 'installation', or 'structure'. The jurisdiction over installations or structures is contingent upon the marine zone in which they are situated. Although the LOSC does not explicitly grant coastal States the right to construct artificial islands or installations within their internal and territorial waters, the territorial sovereignty vested in these States over such areas unequivocally affirms the existence of this entitlement. Insights may be gleaned from Article 21 of the LOSC, which stipulates that coastal States may enact laws and regulations governing 'installations' within their territorial seas. However, such laws and regulations provided by coastal States must align with the Convention's provisions and 'other rules of international law'. Though the precise contours of 'other rules of international law' may elude definition, it is widely acknowledged that these rules encompass principles mandating coastal States to facilitate the innocent passage of foreign vessels through their territorial seas. While a coastal State retains the prerogative to temporarily suspend innocent passage, such action is permissible only under extraordinary circumstances and in the interest of 'security'.[63] One may argue that the deployment of a FNPP within the territorial sea could hamper the innocent passage of ships, as that would mean shutting off certain areas of the sea. However, coastal States possess the prerogative to designate specific sea lanes for navigation by other States and may opt for this approach in areas where FNPPs are deployed to ensure the preservation of navigational rights for other States.[64]

Article 56(1)(b) of the LOSC confers on the coastal State the right to establish artificial islands, installations, and structures in the EEZ. Article 60(1)(a)

61 *Ibid.*; Q Wang, Y Zhang and H Zhang, 'The Development of Floating Nuclear Power Platforms: Special Marine Environmental Risks, Existing Regulatory Dilemmas, and Potential Solutions' (2023) 15 *Sustainability* 3022.

62 GK Walker and JE Noyes, 'Definitions for the 1982 Law of the Sea Convention: Part II' (2003) 33 *California Western International Law Journal* 191–324.

63 LOSC (n 1), Article 25(3).

64 *Ibid.*, Article 22.

stipulates that the coastal State possesses the exclusive right to construct, authorise, and regulate the construction, operation, and utilisation of artificial islands, along with exclusive jurisdiction over them, particularly concerning customs, fiscal matters, health, safety, and immigration laws and regulations. These regulatory powers extend equally to installations and structures, albeit with the caveat that their construction and use are limited to purposes outlined in Article 56 and other economic activities. If the deployment of a FNPP is essential for electricity supply that boosts the economic activities of a State, it may be classified as an installation or structure. Where it cannot fall into that category, it may be more appropriate to classify it as an artificial island. If FNPPs are classified as artificial islands, installations, or structures rather than ships, coastal States deploying them would possess the authority to delineate safety zones within the EEZ. In determining the extent of the safety zone, coastal States are obligated to consider 'applicable international standards'. However, regarding safety zone issues related to FNPP deployment, there is a notable absence of 'applicable international standards' under the LOSC.[65] Given this deficiency in international standards and guidelines, granting coastal States discretion in deploying FNPPs may result in safety zones of varying breadth, potentially impeding navigation and other marine activities.[66] Furthermore, the deployment of FNPPs and the establishment of corresponding safety zones may impact coastal State jurisdiction. If the deploying State locates FNPPs within its coastal waters, regulatory challenges pertaining to these FNPPs would not arise. In instances of conflicts between the rights of the coastal State and those of other States, the resolution is guided by principles of 'equity' and consideration of all relevant circumstances, considering the significance of the interests involved, both for the Parties and the international community.[67] This could be further concretised through the LOSC mechanisms for dispute resolution.[68] According to Article 80, Article 60 applies *mutatis mutandis* to artificial islands, installations, and structures on the continental shelf. Article 60(3) requires due notice of construction of installations with requirements to not abandon such installations.

65 *Ibid*., Article 60.

66 Q Wang, H Zhang, J Huang and P Zhang, 'The Use of Alternative Fuels for Maritime Decarbonization: Special Marine Environmental Risks and Solutions from an International Law Perspective' (2022) 9 *Frontiers in Marine Science* 1082453.

67 LOSC (n 1), Article 59.

68 B Kwitatkowska, *The 200 Mile Exclusive Economic Zone in the New Law of the Sea* (Martinus Nijhoff, The Hague, 1989) 406.

8 Marine Environmental Obligations

Part XII of the LOSC sets out obligations on marine environment protecting for States considering FNPPs across jurisdictional lines, obligations which have become critical in the era of climate change. After the ITLOS 2024 Advisory Opinion, it is clear that two sets of obligations originate from Part XII. First, States ought to abate carbon emissions. Second, in so doing, they must protect and preserve the marine environment. Under the first obligation, States must deploy due diligence and best available technology. This standard is evolutive. It can comprise the duty to consider and develop and then deploy novel, alternative technologies to generate energy with low-carbon emissions. A FNPP is such a technology. In so doing, however, States must comply with the second obligation. Article 194 obligates States to prevent pollution of the marine environment through the introduction of energy or substances, which includes nuclear matter. Thus, States must also apply due diligence regarding the FNPP technology.

Procedurally, there must be an assessment of the environmental impact. Article 206 outlines what could be characterised as a 'pre-construction' obligation, mandating a State that has reasonable grounds to believe that planned activities under its jurisdiction or control may result in substantial pollution of or significant and harmful alteration to the marine environment assess the potential effects of those activities on the environment, to the extent practicable. The findings of such assessments are then required to be communicated to the relevant international organisation, which in turn should disseminate the results to all States.[69]

Further, the LOSC enjoins coastal States to maintain vigilant oversight over any activities they authorise or engage in and to discern their potential to detrimentally impact the marine environment. Complementing these imperatives regarding environmental monitoring and assessment, the LOSC mandates States, whether acting individually or collectively as circumstances dictate, to undertake all necessary measures to prevent, mitigate, and control pollution of the marine environment stemming from the utilisation of technologies falling within their jurisdiction or oversight.[70] These mandated measures encompass a spectrum of strategies aimed at mitigating pollution originating from all installations operating within the marine realm, regardless of their intended purpose. Among the measures specifically delineated are those aimed at accident prevention, emergency response protocols, the assurance of operational

69 LOSC (n 1), Article 129.
70 *Ibid.*, Article 196(1).

safety at sea, and the regulation of the design, construction, equipment, and crewing of such installations.[71]

There are prospects for deploying a FNPP on the high seas to alleviate congestion in territorial waters of coastal States. The high seas also afford some land-locked States access to have a share in offshore energy deployment. For FNPP deployment on the high seas, there may be a need to conduct an environmental impact assessment (EIA) under the recently concluded UN Agreement on Marine Biodiversity of Areas beyond National Jurisdiction (BBNJ Agreement).[72] This is particularly necessary due to the potential disruption of the high seas by FNPP deployments, which will require the installation of cables and other infrastructure. There is also the potential for the release of radioactive materials that could endanger the marine environment of the high seas and biodiversity. However, an EIA for a FNPP may not be required where such a deployment falls within any of the exceptions under the BBNJ Agreement.[73] An EIA is not required for a planned activity on the high seas if the State intending to deploy the FNPP states that the potential impacts of the FNPP deployment have already been assessed in line with the requirements of other relevant legal instruments or frameworks, or by relevant global, regional, subregional, or sectoral bodies.[74] Such legal instruments may include treaties, guidance or other standards of practice formulated by the IAEA and IMO.

9 Regulation of FNPPs under International Nuclear Energy Law

The discourse on FNPPs as an installation also warrants a nuanced exploration under the international nuclear regulatory framework, particularly concerning nuclear safety.

The LOSC does not address liability in the event of damage caused by the deployment of a FNPP. However, recourse may be had to existing nuclear liability conventions. There are essentially two international regimes for nuclear liability. On one hand, there is the 'Paris Regime', which applies to Member States of the Organisation for Economic Co-operation and Development (OECD) and may extend to other States only with the consent of all parties

71 *Ibid.*, Article 194(3)(d).

72 Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (New York, 19 June 2023, not in force) UN Doc A/CONF.232/2023/4* (19 June 2023) [BBNJ Agreement].

73 *Ibid.*, Article 29(4).

74 *Ibid.*, Article 29(4)(b).

involved. The Paris Regime consists of the Paris Convention[75] and the Brussels Supplementary Convention.[76] Subsequent protocols have amended both Conventions.[77] On the other hand, there is the 'Vienna Regime', which includes the Vienna Convention[78] and the Vienna Protocol.[79] These agreements were concluded under the auspices of the IAEA and are open to all Member States of the United Nations. However, for these conventions to apply, FNPPs must fall within 'nuclear installation' as defined by the Conventions.

Article 3 of the Convention on Nuclear Safety (CNS)[80] delineates the scope and application of the framework, focusing explicitly on 'nuclear installations'. Under Article 2(i), a nuclear installation is defined as any 'land-based civil nuclear power plant within its jurisdiction'. However, questions arise regarding whether this definition adequately encompasses FNPPs, as it is tailored specifically for 'land-based civil nuclear power plants'. This exclusion raises concerns regarding liability for nuclear damage resulting from FNPP activities, especially when the power plant serves both civilian and military purposes, blurring the line between their civilian and military applications. The phrase 'within its jurisdiction' further complicates any attempt to apply the CNS to non-land-based power plants. The expression underscores the challenges encountered when an FNPP traverses through or is stationed on the high seas, which is not under the jurisdiction of any State. If the interpretation of 'within its jurisdiction' does not pertain to the maritime zone being traversed but rather to the State responsible for the custody of the FNPP, it might be argued that the State designated as the flag State during the transportation of the FNPP will hold jurisdiction. In either scenario, ambiguity persists.

75 Convention on Third Party Liability in the Field of Nuclear Energy (Paris, 29 July 1960, in force 1 April 1968) 956 *UNTS* 251, as amended by the Additional Protocol (Paris, 28 January 1964, in force 1 April 1968) 956 *UNTS* 335; the 1982 Protocol (Paris, 16 November 1982, in force 7 October 1988) 1519 *UNTS* 329; and the 2004 Protocol (Paris, 12 February 2004, in force 1 January 2022) UNTC No. 13706 [Paris Convention].

76 Convention Supplementary to the Paris Convention of 29th July 1960 as Amended in 1964 and 1982 (Brussels, 31 January 1963, in force 4 December 1974) 1977 *UNTS* 358, as amended [Brussels Supplementary Convention].

77 The 2004 Protocol to the Paris Convention (n 75) improves the monetary compensation for nuclear liabilities; the 2004 Protocol to Amend the Brussels Supplementary Convention also came into force on 1 January 2022.

78 Vienna Convention on Civil Liability for Nuclear Damage (Vienna, 21 May 1963, in force 12 November 1977) 1063 *UNTS* 265.

79 Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage (Vienna, 12 September 1997, in force 4 October 2003) 2241 *UNTS* 270.

80 Convention on Nuclear Safety (Vienna, 20 September 1994, in force 24 October 1996) 1963 *UNTS* 293.

Some scholars have suggested adopting a far-sighted approach by allowing the definition of 'nuclear installations' under the CNS to evolve with societal and technological innovations.[81] Scholars rely on paragraph (viii) of the Preamble, which prioritises 'fundamental safety principles', rather than rigid international safety rules or procedures on nuclear. This provision underscores that safety guidelines, like all technical documents, can be subject to periodic updates to incorporate emerging technologies and address contemporary issues. The Preamble, specifically in paragraph (x), also conveys the drafters' intent not to confine the scope of the CNS solely to the matters specified in Article 3 and defined in Article 2(i). Instead, it signifies a willingness to consider the development of future instruments.

The drafters of the treaties governing the ocean could not have envisaged that technology would advance to the point where a nuclear power plant like a FNPP would be stationed at sea to supply energy. Aside from the fact that there is no international treaty that specifically addresses FNPPs, the international regulatory bodies, including IMO and the IAEA have yet to issue official guidelines for the regulation of this technology. In 2013, the IAEA published a report that explored TNPPs where various categories were subsumed under it.[82] However, a FNPP represents a unique design that was not comprehensively addressed in broader discussions on TNPPs. Moreover, the 2013 IAEA report remains largely theoretical, as operational FNPPs had not yet commenced operations, resulting in certain significant features being left out. It may then appear that the positioning of a FNPP may determine whether it is to be considered a ship with navigational rights or an installation. During transit or transportation from the supplier State to the receiver or host State, the FNPP may be deemed as a ship, with navigational rights, and in such circumstances, the nuclear liability conventions may not apply. Upon reaching its deployment destination, the FNPP may fall within the definition of a 'nuclear installation' under the liability conventions.

10 Conclusion

A FNPP is a novel low-carbon energy source that uses the ocean and addresses many concerns with conventional, land-based nuclear power plants. Part XII

81 R Tscherning, R Papastavridis and C Raetzke, 'Transportable Nuclear Power Plants: An Update on Regulatory Responses in International Nuclear Law' in C Raetzke (ed), *Nuclear Law in the EU and Beyond* (Nomos, Baden-Baden, 2014) 175–200.

82 IAEA 2013 (n 18).

of the LOSC sets out the overarching obligation on States to exercise due diligence to protect the marine environment through the exploration of this low-carbon technology, jointly and individually. At the same time, States must control any pollution of the marine environment by the technology through the release of radioactive substances. In this exercise, States Parties would be supported by the legal framework that the LOSC and the law of the sea more broadly provide. However, there is uncertainty around the qualification of this technology as either a vessel or an installation and the applicable set of rules. Further uncertainty arises because it is not clear which of the nuclear liability conventions applies. This article has sought to increase legal certainty on these issues.