Readiness of International

Legal Instruments to Regulate SMRs

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**Abstract**

There is a new wave of interest in generating nuclear power using SMRs. The effectiveness and appropriateness of current international legally binding instruments to regulate Small Modular Reactors (SMRs) need to be assessed and validated. There seem to be diverse views that international legally binding instruments are not ready to regulate and control SMRs. It is, therefore, a challenge that needs to be investigated and this study aims to unpack that. The purpose is to find and analyze the compatibility and effectiveness of international legally binding instruments in controlling SMRs. The authors will systematically study the identified international legally binding instruments under the auspices of the IAEA in the areas of safety, security, safeguards and nuclear liability, and highlight areas of alliance of sustainability to control SMRs. All the findings will be listed, and all the gaps will be identified. The analysis of international legally binding instruments is used to identify shortfalls and gaps and correct them to effectively regulate and ensure safety and security during the operational life of an SMR. This conclusion aims to show all the gaps identified by the analysis methodologies and propose possible solutions and amendments to become effective and compatible with SMRs.

## INTRODUCTION

The demand for nuclear electricity production has been escalating through the years. This contributed significantly to the demand to develop low-carbon technologies such as Small Modular Reactors (SMRs), which is also increasing. Currently, more than 80 SMR designs are being developed around the world. SMRs can be land-based, which are almost similar to the current nuclear power plants or can comprise of the factory fuelled reactor modules to be used, reactor modules and any constitutive module to be sent to a decommissioning facility at the end of reactor lifetime and reactor module to be sent to a dedicated facility to be replenished or refuelled.[[1]](#footnote-2)

SMRs are defined as “advanced nuclear reactors that have a power capacity of up to 300 MW(e) per unit, which is about one-third of the generating capacity of traditional nuclear power reactors. SMRs, which can produce a large amount of low-carbon electricity, are **Small** – physically a fraction of the size of a conventional nuclear power reactor. **Modular –**making it possible for systems and components to be factory-assembled and transported as a unit to a location for installation and multiple modules can be added at the same site. **Reactors –**harnessing nuclear fission to generate heat to produce energy.” According to the SMR Regulators’ Forum SMRs are defined as follows: “Small Modular Reactors typically have several of these features: nuclear reactors typically designed for commercial use, i.e., electricity, production, desalination, process heat (as opposed to research and test reactors); designed to allow addition of multiple reactors near the same infrastructure (modular reactors); may be light or non-light water cooled; and use novel designs that have not been widely analyzed or licensed by regulators.”[[2]](#footnote-3) SMR is similar to a large nuclear power plant[[3]](#footnote-4), it has an output of over 1000 MWe and can produce 24 000 000 kWh per day.[[4]](#footnote-5) Additionally, compared to nuclear power plants, SMRs require less space and less water for cooling and are more flexible regarding site selection.[[5]](#footnote-6)

SMRs have various uses, such as power generation, water desalination, process heat, and other industrial uses. In addition to water as a coolant, they can use other non-light water coolants, such as molten salt, gas, or liquid metal.

According to the IAEA, "In comparison to existing reactors, proposed SMR designs are generally simpler, and the safety concept for SMRs often relies more on passive systems and inherent safety characteristics of the reactor, such as low power and operating pressure. In such cases, no human intervention, external power, or force is required to shut down systems because passive systems rely on physical phenomena, such as natural circulation, convection, gravity, and self-pressurization. These increased safety margins, in some cases, eliminate or significantly lower the potential for unsafe releases of radioactivity to the environment and the public in case of an accident.”[[6]](#footnote-7)

Efforts have been made to achieve the Sustainable Development Goals (SDG,) the target of universal access to energy, in this case, clean energy. However, there are still gaps to be filled. Such gaps range from the legislative and regulatory infrastructures of SMRs. There is currently, a deployed floating nuclear power plant (FNPP) which is a commercial nuclear power plant operationalized in May 2020 in the Russian Federation.

There are diverse views that international legally binding instruments under the auspices of the IAEA are not ready to regulate and control SMRs. Therefore, the research will analyze these instruments, their compatibility, and their effectiveness in regulating and controlling SMRs irrespective of the risk and quantity of nuclear material involved, especially the SMRs being commissioned in floating nuclear power plants.

## LEGALLY BINDING INSTRUMENTS UNDER THE AUSPICES OF THE IAEA

Various Conventions (legally binding instruments) are adopted under the auspices of the IAEA. The IAEA has quite several instruments. This part of the paper will dwell on legally binding instruments for safety, security, safeguards, and nuclear civil liability. They are analyzed individually with their application to SMRs, particularly floating nuclear power plants (FNPPs).

### Safety

### Convention on Early Notification of a Nuclear Accident applies in the event of any accident involving facilities or activities of a State or of persons or legal entities under its jurisdiction, from which a release of radioactive material occurs or is likely to occur and which has resulted or may result in an international transboundary release that could be of radiological safety significance to another State.[[7]](#footnote-8)Under this Convention, a State Party where the accident occurs is obligated to directly inform the IAEA or another State or another State that may be affected in the event of a nuclear accident.[[8]](#footnote-9) By doing so, the informing State must provide full details of the accident, such as its nature, the time of its occurrence, and the exact location of the accident.[[9]](#footnote-10) The IAEA also has the obligations under this Convention to inform State Parties, Member States and Other States that may be physically affected, as well as other relevant international organizations, to promptly provide any State Party, Member State, and any other applicable international organization with information it has received from the affected State;[[10]](#footnote-11) It is also required to maintain an up-to-date list of national authorities and points of contact, as well as points of contact of relevant international organizations.[[11]](#footnote-12) Further, the Convention made provisions for other nuclear accidents not covered in Article 1, which are believed to cause radiological consequences.[[12]](#footnote-13) By analyzing the provisions of Articles 1 and 3 of the Convention, SMRs are also included irrespective of where the nuclear accident occurred because it is also a nuclear reactor, and the difference between the usual nuclear reactor is that it is smaller in size and offers more flexible benefits than the larger nuclear reactor. This ought to be interpreted as FNPP operating in international waters are covered by the Convention. Although FNNP will be regulated at least by the constructing State and also by the receiving or host State. There will be challenges ranging from regulation, reporting of accidents, and licensing of the operator to operate in international waters, as there is no regulatory body to regulate such FNPPs. The IAEA has no mandate to regulate nuclear activities but “to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world”[[13]](#footnote-14)

### The Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency encourages the cooperation of the State Parties between themselves and the IAEA to facilitate prompt response or assistance in the event of a nuclear accident or radiological emergency, minimize the consequences, and protect life, property, and the environment from the effects of radioactive releases.[[14]](#footnote-15) The Convention generally covers all SMRs and will apply similarly to the Convention on Early Notification of a Nuclear Accident. However, FNPP in international waters are not covered.

The Convention on Nuclear Safety is the first legally binding international instrument that addresses the safety of nuclear installations and seeks to ensure that nuclear installations are operated in a safe, well-regulated, and environmentally sound manner.[[15]](#footnote-16)To determine if the Convention applies to SMRs, the definition of "nuclear installation" must be first explored. According to the Convention of Nuclear Safety, ‘"nuclear installation" means for each Contracting Party **any land-based civil nuclear power plant** under its jurisdiction including such storage, handling and treatment facilities for radioactive materials as are on the same site and are directly related to the operation of the nuclear power plant. Such a plant ceases to be a nuclear installation when all nuclear fuel elements have been removed permanently from the reactor core and have been stored safely in accordance with approved procedures, and a decommissioning programme has been agreed to by the regulatory body.’ The term “land-based” means “‘activities on land’, ‘earthbound activities’”[[16]](#footnote-17). For an SMR to be considered under this Convention, it has to be on a land-based nuclear power plant. For instance, if a vessel or ship using an SMR is anchored, then the Convention applies; however, if the vessel/ship is not anchored, then the Convention does not apply.[[17]](#footnote-18) If the SMR is being used for research purposes, the Convention does not apply to research reactors.

Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management is the first legally binding international instrument in the areas of spent fuel and radioactive waste management. The objectives of this Convention are to achieve and maintain a high level of safety worldwide through the enhancement of national measures and international cooperation, to ensure that there are effective defenses against potential hazards so that individuals, society and the environment are protected from harmful effects of ionizing radiation so that the needs and aspirations of the present generation are met without compromising the ability of future generations to meet their needs and aspirations and prevent accidents with radiological consequences and to mitigate their consequences should they occur.[[18]](#footnote-19) The Convention applies to the safety of spent fuel management when the spent fuel results from the operation of civilian nuclear reactors, the safety of radioactive waste management when the radioactive waste results from civilian application, and certain discharges.[[19]](#footnote-20) The Convention defined "Nuclear Facility," which means that "a civilian facility and its associated land, buildings, and equipment in which radioactive materials are produced, processed, used, handled, stored or disposed of on such a scale that consideration of safety is required."[[20]](#footnote-21) Analyzing the given definition shows that SMRs are included as they use the same fuel as large nuclear reactors. Therefore, they will generate spent fuel as large nuclear reactors and have to be managed in the same way or a similar manner. The Convention applies to SMRs in civilian nuclear operations, except to SMRs within the military and defence programmes, unless declared as spent fuel or radioactive waste in terms of the Convention by the Contracting Party.[[21]](#footnote-22)

### Security

Under the auspices of the IAEA, there is only one legally binding international instrument, which is also part of the counter-terrorism international instruments in the area of physical protection of nuclear material, the Convention on the Physical Protection of Nuclear Material and its Amendment. The objective of the Convention is to achieve and maintain worldwide effective physical protection of nuclear material used for peaceful purposes and of nuclear facilities used for peaceful purposes; to prevent and combat offenses relating to such material and facilities worldwide, and to facilitate co-operation among States Parties to those ends. The Convention applies to nuclear material used for peaceful purposes in international nuclear transport and, with certain exceptions, in domestic use, storage, and transport.[[22]](#footnote-23) According to the Convention ‘"nuclear material" means plutonium except that with isotopic concentration exceeding 60% in plutonium-238; uranium-233; uranium enriched in the isotope 235 or 233; uranium containing the mixture of isotopes as occurring in nature other than in the form of ore or ore-residue; any material containing one or more of the foregoing;’[[23]](#footnote-24) The CPPN applies to nuclear material only. Therefore, under this Convention, if the SMR is fuelled with enriched uranium or plutonium, it will applyare as long as it is used for peaceful purposes, in international nuclear transport, in domestic use, storage, and transport. This would mean that SMRs to be used in remote areas or international water would be covered, as the geographical location of the nuclear material does not matter.

In 2005, the State Parties agreed to amend the Convention and strengthen its provisions, whereby the scope was expanded to include the cover nuclear facilities, nuclear material in domestic use, storage and transport used for peaceful purposes as well as sabotage[[24]](#footnote-25), while it excludes any activities undertaken by armed forces or in armed conflict or by military forces and any nuclear material in possession of military forces or facilities owned by the military.[[25]](#footnote-26) The definition of “nuclear facility” provided by the Amendments to the Convention means that “a facility (including associated buildings and equipment) in which nuclear material is produced, processed, used, handled, stored or disposed of if damage to or interference with such facility could lead to the release of significant amounts of radiation or radioactive material”[[26]](#footnote-27), the definition is broad and it indicates that the Amendment to the Convention applies to SMRS and nuclear material wherever they are being produced, processed, used, handled, stored, or disposed of if damage to or interference with such facility could lead to the release of significant amounts of radiation or radioactive material. Further, the Amendments to the Convention apply to the sabotage of SMRs if it could directly or indirectly endanger the health and safety of personnel, the public, or the environment by exposure to radiation or release of radioactive substances[[27]](#footnote-28), irrespective of the geographic location.

### Safeguards

Under the auspices of the United Nations, the Non-Proliferation Treaty mandated the IAEA to conclude Comprehensive Safeguards Agreements with non-nuclear-weapon State Parties to the NPT and nuclear-weapon-free zone States. Article III (5) of the IAEA Statute also complements the conclusion of such agreements.[[28]](#footnote-29) Under the Comprehensive Safeguards Agreement, the Agency has the right and obligation to ensure that safeguards will be applied, by the terms of the Agreement, on all source or special fissionable material in all peaceful nuclear activities within the territory of the State, under its jurisdiction or carried out under its control anywhere, for the exclusive purpose of verifying that such material is not diverted to nuclear weapons or other nuclear explosive devices.[[29]](#footnote-30) The Agreement should provide that nuclear material subject or required to be subject to safeguards thereunder which is transferred internationally shall, for purposes of the Agreement, be regarded as being the responsibility of the State: (a) In the case of import from the time that such responsibility ceases to lie with the exporting State, and no later than the time at which the nuclear material reaches its destination; and (b) In the case of export, up to the time at which the recipient State assumes such responsibility, and no later than the time at which the nuclear material reaches its destination. The Agreement should provide that the States concerned make suitable arrangements to determine the point at which the transfer of responsibility will take place. No State shall be deemed to have such responsibility for nuclear material merely because the nuclear material is in transit on or over its territory or territorial waters, or that it is being transported under its flag or in its aircraft.[[30]](#footnote-31) Comprehensive safeguards agreements apply to SMRs irrespective of where they are located. And the agreement made it explicitly clear that the exporting States should take responsibility for such nuclear material until it reaches the recipient State, in case of exporting. It, however, excludes nuclear material used for military purposes.

Additional Protocol states that a State shall provide the IAEA with a declaration containing a general description of and information specifying the location of nuclear fuel cycle-related research and development activities not involving nuclear material carried out anywhere that is funded, specifically authorized, or controlled by, or carried out on behalf of, the State; information identified by the Agency based on expected gains in effectiveness or efficiency, and agreed to by the State, on operational activities of safeguards relevance at facilities and at locations outside facilities where nuclear material is customarily used; information regarding the quantities, uses and locations of nuclear material exempted from safeguards under [paragraph 37 of INFCIRC/153]; and The following information regarding specified equipment and non-nuclear material listed in Annex II.[[31]](#footnote-32) The definitions of “facility” and “location” provided for in Article 18 (i) and (j)[[32]](#footnote-33) of the Additional Protocol, they are quite broad as they extend to locations outside facilities. Additional Protocol provides a comprehensive cover for SMRs in totality.

### Nuclear Civil Liability

This section will mainly focus on the Vienna Convention on Civil Liability for Nuclear Damage (Vienna Convention), the Protocol to amend the Vienna Convention on Civil Nuclear Liability, and the Convention on Supplementary Compensation for Nuclear Damage. The Joint Protocol is also part and parcel of the instruments on nuclear civil liability under the auspices of the IAEA; however, it will be excluded as it establishes treaty relations and extends mutual benefits between the Contracting Parties of the Vienna and Paris Conventions on civil liability for nuclear damage.

The Vienna Convention on Civil Liability for Nuclear Damage aims to harmonize the national law of Contracting Parties by establishing minimum standards to provide for financial protection against damage emanating from peaceful uses of nuclear energy, irrespective of their differing constitutional and social systems.[[33]](#footnote-34) It applies to nuclear damage arising out of nuclear incidents occurring at nuclear installations as defined in the Convention (i.e. land-based reactors, factories for the production or processing of nuclear material, facilities where nuclear material is stored unless storage is incidental to transport), or in the course of transport of nuclear material (nuclear fuel, excluding natural and depleted uranium, and radioactive products or waste) to or from such installations.[[34]](#footnote-35) It does not apply to installations and radioactive substances which do not pose the risk of large-scale nuclear damage.[[35]](#footnote-36) The definitions of "nuclear reactor" and "nuclear installations" are broad and include SMRs. Therefore, the Convention applies to SMRs except for those used in air and sea transportation and for military purposes.

The Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage was adopted in 1997. It provides for a broader scope, increased liability of the operator of a nuclear installation, and enhanced means for securing adequate and equitable compensation.[[36]](#footnote-37) It applies to nuclear damage wherever it is suffered; however, it excludes damage emanating from nuclear installations not used for non-peaceful purposes. The Protocol also applies to SMRs, similar to the Vienna Convention, but it does not apply to FNPP.

The Convention on Supplementary Compensation for Nuclear Damage aims to establish a worldwide liability regime to supplement and enhance these measures and increase the amount of compensation for nuclear damage.[[37]](#footnote-38) The Convention applies to nuclear damage arising out of nuclear incidents occurring both at nuclear installations, as defined in the Convention, and in the course of transport of nuclear material to and from such installations.[[38]](#footnote-39) The definitions of nuclear reactor and nuclear installation are the same as the ones provided in the Vienna Convention and its Protocol. They are broad to such an extent that they include SMRs. Regarding the damage suffered in terms of the CSC, the geographical application is well articulated as it applies to the damage suffered in the territory of a Contracting Party, in or above maritime areas beyond the territorial sea of a Contracting Party on board or by a ship flying the flag of a Contracting Party, or onboard or by an aircraft registered in the territory of a Contracting Party, or on or by an artificial island, installation or structure under the jurisdiction of a Contracting Party or by a national of a Contracting Party.[[39]](#footnote-40) It does not apply damage suffered in or above the territorial sea of a State not Party to this Convention or above the exclusive economic zone of a Contracting Party or on the continental shelf of a Contracting Party in connection with the exploitation or the exploration of the natural resources of that exclusive economic zone or continental shelf, provided that the courts of a Contracting Party have jurisdiction pursuant to Article XIII.[[40]](#footnote-41)

## Floating nuclear power plants (FNPP)

Apart from challenges addressed under safety and security, the floating nuclear power plants face many challenges such as classification, legislative framework, and regulatory framework, unresolved territorial disputes, fragile ecological balance, lack of harmonization of the international legally binding instruments under the auspices of the United Nations, International Maritime Organisation and IAEA. Particularly the floating nuclear power plants beyond the exclusive economic zones or in international waters, as only some of the legally binding instruments under the auspices of the IAEA cover such FNPPs. Some are applying in totality, some are applying with limits, and some are not applying at all.

Classification of the FNNPs is the first important step in determining their safety and security requirements and how they will be regulated. Safety: The Convention on Early Notification of a Nuclear Accident applies to SMRs as long as there is international transboundary, including FNPPs; the Convention on Assistance in the Case of a Nuclear Accident or Radiological- Emergency applies to SMRs except to SMRs in FNPPs; Convention on Nuclear Safety it does not apply to SMRs, except if they are land-based SMRs; Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management, applies to all SMRs in civilian nuclear operations, except to SMRs within the military and defence programmes, unless declared as spent fuel or radioactive waste in terms of the Convention by the Contracting Party[[41]](#footnote-42). Security: Convention on the Physical Protection of Nuclear Material and its Amendments, SMRs are covered as long as they are being used for peaceful purposes, in international nuclear transport, in domestic use, storage and transport and SMRs to be used in remote areas or international water would also be covered as what matters is the geographical location of the nuclear material. The Amendments expanded the scope to SMRs, nuclear material and sabotage of SMRs irrespective of the geographical location. SMRs and nuclear material in possession of or used for military purposes or in armed conflicts are excluded by the Convention and its Amendments. Safeguards: Comprehensive Safeguards Agreement and Additional Protocol applies to SMRs wherever they are located except the SMRs used for military purposes. Nuclear Civil Liability: The Vienna Convention on Civil Liability for Nuclear Damage (Vienna Convention) applies to SMRs except those used in air, sea transportation and for military purposes. Protocol to amend the Vienna Convention on Civil Nuclear Liability also applies to SMRs similar to the Vienna Convention and does not apply to FNP. Convention on Supplementary Compensation for Nuclear Damage2 applies to SMRs, except for FNPPs in international water or beyond exclusive economic zones of Contracting Parties.

The regulatory framework of FNPPs is a challenge as there is no regulatory body which regulates or issues licenses to FNPPs in international waters. Such an institution is needed, or else Member States of the IAEA should find a better solution to that challenge.

Other safety challenges will be accidents caused by natural disasters such as Tsunamis or rough seas(oceans) or as a result of piracy or ocean collision. This will compromise safety as there will be dispersion of nuclear material in the ocean. Inexperienced individuals handling nuclear material in the floating nuclear power plant may expose themselves to harmful radiation. As for ocean collision, depending on the magnitude of the impact it will result in minor damage (e.g. a dent) or major damage (which may lead to the sinking of the floating nuclear power plant) and can cause marine environmental challenges which can lead to political tensions and disagreements between States. Concerning accidents caused by natural disasters may lead to the loss of nuclear material which pose as a threat or risk to nuclear security. Other security challenges will be piracy[[42]](#footnote-43) or ocean collision[[43]](#footnote-44) (these are criminal intents), as for piracy nuclear material will end up in the wrong hands. Whilst for ocean collision, may lead to the loss of nuclear material which may also be removed from the SMR prior to the damage.

## conclusion

The current legally binding international instruments under the auspices of the IAEA can control and regulate SMRs, however, they need to be more adequate, especially for FNPPs. There is a need for a regulatory body to regulate FNPPs in international waters and for Member States to strengthen their national laws to complement the legally binding international instruments under the auspices of the IAEA in relation to nuclear activities. As the technology evolves, the needs arise, although it is time-consuming, there is a need to amend, expand the scope, and harmonize legally binding international instruments and the civil nuclear liability regime; there is a need to conduct marine environmental impact assessment; and states which intend to deploy FNPPs should engage other states which may be affected before the deployment of such FNPP and also if there is unresolved territorial dispute or issue, it should be addressed before the deployment of the FNPP or else mechanism should be put in place to allow the smooth operation of the FNNP.

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    …. “(i) Facility means (i) A reactor, a critical facility, a conversion plant, a fabrication plant, a reprocessing plant, an isotope separation plant or a separate storage installation; or (ii) Any location where nuclear material in amounts greater than one effective kilogram is customarily used.

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