Powering the North: the deployment of floating nuclear power plants in the High North to facilitate Arctic development

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Arctic communities face severe environmental and logistical challenges in meeting high energy demands driven by extreme temperatures and seasonal light variations. Historically, over 80% of these settlements have relied on fossil fuels—primarily coal and diesel—which generate substantial greenhouse gas emissions, severe black carbon deposition that accelerates ice melt, and dangerous particulate matter detrimental to human health. While intermittent renewables like wind and solar struggle against polar weather extremes and lack continuous base-load capacity, and conventional nuclear plants remain economically unviable for small populations, Floating Nuclear Power Plants (FNPPs) present a promising, scalable alternative. Exemplified by Russia's operational Akademik Lomonosov, FNPPs combine low-carbon base-load power and thermal heating with mobility, allowing them to be constructed in shipyards, towed to remote coastal locations, and relocated as needed. This technology offers a reliable power source for strategic economic development, resource extraction, and geostrategic locations such as Svalbard. However, their deployment introduces complex challenges regarding low-enriched uranium fuel management, facility security, Arctic communications, and governance. Furthermore, a critical regulatory gap persists at the intersection of international maritime and nuclear law regarding whether FNPPs constitute vessels or offshore industrial facilities. This paper examines the technical viability of FNPPs as a sustainable replacement for diesel, evaluates their role in Arctic geopolitics, and highlights the urgent need for a cohesive international legal and regulatory framework to ensure safe and transparent deployment.

Introduction

Due to their location and weather, Arctic communities require high levels of energy generation. For example, Longyearbyen, the world's most northerly town and main settlement of Svalbard, is located at 78.22^0 North, meaning that there is 24-hour light (midnight sun) for 141 days, and complete darkness (polar night) for 128 days (Torkildsen, 1984). Midnight sun and polar nights, although less, are also experienced in Pevek, one of the easternmost Arctic settlements in Russia, due to its location at 69.70^0 North. Each location also experiences severe cold – both settlements

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experience temperatures well below -20^{0}C in winter and contend with challenges associated with extremely low temperatures such as permafrost, freezing pipes travel disruptions and food security issues.

Such extremes in light and temperatures require greater than normal energy generation and consumption, for heating, lighting, cooling (to prevent permafrost melt around buildings). Given the location and conditions, the Arctic is a difficult location to generate energy. To date there have been limited options for such energy generation for the more than 4 million people that live in the Arctic, with more than 80% of Arctic communities depending exclusively on diesel fuel for energy generation (de Witt, Stenfánsson and Valfells, 2019). Until 2023, coal was used for power generation for Svalbard's Longyearbyen community. However, with the imminent closure of coal Mine No. 7 in 2025, in 2023 the Norwegian Government switched energy generation in Longyearbyen from coal to diesel (de Witt, Stenfánsson and Valfells, 2019).

Studies place the utilisation of diesel (as installed capacity) in the Arctic at between 75% and 80% (de Witt, Stenfánsson and Valfells (2019, p. 144). The burning of diesel for energy generation in the Arctic results in several sources of harm. Firstly, it emits greenhouse gases (GHGs), including carbon dioxide (CO_2), nitrous oxide (NO_2), and methane (CH_4) (NASA, 2024). An over-abundance of these gases potentiates the greenhouse effect of the atmosphere, trapping infrared radiation, which is absorbed by the GHGs and re-emitted to the earth's surface, causing warming of the planet and gradual increase in the Earth's average temperature (NASA, 2024), a phenomenon known as global warming.

Secondly, when burned diesel emits black carbon emissions, or soot, which results from the incomplete combustion of the fuel (Climate and Clean Air Coalition (CCAC), 2025). These emissions pose a huge threat to the Arctic as they pollute ordinarily white snow and glaciers with dark spots. In accordance with the ice-albedo feedback mechanism, the snow polluted with black carbon absorbs the light rather than reflecting it, exacerbating warming of the surface where the soot is concentrated, thus leading to greater melting and warming (CCAC, 2025). According to the UN's Climate and Clean Air Coalition initiative, even though the atmospheric lifetime of black carbon particles is only 4-12 days, black carbon has a warming impact of up to 1,509 times greater than CO_2 per unit of mass (CCAC, 2025).

Not to be dismissed, another significant effect of utilising diesel for Arctic energy generation is health impacts. The burning of diesel and the resultant soot generates emissions with fine particulate matter.[1] These particulates are extremely small, and upon entering the lungs the particles can penetrate deep into lung lobes and enter the bloodstream, causing associated cardiopulmonary disease, lung cancer and premature death (WHO, 2012; Pope, 2011, p. 1616). The WHO air quality guideline (AQG) (WHO, 2021) states that annual average concentrations of $PM_{2.5}$ should not exceed 5 $\mu g/m^3$, while 24-hour average exposures should not exceed 15 $\mu g/m^3$ more than 3-4 days per year. $PM_{2.5}$ readings for Pevek are not available, while currently $PM_{2.5}$ in Longyearbyen fluctuates, with summer cruise ships and other vessels contributing to fluctuating and often increased $PM_{2.5}$ levels above 15 $\mu g/m^3$ more than 3-4 days per year (Accuweather, 2025).

[1] This particulate matter is known as $PM_{2.5}$, a particulate matter of less than 2.5 micrometres of less in diameter.

However, the use of diesel is necessary, hence its continued and widespread use. Although its use has many disadvantages, as noted above, diesel provides what no renewable energy source can: the reliable generation of energy at predictable and stable frequency all year round, even in the coldest and darkest of winters. The switch from coal to diesel for energy generation on Svalbard in 2023, was undertaken for two main reasons. First was the imminent closure of the Island's last coal mine, meaning no more fuel would be available. The use of diesel ensures constant energy generation, backed up by batteries to ensure that short term power is still available in case of brief interruption to diesel generation (Longyearbyen Lokalstyre, 2020). By the far the greatest motivation for switching from coal to diesel was the reduction of greenhouse gas emissions, cutting electricity production CO_2 emissions by around 35,000 metric tons per annum and significant lowering of SO_2 and particulate air pollution (Longyearbyen Lokalstyre, 2020), The energy source chosen to replace diesel must be able to provide, at a minimum, the same energy generation capacity and reliability, with lower carbon emissions. This article demonstrates the capacity of FNPPs to achieve such capacity and reliability with few GHG emissions, making them the logical replacement for diesel electricity generation.

The Arctic region, and most notably the Russian Arctic, represents a critical frontier of strategic, geopolitical, and economic expansion. Encompassing vast coastal territories and severe polar environments, the High North is host to major industrial operations, crucial maritime routes such as the Northern Sea Route, and isolated coastal settlements (Humpert and Raspotnik, 2012). However, sustaining human presence, expanding communities, and extracting vast oil, gas, and mineral reserves in this environment depends entirely on continuous, uninterrupted power generation. Historically, energy generation across the Russian Arctic has relied heavily on fossil-fuel infrastructure, including coal, heavy fuel oil, and diesel generators, as well as terrestrial nuclear reactors (gen II primarily) (Enerdata2019).[2] Relying on imported fossil fuels introduces severe logistical vulnerabilities in inhospitable locations where supply lines are season dependent.

The adoption of lower carbon energy sources in the Arctic could alleviate much of the challenges associated with electricity and heat generation attributable to difficult geography, meteorologic conditions and technological limitations. Until recently, options for powering communities in the Arctic region have been limited to fossil fuels, although attempts have been made to deploy wind and solar power with varying degrees of success (Statkraft, 2019; de Witt, Stenfánsson, Valfells and Larsen, 2021; Russian International Affairs Council, 2021; Boute, 2016). To combat the use of hydrocarbons, renewable energy sources such as wind and solar can be deployed, but this has had limited success to date (Soliman-Hunter, 2026). An alternative fuel form is nuclear energy, however land-based conventional nuclear energy generation is exceptionally costly and confined to large communities, such as Murmansk. Therefore, for Arctic communities with generally low community populations, conventional nuclear power plants are limited by their economic viability. Thus, there is a need to explore alternatives to the deployment of renewable energy and conventional nuclear energy.

While renewable energy technologies like wind and solar are increasingly integrated into grid systems globally, their application in the Arctic faces profound physical and environmental

[2] Traditional land-based nuclear plants operating or historically operating in the Arctic, such as the Kola Nuclear Power Plant (using VVER pressurized water reactors) in Murmansk Oblast and the aging Bilibino Nuclear Power Plant.

limitations. Extreme seasonal variation extended polar nights, severe icing conditions, and unpredictable weather patterns mean that intermittent renewables cannot reliably satisfy the critical base-load energy demands of isolated polar communities and resource extraction facilities. Therefore, the transition toward low-carbon, non-renewable energy solutions that can provide dependable, continuous power without the physical constraints of weather-dependent renewables or the high carbon footprint of fossil fuels narrows the options considerably, with nuclear power, especially Small Modular Reactors (SMRs) integrated into floating platforms, stands out as the primary viable technology capable of fulfilling this role in remote coastal zones.

These floating nuclear power plants (FNPPs) offer an unprecedented combination of low-carbon base-load power and mobility. By mounting SMR technology onto flexible floating vessels, power and heat generation can be constructed at specialized shipyards and towed directly to high-priority Arctic locations. Once installed, an FNPP provides steady electrical power and thermal heating to replace obsolete land-based infrastructure. Furthermore, if local energy needs change or permanent onshore facilities are built, the unit can be relocated to support other coastal communities or resource hubs.

Such FNPP technology is no longer theoretical. In 2019 the Russian Federation demonstrated the commerciality of FNPP with the deployment of the world's only operating FPP Russia's eastern Arctic to replace aging infrastructure in Pevek. The vessel acts as a working prototype for a planned fleet of SMR-based floating installations. This initiative directly underpins broader state policy, including Russia's *2035 Arctic Strategy*, which targets massive economic development, resource extraction, and infrastructure expansion across the High North.

As the necessity to decarbonize Northern Arctic communities intensifies, there is a need to examine the applications of nuclear energy for power in the North, and how these applications should be regulated. This paper will examine the utility of utilising nuclear energy for northern communities as part of the energy transition, focusing on ship-based nuclear reactors for power generation in coastal communities. In considering the deployment of FNPPs for energy generation in the High North, this paper will focus on the Russian far North and the Norwegian-administered archipelago Svalbard, although this analysis is also applicable to other High North jurisdictions. The paper will examine the development and application floating nuclear power plant and consider the potential further deployment of such technology as a tool for powering the North and reducing climate impacts and health issues within these communities. In examining the deployment of FNPPs, this paper will identify areas of current law regulating FNPPs and identify areas requiring future legal development. The structure of this paper is as follows.

Floating nuclear power plants for energy generation: an overview

To understand the potential widescale application of FNPP in Arctic communities, it is essential to examine the definition, characteristics, application and uses of FNPPs. Therefore, what follows is an overview of the characteristics and uses of FNPP, future opportunities, and challenges in the deployment of FNPP. It is important to note that to date, only one FNPP, the *Akademik Lomonosov,* designed and built in the Russian Federation, is operational. Therefore, the discussion based on FNPPs in this study refer to the *Akademik Lomonosov,* which has been described as both a pilot project and a 'working prototype' for a future fleet of FNPPs and onshore installations based on Russian-made small modular reactors (SMRs) (World Nuclear News, 2023).

Characteristics and key uses of floating nuclear power plants

Flexibility in power generation

Perhaps the greatest value of the FNPP lies in its flexibility of deployment and power generation. As discussed below, the world's only FNPP, the *Akademik Lomonosov,* was originally to be deployed to a shipyard in Arkhangelsk Oblast in Russia's western Arctic and instead was deployed to an area of greater need, in Russia's eastern Arctic Region to replace ageing and inefficient energy generation infrastructure. Once permanent energy generation facilities are built in the far-east Arctic coastal communities, the *Akademik Lomonosov* can be relocated to other coastal communities where energy generation is needed.

This flexibility is essential to enable states to deploy this portable power generation in areas of high geopolitical importance. For example, Russia, has set out its Arctic ambitions in *On the fundamentals of the State policy of Russian Federation in the Arctic for the period up to 2035* (2035 Arctic Policy), and the *Russian Arctic Strategy to 2035* (2035 Arctic Strategy). (Russian Federation 2020a; Russian Federation, 2020b). Together these documents define the goals, strategies, directions, and tasks Russia will undertake to implement Russian ambitions for economic development in the Arctic region on the back of Arctic resource development, the expansion of the Northern Sea Route, and increased settlement in the Arctic Region. Without power generation, increased settlement in the Arctic region is difficult, since settlement in the High North is completely dependent on the generation of power.

Similarly, the Norwegian government sees the Arctic, especially the Svalbard Archipelago, as both geopolitically and economically important, given that 35% of Norway's mainland territory and 9% of its population are in the Arctic (Norwegian Ministry of Foreign Affairs, 2020), and significant oil, gas, fish, and mineral resources are located there. The Norwegian Government has established that the Arctic will 'continue to be Norway's most important area of strategic responsibility' (Norwegian Ministry of Foreign Affairs, 2020, p. 7). Therefore, Norway's approach to geopolitics has, and continues to be that of security, stability, and interest-based international cooperation (Norwegian Ministry of Foreign Affairs, 2020, p. 4) which requires the maintenance of existing Arctic communities, and the establishment of new communities where necessary (Norwegian Ministry of Foreign Affairs, 2020).

Fuel, refuelling, and waste management

A point of attraction for the Russian-designed FNPP is its reactors' fuel and refuelling capacity. The *Akademik Lomonosov* comprises two KLT-40S pressurized-water nuclear reactor units (PWRs), each with a capacity of 35MW, possess a core consisting of fuel assemblies, control rods and startup neutron sources (Atom Media, 2024). It utilises low-enriched uranium containing less than 20% of Uranium-235 as the nuclear fuel for its power generation, thereby largely allaying fears regarding nuclear weapon proliferation and vulnerabilities of the FNPPs to terrorist activities. The fuel cycle of such fuel requires refuelling every 3 to 5 years. Rosatom's fuel division TVEL notes that unlike land-based large reactors which require replacement of a proportion of their fuel rods every 12-18 months, its FNPP is refuelled 'once every few years and includes unloading of the entire reactor core and loading of fresh fuel into the reactor,' enabling longer periods between refuelling (World Nuclear News, 2023).

The *Akademik Lomonosov* is uniquely designed to allow refuelling without cessation of energy generation. In 2023 MSZJSC, Rosatom's fuel division, shipped replacement nuclear fuel for the *Akademik Lomonosov*. Reactor Unit 1 (starboard) was taken offline and refuelled in situ at the end of 2023, whilst reactor unit 2 remained operational. Reactor Unit 2 (port) was taken offline and refuelled in 2024, whilst reactor unit 1 remained operational (World Nuclear News, 2023). This is a significant attribute of this design, as it allows complete refuelling of the FNPPs two reactors with LEU whilst the plant remains insitu, operational, and energy generation continues. This is significant for Russian nuclear technologies and industry given Russia's establishment of the world-first LEU reserve in Angarsk in 2010 (IAEA, 2010).

Given the low enrichment of the uranium (less than 20% U_{235}) waste management is simpler, focussing on safe storage and disposal, given its relatively low levels of radiation. According to the IAEA, low enriched uranium (LEU) is a useful nuclear fuel as it does not deteriorate and can be safely stored for many years (IAEA, 2010). Once interim storage in water pools, designed to assist cooling and shield personnel and the environment from radiation, has occurred, it is possible to either dispose of the spent fuel through packaging and placing in a geological repository, or reprocessing to recover useable fuel at a nuclear fuel recycling facility. Such facilities are readily available globally, located in France, Russia, United Kingdom and Japan (World Nuclear Association, 2022).

The generation of nuclear waste from FNPP presents a conundrum. Whilst the deployment of nuclear energy generation clearly reduces the harmful impacts of diesel use for energy generation, the generation of nuclear waste also presents challenges. The generation and disposal of nuclear waste has been a contentious issue for communities, citing safety and security as the main concerns, however, a robust legal framework and management regime has been established and maintained through rigorous international frameworks. Such frameworks include the International Atomic Energy Agency (IAEA) Safety Standards, and the legally binding *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*. These conventions ensure that national strategies, regardless of fuel cycle choice, adhere to a unified, high-safety threshold.

Reduction in black carbon

Mitigation of the impacts of black carbon can only come from decreasing concentrations of black carbon in the lower atmosphere (Quinn et al., 2008, p. 16). The *Arctic Council* recognises the importance of reducing emissions of black carbon in both the Arctic and globally, since global emissions of black carbon pollute the Arctic through long-range transport. Kuhn et. al. opine that the application of technology can support sustainability, as global anthropogenic black carbon emissions could be reduced 70% below the 2010 level by 2030 if currently available technologies are utilised (Kühn et al., 2020, p. 5532). Quinn et. al. agrees, stating that a reduction in the concentration of black carbon can only be achieved through the reduction of within-Arctic emissions from energy generation, as well as control over marine transport (Quinn et al., 2008, p. 17). Moreover, if such mitigation strategies were implemented by Arctic Council member countries,[3] the reduction in black carbon emissions would be around 15% (EUA-BCA, 2021).

[3] Norway, Russia, USA, Canada, Iceland, Denmark (Greenland), Sweden and Finland.

Thus, there is an imperative to develop and implement non-hydrocarbon-based fuels in the Arctic regions to improve environmental and human outcomes in the region.

Although Russia utilises hydropower in some areas of the Arctic, new opportunities for hydropower energy generation in the Arctic are limited, and therefore choices for the generation of energy are limited, confined to fossil fuels with coal and diesel fuel dominating de Witt, Stenfánsson, Valfells and Larsen, 2021). Communities with access to abundant coal sources, such as Barentsburg in the Svalbard Archipelago and in the eastern Arctic the Syradasaysky coal deposit in Taimyr, utilise these coal deposits for energy generation (Tabachkova, Prosekpv and Sokolinskaya, 2020, p. 472). Without insitu coal deposits, energy generation in the Russian Arctic relies on either gas, or if absent, diesel fuel. Generally, in the short term, energy generation for increases in population and new settlements has been met with the use of diesel fuel. In the long term, the development of the Russian Arctic Zone (RAZ), as set out in the 2035 Arctic Strategy requires a shift to low carbon alternatives with the development and use of renewable and alternative energy sources, including floating nuclear thermal power plants (Russian Federation, 2020b, Art 9).

According to a study of sources of black carbon from four sites in the Russian Arctic during the period 2000-2016 (Vinogradova and Ivanova, 2023, p. 764),[4] all sites contributed anthropogenic black carbon in levels much higher than that associated with wildfires in the region (Vinogradova and Ivanova, 2023, p. 764). Furthermore, the study demonstrated that the Nenets Reserve and the adjacent Pechora Sea, where the giant Yamal gas fields and LNG processing trains are located, had the highest concentrations of black carbon emissions (Vinogradova and Ivanova, 2023, p. 764). Such contribution is only likely to increase, given further largescale development of gas resources in the Yamal and Gydan Peninsulas (Staalsen, 2021; High North News, 2025).[5]

The use of hydrocarbons in the Norwegian Arctic is location-dependant. Almost 100% of the Norwegian mainland's onshore energy generation is by hydropower (Norwegian Ministry of Justice, 2024, p. 65). This means that energy generation in mainland Arctic Norway is devoid of fossil fuels. This is not the case for Svalbard. Until 2023, coal was used for power generation for Svalbard's Longyearbyen community. However, with the imminent closure of coal Mine No. 7 in 2025, in 2023 the Norwegian Government switched energy generation for the Longyearbyen settlement from coal to diesel (Norwegian Ministry of Justice, 2024, p. 65). until a zero-carbon emissions replacement fuel for energy generation system can be established.

Challenges in the deployment of floating nuclear power plants

Security of facility

Security of any nuclear installation remains a challenge in the 21st century, with fears that uranium fuel will fall into the hands of non-state actors, to be used for weaponisation against domestic targets. However, the World Nuclear Association considers LEU (uranium comprising less than

[4] These sites were located on the Kola Peninsula, Arkhangelsk oblast, the Nenets and Gydan regions.

[5] For instance, in 2021 Yamal Nenets region produced 526.2 Bcm, and projected to increase to 639.9 Bcm in 2021. Several new projects are under development, including Novatek's Arctic LNG 2, Gazprom's Kharasaveyskoye and Gazprom Neft's Kamennomysskoye in the region contribute to increasing production. Even with sanctions gas production continues, with the Yamal LNG plant dispatching 287 LNG vessels in 2024. Europe remains the key market for the LNG with 227 of the 297 cargoes bound for Europe.

20% U-235) to be an 'indirect material' for the purpose of nuclear weapons, as it cannot be used to directly manufacture nuclear weapons (World Nuclear Association, 2023). This differs from highly enriched uranium, such as that found in military nuclear propulsion systems and containing more than 20% uranium, which is considered by the World Nuclear Association to be a direct use material, as it is used to make nuclear weapons. However, it should be noted that LEU waste can be used by rogue actors to make dirty bombs[6] capable of spreading nuclear radiation, thereby constituting a security threat. Therefore, all FNPP facilities require adequate securing, as discussed below.

Remote locations, extreme weather, and challenges in digital connectivity

The Arctic presents a challenge in establishing and maintaining communications, impacting on all efforts to generate electricity and mitigate CO_2 emissions. Atmospheric ionisation and scintillation cause disruptions to communications, including outages for significant periods (Yastrebova, Höyhtyä, Boumard, Lohan, and Ometov 2021). Extreme low temperatures also affect communications, causing atmospheric contraction, which can affect signal strength and clarity (Saunavaara, Kyilli and Salminen, 2021). Furthermore, low Earth angles due to polar tilt, particularly during the polar winter, can significantly affect communications (Saunavaara, Kyilli and Salminen, 2021). Without upgraded and significantly improved information and communications technology (ICT), digital capabilities necessary for navigation and signal-dependent communication will be significantly impacted.

In 2018, the Russian military established a new stationary satellite communication system was established in Anadyr to address such issues, ensuring secure and uninterrupted communication, even in temperatures of -40^0C, and at low angles due to polar tilt. Such deployment of new satellites and upgrading of telecommunications infrastructure will enable Arctic states to significantly enhance communication in this region (Naumova, Ivanova, Prischepa, Soshnev, and Fedyukovsky, 2015, pp. 1-7), which is likely to increase population and activities in the region, presenting an increased need for energy generation from low or no-carbon sources such as FNPPs.

It is important to realise that FNPPs have limitations in application. By their very nature (floating on water) FNPPs are confined to coastal, fjord and fluvial (including estuarine) communities. This means that inland arctic communities located away from fjords and large rivers are unable to utilise FNPPs. However, SMRs, the technology utilised for FNPPs, can be installed in land, thus filling the gap due to the limitations of FNPPs. One limitation of SMR technology is that such installations are more permanent in nature, and not moveable like FNPPs. In larger communities this may be suitable, however SMRs will not suit all communities. This is surmountable through the deployment of transportable SMRs, currently under consideration by the IAEA. These portable nuclear power plants also have legal challenges, as outlined in a 2013 study undertaken by the IAEA (IAEA, 2013).

The utilisation of SMRs, although outside the scope of this study, may, in many instances provide an appropriate, sustainable source of energy generation for some Arctic communities. Indeed, in

[6] According to the US Department of Health and Human Services, a dirty bomb is 'an explosive method of dispersion of radioactive and non-radioactive shrapnel and radioactive dust'. It is a weapon that combines conventional explosives with radioactive material, designed to scatter radioactive contamination over an area, rather than to explode a weapon with a nuclear warhead.

2013 the International Atomic Energy Commission (IAEA) studied nuclear power plants capable of transportation by rail, truck or barge, for a variety of uses including desalination, district heating, steam production for various industrial processes, or energy generation (IAEA, 2013), finding that in remote locations, although challenging such transportable reactors are useful. Further research into the application of SMRs to the High North is crucial for community development and environmental protection.

Deployment of floating nuclear power plants in the Far North

Large-scale nuclear energy for power generation in the European Arctic is utilised exclusively in Russia, such as the *Kola I Nuclear Power Plant* (KNPP) at Polyarnye Zori near Murmansk, which serves the energy needs of the civilian sector of the Murmansk Region's economy. Constructed in the early 1970s and 1980s, the KNPP is a Generation II VVER-440 pressurised water reactor which, although forcibly shut down in European Union countries, has had its life extended (Bellona, 1997). *Kola II Nuclear Power Plant* (K2NPP) will commence construction of two VVER-600 reactors from 2028, to expand nuclear energy generation in the region and to assume energy generation for the region after the closure of KNPP (Nuclear Engineering International, 2023). However, in smaller Arctic communities, there is a need for nimble, small-scale nuclear power that can respond to population growth, changes in economic activities, and shifts in energy generation needs.

Deployment of the Akademik Lomonosov

The Arctic remains the economic powerhouse of Russia. Although it comprises less than two percent of the population, the Russian economy is heavily reliant on the natural resources of the region. Therefore, in addressing its national interests in the region, Russia's *2035 Arctic Policy* incorporated the well-being for the population of the Arctic zone of the Russian Federation in addition to the development of the Russian Arctic as a strategic resource base and its rational use to accelerate the economic development of the Russian Federation (Russian Federation, 2020a).

The Russian *2035 Arctic Strategy* sets out the greater use of thermal nuclear power plants, including FNPPs (Russian Federation, 2020b, Art. 9). To this end, Russian state-owned nuclear company Rosatom developed the world's first floating nuclear power plant (FNPP) *Akademik Lomonosov,* which has been deployed for energy generation in Russia's eastern Arctic. Development of a FNPP in the Russian Federation commenced in began in 2000, when the Ministry for Atomic Energy of the Russian Federation was tasked with its development. On March 9, 2004, the Ministry for Atomic Energy of the Russian Federation was reorganized into the Federal Atomic Energy Agency (FAEA), which was transformed into the State Atomic Energy Corporation "Rosatom" in December 2007. The FAEA (and its successor Rosatom) selected Severodvinsk (Murmansk Oblast) for its construction, which was awarded to state-owned shipbuilder *Sevmash*. The keel was laid in April 2007, although construction of the *Akademik Lomonosov,* and all future FNPPs was transferred in August 2008 from *Sevmash* to the Baltic Shipyard in St Petersburg.

At an estimated cost of RUB6 billion (USD232 million), the hull of the *Akademik Lomonosov* was launched in July 2010. Its reactors, two KLT-40S pressurised water reactors whose design was derived from Russian icebreaker propulsion reactors, were delivered in May and August 2009 by

AtomEnergoProekt (AEP),[7] and installed in October 2013. Fuelling of the reactors was completed in October 2018, with Reactor Unit 1 commencing operation at 10% of capacity by December 2018 (Power Technology, 2021). Both reactors reached capacity in 2019, and *Rosenergoatom*, the operator of *Akademik Lomonosov*, secured a licence from *Rostechnadzor* (Russia's Federal Environmental, Industrial and Nuclear Supervision Service) to operate the FNPP for a period of ten years from June 2019 (Power Technology, 2021).

Soon after, the *Akademik Lomonosov* was towed to its permanent port of Pevek, connected to the isolated Chaun-Bilibino electricity grid in December 2019, and commenced energy generation in May 2020 (Power Technology, 2021). Although the *Akademik Lomonosov* was intended to be used to power the Sevmash shipyard, its deployment to Pevek instead was required due to delays in its availability for Sevmash (almost 10 years from hull completion to electrical generation). It was therefore sent to Pevek to replace the aging Bilibino nuclear power plant and the Chaunsk coal-fired power plant Rosatom, 2022). The Akademik Lomonosov today has the capacity to generate enough emissions-free electricity and heat for a city of 200,000 population (Power Technology, 2011) and therefore can easily meet the energy needs of the Pevek region's 50,000 inhabitants.

Rather than being an isolated deployment confined to Russia, increasingly both Russia and International Atomic Energy Agency (IAEA) member states are considering FNPPs to meet energy challenges such as electricity generation, desalination, and the production of hydrogen for use in synthetic fuels for the transportation sector (IAEA, 2023; Lyshenko, Bedenko, and Dalnoki-Veress, 2019, p. 62). Russia is keen to export its FNPP technology, and Rosatom will build and deploy several FNPPs (IAEA, 2023; Rosatom, 2025) with Rosatom is currently working on second generation floating power units – *Optimised Floating Power Units* (OFPUs), which are second generation FNPPs based on *Akademik Lomonosov* technology. The OFPUs, designed to be more compact and efficient than the *Akademik Lomonosov,* will be equipped with two icebreaker-based advanced RITM-200M reactors, and are designed for regions with limited access to electrical grids, experience power shortages or outages, and lack extended coastlines (IAEA, 2023).

Interest in Russia's development and use of FNPPs has come from several counties, including China, Denmark, South Korea, and India (IAEA, 2023), making the notion of deploying FNPPs for energy generation in coastal communities realistic. Indeed, the IAEA has undertaken several studies on FNPPs as part of its *INPRO Studies on Transportable Nuclear Power Plants* (TNPPs), as well as incorporating consideration of FNPPs into the Specific Safety Guide *Safety Demonstration of Innovative Technology in Nuclear Power Plants* (IAEA, 2016). It is expected that FNPPs will be an appropriate low carbon technology for coastal communities to consider both in the Arctic and beyond. However, it should also be noted that transportable terrestrial microreactors, such as the 5mw microreactor that will be deployed as a pilot program at Alaska's Eielson Air Force base early 2030s (Eison Airforce Base, 2026), may also prove to be practical for the generation of electricity and heat for smaller arctic communities.

The Scientific Forum *Nuclear Energy for Climate* notes that there are extraordinary benefits to be had with the use of FNPPs, including: continuous energy production for a period of 5-10 years; capacity to rapidly change power output; reduced CO2 emissions; construction in factory rather than onsite;

[7] *AtomEnergoProekt* is Rosatom's engineering division and designer of the generation III+ nuclear power reactor, based on Rosatom VVER technology.

capacity alteration based on client need possible (changing the number of power units on the operation site); operation site characteristics immaterial for operation; competitive in comparison to gas; and sustainable construction and decommissioning. Importantly, an additional benefit of FNPs is the ease of financing compared to standard reactors. This is because lenders have an asset that is moveable, therefore enabling the financier to recoup the asset and resell if necessary. This moveable asset is much more favourable than a fixed nuclear asset, which is unable to be moved and if finance is withdrawn, ultimately becomes stranded.

However, as there are many inland Arctic communities FNPPs are not suitable. In these instances, small modular reactors (SMRs) for deployment to remote terrestrial locations may be more appropriate to ensure sustainability of these communities. Russia is constructing its first land-based SMR in Yakutia, the coldest permanently inhabited region on earth, where temperatures fall to below -50^{0}C in winter. To be operated by Rosenergoatom, a subsidiary of government-owned Rosatom, the SMR will be a 55MW water-cooled RITM-200N reactor adapted from the RITM-200 reactor series used to power Russia's latest fleet of nuclear-powered icebreakers world (Nuclear News, 2024a). Projected to be operational by 2028, the facility will have a refuelling schedule of five years and enable the establishment of new industrial enterprises and social and transport infrastructure (World Nuclear News, 2024b).

Floating nuclear power plants for geopolitical stability – the case of Svalbard

There is also potential for the deployment of nuclear power in similar Arctic Communities that currently rely on diesel or coal for energy generation. Svalbard is one such example. Climate-induced energy vulnerabilities in the Arctic are well recognised, with power outages have serious ramifications, particularly the polar nights and the Svalbard winter (Nygaard, 2024). To address such energy insecurity and support the planned transition to low-carbon energy generation for the community has prompted the installation of a battery system in 2020 (Enova, n.d.). Six 20-foot container batteries, with a combined capacity of six megawatts, provide energy security during the transition to emissions-free energy generation in Svalbard (Jonassen, 2022). However this is recognised as a support system, not a primary energy generation system.

To alleviate energy insecurity and ensure sustainability in energy generation at Longyearbyen, the Norwegian government has assessed many forms of energy generation. Modelling demonstrates that Longyearbyen has the potential for sustainable energy sources, particularly renewable energy generation, with wind and solar energy both complementary and critical contributors (Ringkjøb, Haugen, and Nybø, 2020). Furthermore, the researchers note that the potential of harnessing wind and solar in Arctic locations is significant, and when combined, the complementary properties of each energy source are beneficial (Ringkjøb, Haugen, and Nybø, 2020). Installed capacities that also incorporate imported hydrogen could significantly reduce system costs, increase robustness, and system reliability whilst still maintaining major reductions in hydrocarbons emissions (Ringkjøb, Haugen, and Nybø, 2020). Thus, even in areas with high and variable wind, snow drifts and permafrost, wind and solar energy may be deployed.

However, it is also recognised that wind energy generation in Arctic climes pose special and recognised challenges. The IEA notes that special technologies will be required for wind power in cold climates, including ice protection for turbines, low temperature adaptations, adapted control systems for operating in icing conditions, and safety for ice shedding from blades (International

Energy Agency Wind Task 19, 2016). Such modifications are at the technical development stage. Meanwhile FNPP has demonstrable applications in coastal Arctic communities.

For Longyearbyen, Svalbard's main settlement, FNPP deployment is logical, given the harbour-energy generation plant proximity and depth of harbour. Its deployment could provide reliable and low carbon power whilst significantly reducing both CO_2 and black carbon emissions. Indeed, the CEO of Norsk Kjernekraft, the power company supplying energy generation to Longyearbyen, notes that 'now that the coal-fired power plant in Longyearbyen has been closed, nuclear power is the only long-term solution to maintain energy security without using fossil fuels' (World Nuclear News, 2025). Only a few years ago the technology available for the deployment of an FNPP on Svalbard would have been confined to Russia's second generation RITM-200N FNPP. However, interest in FNPPs by private entities and the IAEA has firmly placed reactor and vessel development at the forefront, with companies such as MODEC seeking to bring FNPPs and AI together in coastal waters to solve energy issues for AI facilities (MODEC, 2026). Crucially, the IAEA's new *Atomic Technologies Licenced for Applications at Sea* (ATLAS) initiative, which advocates the peaceful use of marine nuclear technologies (FNPPs and nuclear propulsion), shall create a framework for civilian applications of FNPP outside of the Arctic and independent of Russian technology (IAEA, 2026). Such a framework, once established, will ensure that FNPP technology is accepted as mainstream, and encourage the use of FNPP in Arctic communities.

Onshore nuclear energy generation is also being considered for Longyearbyen, with an assessment program for the construction of a small modular reactor (SMR) power plant by a consortium of Swedish lead-cooled SMR technology developer Blykalla and Norwegian nuclear project developer Norsk Kjernekraft, who have established the joint project company, Svalbard Kjernekraft AS for this project (World Nuclear News, 2025). However, given this paper's focus on FNPPs, SMR deployment on Svalbard is outside the scope of this paper.

Regulating FNPPs: a black hole?

Is a FNPP a vessel/ship?

To assess both international and international law relating to FNPPs, it is necessary to determine whether it is a vessel or a ship. In the *United Nations Convention on the Law of the Sea* (UNCLOS) the word 'ship' is not defined. However, according to McKenzie, its plain meaning is conducive to broad interpretation, and as a generic term it can refer to a wide range of devices, from large commercial container ships to much smaller sailing vessels (McKenzie, 2020, pp. 12-13). According to Art. 1(b) of the *International Convention on Salvage 1989* a vessel is defined as 'any ship or craft or any structure capable of navigation.' Under Art. 2(4) of the *International Convention for the Prevention of Pollution from Ships* (MARPOL), a ship is defined as 'a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms' (Kirkin, 2025).

The Scientific and Engineering Centre for Nuclear and Radiation Safety of the *Russian Federal Environmental, Industrial and Nuclear Supervision Service* (Rostechnadzor) defines a FNPP as *a vessel or other floating craft (propelled or non-self-propelled floating structure), designed for energy generation using nuclear reactor(s), which also houses complexes for performing its functions and ensuring safe operation provided by design* (Kirkin, 2025). This comprehensive definition of FNPPs incorporates the use of the term 'vessel'. This is critical since the application of legal instruments will rest on whether the FNPP is a vessel

or not. In addition, the design and propulsion of the vessel, equally defining as a vessel that is either propelled on non-self-propelled, is important in both international and domestic law.

It can be seen in international law and practice that there are other, analogous examples of non-powered barges deemed ships or vessels. Such examples include floating storage and regasification units (FSRUs) for recipient port LNG storage and regasification, floating production, storage and offtake vessels (FPSOs) used in the production of petroleum, and a floating liquified natural gas (FLNG) vessel, which is a vessel that produces, liquefies, stores, and transfers natural gas at sea. What each of these vessels have in common is that they may or may not have a system of propulsion and are moored for long periods where they do not act as vessels, but rather take on the role of a production, storage or processing facility. As Polemis and Boviatsis note, with the current rapid development of the FLNG industry, 'the regulatory framework has to follow the rapidly growing new technological advances in the field, thus making it almost impossible to arrive at a definitive legal characterisation of this group of floating ships' (Polemis and Boviatsis, pp. 4660-4662). Such lack of definitive characterisation can be applied to FPSOs, FLNGs, and of course FNPPs.

International law regulating FNPPs

There are several international law instruments and issues that require consideration in the deployment of FNPPs. International instruments include the *United Nations Convention on the Law of the Sea* (UNCLOS) 1984, the *Treaty on the Non-Proliferation of Nuclear Weapons* (NPT) 1968; and the *Convention on Long-range Transboundary Air Pollution* (CLTAP) 1979. Another general convention is the *International Convention for the Safety of Life at Sea* (SOLAS) 1974, however it does not cover FNPPs as SOLAS only applies to self-propelled vessels (Röben, 2025, p. 13). The 1962 *Brussels Convention on the Liability of Operators of Nuclear Ships* addresses civil liability but is yet to enter into force.

Given the polar location of the operation of FNPPs, there is a requirement to consider the international law instruments that pertain to either the geographical location (the Arctic), or the source (nuclear vessel). Therefore, it is essential that *UNCLOS Art. 234* is observed when deploying nuclear vessels. In the Arctic environ, specialised IMO Codes are critical. Firstly, *IMO Resolution A.491(XII) Code of Safety for Nuclear Merchant Ships* is relevant for FNPPs. However, there is a question as to whether this instrument applies to FNPPs, given they are not merchant vessels. Polemis and Boviatsis contend that a practical way to deal with FNPPs is to deal classify FNPPs as merchant vessels, ensuring the Resolution applies (Polemis and Boviatsis, 2023, p. 4663). Similarly, the design of the FNPP, which will be acting as a vessel when towed to its location of operation, and its use in Arctic locations means that the requisite requirements of the *IMO Polar Code* must be incorporated into the vessel design to ensure human safety and the protection of marine and terrestrial environments and communities.

It is recognised that there remains much to be done in international law to a comprehensive framework for FNPPs and TNPPs in the future, particularly encompassing the areas of nuclear proliferation safeguards, installation security, security, and liability, which are outside the scope of this study.

Laws regulating Akademik Lomonosov

The advent of the *Akademik Lomonosov*, like all breakthrough technologies, require appropriate legal regulations. The question with new technologies is whether the existing legal framework extends

to the new technologies, reforms to the existing legal framework are required, or whether new laws need to be established. In the case of the *Akademik Lomonosov,* Lysenko et. al. note that once constructed, the FNPP was transported to its destination within Russian territorial seas, on a route often used by vessels traversing the Northern Sea Route (NSR). Given how widely the NSR is utilised by Russian icebreaker vessels, the Russian domestic legislation for nuclear vessels is well advanced (Lyshenko, Bedenko and Dalnoki-Veress, 2019, p.62). Furthermore, Lyshenko et. al. deduces that 'no collisions with the rules of international laws are expected', although advise that a federal law implementing the *1963 Convention on the Civil Liability for Nuclear Damage* (which Russia has ratified but is yet to implement into domestic law) is required.

Domestic regulation of FNPPS occurs under two areas. First are the federal rules and regulations pertaining to atomic energy use.[8] This are based on principles established in IAEA documents and considerations of the provisions of the IMO's 1981 'Nuclear Code': IMO Resolution A.491(XII) (Kirkin, Sviridov and Sinegrobov, 2025). These include general safety provisions, specialised nuclear safety provisions, requirements for the content and structure of Safety Analysis Reports, requirements for planning measures for actions and protection of personnel in radiation and nuclear accidents, security and safety requirements during decommissioning, and rules for the design and safe operation of equipment and pipelines of FNPPs (Kirkin, Sviridov and Sinegrobov, 2025). Secondly, laws developed under Russia's *Merchant Shipping Code,* and based on the 1981 Nuclear Shipping Code and international maritime conventions are applied to the Akademik Lomonosov (Kirkin, Sviridov and Sinegrobov, 2025). These include rules for the classification and constriction of nuclear vessels floating facilities and nuclear support vessels, and rules for technical supervision on nuclear vessels (Kirkin, Sviridov and Sinegrobov, 2025).

Supply state vs recipient state – regulating operational capacity

Due to the mobile nature of FNPPs, there are challenges in regulating their location and activities. Often an energy generating asset, such as a wind turbine, will have component parts manufactured in one country (the supply country), then supplied to another country (recipient state) where it will be constructed insitu according to the legal and technical requirements of the recipient state. At present, the full construction of an FNPP is undertaken in a supply state and, upon completion, will be shipped to the recipient state for operation. In some states, these FPSOs are deemed to be a vessel when moving (either by its own steam or that of another vessel) to its site of operation, and then categorised as an offshore industry unit, such as in Australian Commonwealth offshore waters.[9]

Regulatory Uniformity – design, construction and survey of FNPP vessels

The issue of supply state versus recipient state law and regulation should not be difficult to overcome given the plethora of examples that have preceded FNPPs, including merchant ships and oil tankers that move from port to port throughout the world. These vessels are designed with universal and to operate in multiple jurisdictions. This would certainly require the IMO to establish acceptable codes. IMO instruments for the construction of vessels, such as the IMO regulations

[8] *Federal Law No. 170-FZ of 21 November 21, 1995, On the Use of Atomic Energy*

[9] Commonwealth offshore waters' jurisdictions are from 3nm seaward to 200 nm. See *Navigation Act 1912* (Cth), Marine Order 47 (Offshore Industry Units).

for the requirements for the cargo area of oil tankers,[10] establish clear requirements for the construction of a vessel carrying oil as cargo.

Similarly, such a standard is required for FNPPs moving forward. Whilst the IMO is yet to implement a standard for FNPPs, Russian experts have identified that FNPPs designed for export need to consider the legislation of the country of origin and that of the host country, as well as interested third-party states Romanova and Handrlica, 2019, p. 195). Although not directly applicable since a FNPP is not a merchant vessel, *IMO Resolution A.491(XII)* nevertheless establishes uniformity in design criteria and conditions, and ship design and construction that is pertinent for the construction of FNPPs that by establishing standards will not only enable the FNPP to operate outside of the supply state, but to do so in a manner that is safe for human and marine life. Although not binding in international law, the American Bureau of Shipping (ABS) has developed the first set of international rules FNPPs. This standard covers the design, construction, and survey of vessels (ABS, 2024, p. ii)[11] fitted with nuclear power generation systems which are transferred or distributed to onboard industrial or adjacent facilities while *temporarily* or *permanently* stationed (ABS, 2024, p. ii).

Conclusion

The urgency of transitioning Arctic communities away from high-impact fossil fuels is one of immediate necessity. This paper has established that the heavy reliance on diesel fuel, while historically necessary, constitutes an environmentally and socially unsustainable practice that actively undermines the principles of intergenerational equity and sustainable development in the Arctic. Diesel combustion not only contributes to global climate change through GHG emissions but also accelerates the localized catastrophe of ice melt via high concentrations of black carbon. Furthermore, the fine particulate matter resulting from the combustion of diesel for energy generation poses severe, quantifiable health risks to residents of communities like Longyearbyen, compromising the social pillar of sustainable development.

Given the unique geographical and atmospheric extremes of the Arctic, including the challenges presented by polar nights, permafrost, and the limitations of conventional renewable technologies, the deployment of scalable, reliable, and lower-carbon energy alternative is paramount. The consideration of FNPPs, exemplified by Russia's *Akademik Lomonosov*, reveals a potential strategic solution. The flexibility and portability of FNPPs address the logistical difficulties of powering small, remote coastal settlements that are crucial for geopolitical and economic development in the European Arctic.

Ultimately, the technical feasibility of FNPPs as an alternative to hydrocarbons needs to be reconciled with the international law requirements and a need for robust regulatory governance. This analysis suggests that while the technology offers a pathway to energy security and sustainability for Arctic communities, its deployment cannot proceed without a clear, internationally coordinated framework. Therefore, subsequent research must address the critical task of identifying and developing the international legal architecture necessary to effectively

[10] IMO, *MARPOL Convention, Annex 1 Regulation for the prevention of Pollution by Oil, Chapter 4 – Requirements for the Cargo Areas of Oil Tankers* 1996.
[11] Under the American Bureau of Shipping standard, the term 'vessel' includes ships, barges, offshore units, and installations., ii.

regulate the safe, transparent, and sustainable deployment of FNPPs to ensure that this technology serves as a tool for improved sustainability and intergenerational equity rather than a source of new risks in the fragile Arctic environment.

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