Small Modular Reactors and Nuclear Non-Proliferation; to What Extent will the Global Spread of SMRs Impact Nuclear Proliferation?

Joel Christoph[1], Omar Sayeed Saimum[2], Adjoa Amponfi[3*],

[1] European University Institute

[2] Korea Advanced Institute of Science and Technology

[3]School of Nuclear and Allied Sciences. College of Basic and Applied Sciences. University of Ghana, Legon.

*Corresponding author

Abstract

The concern about proliferation risks associated with the development and deployment of small modular reactors (SMRs) may be historically motivated. For instance, small power reactors have been used to produce fissile material for weapons. Moreover, the nuclear industry started with small machines that bulked up over the years to take advantage of economies of scale. The Shippingport nuclear plant in Pennsylvania operating in 1957 had a power capacity of 60MW. Similarly, many of today's SMR plans have their roots in naval reactor technology, such as the Westinghouse reactor that powered the first US nuclear submarines. This article studies the proliferation risks of SMRs, based on review of existing literature, models in development, estimates of future market outcomes and detailed review of published information of selected SRM designs. However, there remains uncertainty over the extent to which widespread SMR use might increase or decrease non-proliferation risk. On the one hand, some SMRs require less frequent refueling than conventional nuclear reactors, thereby mitigating some risk scenarios. Conversely, more integrated designs may be more challenging to inspect, and some designs use more highly enriched uranium than conventional nuclear reactors. Both aspects could increase proliferation risk. Ultimately, SMR proliferation risk depends on both technical and non-technical factors such as which SMRs are deployed in which locations. As such, narrow cost-effectiveness analyses for particular locations may be needed to assess factors including the location's nuclear regulatory requirements, the customer profile, reactor size, and technology readiness. Consequently, the IAEA safeguards system will have to adapt its financial and personnel capacity to cope with the additional workload arising from the number and variety of SMRs. For instance, it has been estimated that about 85 GW SMR capacity could be installed by 2035, comprising perhaps 1,000 small reactors. The article concludes with policy recommendations as to increase funding allocations in line with the expected rise in SMR deployment, to facilitate collaboration between inspection authorities and SMR developers to fix gaps that can delay safeguards, to improve non-technical factors such as governance in plausible deployment regions and to pre-empt risks by addressing SMR-specific safeguard issues ahead of time.

Keywords: Small Modular Reactor, Enrichment, Refueling, Nuclear Nonproliferation, Nuclear Energy, IAEA, Safeguards

1 Introduction

Understanding Small Modular Reactors (SMRs) and their risks of nuclear proliferation requires comprehensive approach, considering their distinctive characteristics and evaluating probable vulnerabilities. An approach that includes looking into technological, regulatory, and multinational cooperation aspects. It is very crucial to accentuate the importance of responsible governance, robust safeguards, and an active international cooperation to minimize proliferation risks associated with SMRs [Virgili, 2020]. The global pursuit of clean and sustainable energy sources has brought SMRs to the forefront as a potential solution to meet the world's growing energy demands. However, amidst the increasing interest and development of SMRs, it is crucial to address concerns regarding nuclear non-proliferation. The spread of SMRs across the globe has raised questions about their potential impact on nuclear proliferation, posing significant challenges to global security. It is the aim to critically analyse the extent to which the global spread of SMRs may impact nuclear proliferation. In that vein, there will be exploration of the interplay between SMRs and nuclear non-proliferation, examining the risks, concerns, and potential consequences associated with this emerging technology. By delving into the complex relationship between SMRs and nuclear proliferation, there is a possibility of gaining a deeper understanding of the challenges and opportunities at hand.

Throughout this paper, there will be the examination of the various factors contributing to the proliferation potential of SMRs. This includes evaluating the technological features of SMRs, the implications of their global deployment, and the potential challenges in enforcing safeguards and security measures. Furthermore, we will explore the role of international cooperation, responsible governance, and effective policy frameworks in minimizing the risks associated with the spread of SMRs. As well, by shedding light on the complexities surrounding SMRs and nuclear non-proliferation, this paper directs to contribute to informed decision-making, policy development, and international collaboration. It is crucial to strike a balance between harnessing the benefits of SMRs for clean energy production and ensuring robust measures are in place to prevent the misuse of these technologies. Through a comprehensive analysis of the risks and opportunities associated with the global spread of SMRs, it is possible to provide valuable insights and recommendations to policymakers, industry stakeholders, and the international community. This research will contribute to the ongoing dialogue on nuclear non-proliferation and advances our understanding of the implications of SMRs in the pursuit of sustainable energy solutions.

Nuclear proliferation raises significant concern due to the destructive nature of the power the nuclear weapons have and the likely potential of being used in conflict. This could lead to catastrophic environmental and humanitarian crises. It undermines regional and global security by increasing the number of actors capable of deploying nuclear weapons and potentially destabilizing delicate geopolitical balances. It is therefore crucial to assess the implications of the global proliferation of SMRs and identify strategies to mitigate the associated risks.

2 SMRs, an Overview

A small modular reactor is an advanced nuclear reactor with up to 300-500 MWe or max. 1,000 MWth per unit power capacity for passive safety. Although some newly proposed SMR designs might be as little as 20 MWe, the term "small" often refers to a reactor with an electric power output below a few hundred megawatts. The major characteristics that differentiate them from conventional nuclear power reactors include: small size, it is much smaller than a typical nuclear power reactor only about a fraction of the size of a convention nuclear power reactor; modular, are prefabricated, modularity enables systems and components to be pre-assembled at a factory before being sent as a whole to a place for installation and a reactor- utilizing nuclear fission to create heat and energy through reactors and simplified construction [Liou, 2021]. Unlike traditional large-scale nuclear reactors, which have a capacity of several hundred megawatts, SMRs typically have a capacity ranging from 10 to 300 megawatts. This compact size allows for easier deployment and greater flexibility in terms of location and energy production. The word "modular" refers to a reactor design that could (or probably would) be installed at a specific location utilizing a large number of similar modules. The concept is to deploy two or four SMR modules at a location, however in the most ambitious plans, this might include deploying eight to ten (or more) SMR modules at a location. In addition to lowering capital costs per additional unit compared to the prior unit, the subsequent installation of many units at the same location would also ease-over the financing needs proportionately per unit. The majority of SMRs are made to produce electricity, while a small number are made to create process heat for industrial use, and others are made to produce both heat and electricity. Among the technologies now being developed are small LWRs[2] (which use technology that, for the most part, are relatively comparable to those used in today's big LWRs) and as well as advanced reactor technologies of many other kinds. Homogenous fuel reactors, fast-spectrum sodium or lead-cooled reactors, liquid-salt-coolant reactors with pellet fuels, high-temperature gas reactors, liquid-salt-coolant reactors with pellet fuels, pebble-bed designs, and couple of others. (IAEA, 2016).

The growing popularity of SMRs can be attributed to several factors. First, their smaller size makes them more suitable for remote or off-grid locations, where large-scale reactors may not be feasible. SMRs offer the potential to provide reliable and carbon-free electricity to areas with limited infrastructure or smaller electricity demands, such as remote communities or industrial sites. Additionally, SMRs offer enhanced safety features compared to traditional reactors. In terms of safety, a notable feature of SMRs is their lower thermal power. Given the lower decay heat and relatively high surface-to-volume ratio of SMRs, decay heat removal is easier and can be facilitated by passive mechanisms such as gravity without the need for active devices. Eventual passive cooling by air can also provide a high level of passive safety. Moreover, even in the case of damage to the reactor core, far smaller amounts of radioactive materials would be released. This provides an advantage for possible location near big cities. As such, lower thermal power provides an inherent safety improvement of these nuclear reactors, with an estimate targeted CDF[3] of 10^9-10^7/year, corresponding to one severe accident every ten million years in expectation, comparable in frequency to large asteroid collisions (D~5 km) that occur roughly every 20 million years [Kim Y., 2022, Figure 2.1]. Their modular design allows for standardized manufacturing and improved quality control, reducing the risks associated with construction errors and potential accidents. Another advantage of SMRs is their potential for cost-effectiveness. The modular design enables factory fabrication and shorter construction times, leading to reduced capital costs. The ability to manufacture components in a controlled environment and transport them to the site also enhances quality control and reduces construction risks. SMRs also have the potential for improved operational efficiency, higher fuel utilization rates, and reduced operation and maintenance costs. Furthermore, SMRs offer inherent load-following capabilities, allowing for better integration with variable renewable energy sources. Their flexibility in adjusting power output enables them to complement intermittent renewables, providing a more stable and reliable energy grid.

SMRs offer economic advantages that contribute to their competitiveness [Carelli et al., 2010]. They benefit from features such as modularization, factory fabrication, and shorter construction periods, reducing costs and financial risks. SMRs can be deployed in multiple

[2] LWRs ; Light Water Reactors, [3] CFD: Core Damage Frequency

modules per site, allowing for flexible capacity expansion. Simplification, standardization, and automation are key design principles, enhancing operational efficiency and safety while achieving economies of scale. Passive safety features further mitigate risks. SMRs' flexibility extends to load-following operation, making them compatible with intermittent renewables. Their automation capabilities improve safety and economic viability. Additionally, SMRs can be deployed as distributed power sources, providing energy to remote areas. These economic and operational benefits make SMRs a promising option for meeting future energy needs.

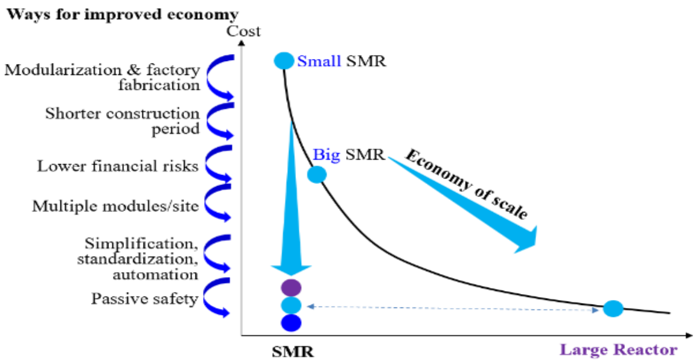

Figure 2.1. SMRs and Economics of Scale (Kim Y. , 2022).

Global Deployment and Market Potential

The global market potential for small modular reactors (SMRs) is estimated at 65-85 GW by 2035, corresponding to a value of 240-400 billion British Pounds or 310-500 billion US $. Over seventy types of SMRs are currently being developed across multiple countries [ERIA Study team, 2022]. The deployment of SMRs is expected to begin in the 2030s, with their connection to the grid being a crucial factor. Research by the [4]OECD - [5]NEA focused on the technical feasibility, economic performance, and market potential of SMRs, highlighted the need for successful licensing, supply chain maturity, and integration into the energy market. The demand for low-carbon technologies and the challenges faced by conventional nuclear projects have further fueled the interest in SMRs as more accessible and less complex nuclear options [NEA, 2016; 2011].

3 Nuclear Proliferation

Nuclear proliferation refers to the spread of nuclear weapons, materials, or technology to additional countries or non-state actors beyond the existing nuclear-armed states recognized under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). It basically consists of acquiring, developing, or transferring nuclear weapons or the capacity to produce them. Nuclear proliferation raises significant concern due to the destructive nature of the power the nuclear weapons have and the likely potential of being used in conflict. This could lead to catastrophic environmental and humanitarian crises. It undermines regional and global security by increasing the number of actors capable of deploying nuclear weapons and potentially destabilizing delicate geopolitical balances [IAEA, 2023].

Nuclear proliferation poses several risks and challenges. Security Risks; the more countries or non-state actors possess nuclear weapons, the greater the risk of accidental or intentional use. Increased proliferation heightens the likelihood of nuclear conflict, miscalculation, terrorism, or

[4]OECD: Organization for Economic Co-operation and Development, [5]NEA: Nuclear Energy Agency

unauthorized access to nuclear materials. Regional Instability; nuclear proliferation can contribute to regional tensions and conflicts, as neighbouring states may perceive an increased security threat and respond by seeking their own nuclear capabilities. This arms race dynamic can escalate regional rivalries and increase the probability of nuclear confrontations. Disarmament Impediment; nuclear proliferation complicates global disarmament efforts. As more states acquire nuclear weapons, the incentives for existing nuclear-armed states to reduce or eliminate their arsenals diminish, perpetuating a state of mutual deterrence and inhibiting progress towards a world free of nuclear weapons. Non-State Actor Concerns; the risk of nuclear materials or technology falling into the hands of non-state actors, such as terrorist groups, is heightened with proliferation. Illicit acquisition of nuclear weapons or materials by non-state actors poses a grave threat to international security and stability. Treaty Erosion: nuclear proliferation challenges the effectiveness and credibility of international non-proliferation treaties, particularly the NPT. The NPT aims to prevent the spread of nuclear weapons while facilitating the peaceful use of nuclear energy. Proliferation strains the treaty's objectives and may undermine its integrity if non-compliance becomes widespread [Panofsky, 2003].

3.1 Nuclear Non-Proliferation Regime:

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) is an international framework that aims to prevent the spread of nuclear weapons, promote disarmament, and encourage the peaceful use of nuclear energy. The NPT has three main pillars:

- Nuclear Disarmament: Nuclear-weapon states commit to working towards complete disarmament through negotiations. The treaty emphasizes the goal of ending the nuclear arms race and achieving general and complete disarmament.
- Non-Proliferation: Non-nuclear-weapon states agree not to acquire or develop nuclear weapons and accept safeguards by the International Atomic Energy Agency (IAEA) to ensure their nuclear activities are peaceful. They must have comprehensive safeguards agreements with the IAEA.
- Peaceful Use of Nuclear Energy: All signatory states have the right to access and develop nuclear energy for peaceful purposes. Non-nuclear-weapon states can receive assistance for peaceful nuclear energy development.

The NPT is vital for global nuclear non-proliferation efforts, fostering international cooperation, verification, and confidence-building measures. However, challenges remain, including uneven compliance and slow progress in disarmament. Sustained international cooperation and diplomacy are needed to address these issues and ensure the treaty's effectiveness in promoting global security and preventing the proliferation of nuclear weapons [IAEA, 2023].

4 Proliferation Risks Associated with SMRs

The global spread of Small Modular Reactors (SMRs) poses potential risks and challenges in terms of nuclear proliferation. One major concern is the dual-use nature of SMR technologies, which can be utilized for both peaceful purposes and weapons development. The compact size and lower proliferation resistance of SMRs compared to larger nuclear reactors increase the potential for misuse or diversion of these technologies. The proliferation of small modular reactors (SMRs) raises concerns about weapons proliferation, especially for governments with latent weapons capacity. SMRs are attractive to proliferators due to their lower cost compared to larger power reactors, and power reactors can produce significant amounts of weapons-grade plutonium on shorter cycles [Shellenberger, 2018].

Small modular reactors (SMRs) have their historic root in military applications, specifically in the development of naval reactors for submarines and naval vessels. The experience gained from these military programs laid the foundation for the advancement of civilian SMRs. Today, many SMR designs draw upon the knowledge and advancements achieved through military nuclear programs, incorporating features such as compact reactor cores, passive safety systems, and modular designs [Maize, 2015]. While the military pursuit of small, portable, and reliable nuclear power systems influenced the concept of SMRs, their focus has shifted towards addressing energy needs and promoting sustainable energy sources for civilian use. SMRs have evolved beyond their military origins and are now primarily aimed at meeting civilian energy demands, reducing greenhouse gas emissions, and ensuring secure and sustainable energy generation. Yet still, there are concerns about the possibility of clandestine construction or diversion of SMRs for military purposes. The smaller size and portability of SMRs make them more difficult to detect and monitor compared to larger reactors. This raises the risk of covert development of nuclear weapons under the guise of civilian SMR programs [Green, 2019]. The potential for military applications of SMRs could undermine the non-proliferation efforts and international security. Furthermore, the spread of SMRs may lead to challenges in safeguarding and verifying their peaceful use. The deployment of numerous SMRs across different countries could strain the capacity of regulatory bodies and international organizations to effectively monitor and verify compliance with non-proliferation commitments. Ensuring robust safeguards, transparency, and international cooperation becomes crucial to address these challenges and mitigate the risks associated with the global spread of SMRs. Analysis of selected SMRs in development has been summarized in Table 4.1.

Table 4.1 Proliferation Risks and Economic Features of Different SMR Models

	Coolant	Moderator	Fuel Burnup (GWd/ton)	Refueling -cycle (years)	Enrichment	Comment
PWR-302 (VBER-300)	L Water	L Water	50	3-6	~5%	Highest refueling cycle
PWR-335 (IRIS)	L Water	L Water	65	4 (max)	~5%	
PWR-125	Water	Water	-	4	~5%	
PRISM	Sodium	Fast reactor	>150	1-2	~25%	Cost least; Risk High
CAREM	L Water	L Water	24	1	~3%	Low output
NuScale	L Water	L Water	>30	2	~5%	
W-SMR	L Water	L Water	>62	2	~5%	
mPower	L Water	L Water	<40	2	~5%	Suspended
SMART	L Water	L Water	<54	2.5	~5%	

Nuclear proliferation risks associated with small modular reactors (SMRs) are a concern due to several factors. Firstly, on-load refueled reactors require frequent handling of irradiated fuel, increasing the risk of diversion. Breeders, a type of SMR, can convert U-238 to Pu-239, which could be used to produce weapons-grade material. Additionally, advanced fuel cycles and smaller fuel element sizes in SMRs pose challenges for safeguards inspections. The use of nontransparent coolants and the storage of fuel elements vertically also complicate inspection efforts. These factors highlight the need for safeguards experts to work with design teams and develop monitoring methods specifically for SMRs [Kim, 2022; UK Houses of Parliament, 2018].

In terms of nuclear non-proliferation resistance, the build-up of transuranics (TRU) in nuclear reactors and the characteristics of the plutonium (Pu) vector in pressurized water reactors (PWRs) are important considerations. For proliferation resistance and the nuclear design, higher burnup in SMRs may reduce the attractiveness of the Pu vector for weapons-grade use. The relationship between reactor characteristics and proliferation resistance reveals that smaller SMRs with lower power, higher burnup, longer cycle length, and autonomous operation can improve proliferation resistance. However, there is no consensus on whether the smaller size of SMRs inherently increases proliferation resistance. The proliferation resistance of different SMR designs, such as solid fuel and molten salt reactors, also varies. Geopolitically, SMR development intersects with the innovation and arms races between great powers, presenting both opportunities and challenges. Governments can support innovation, collaboration, and the development of demonstration projects to foster the responsible use of SMR technology and mitigate nuclear risks internationally [OECD, 2020; Luongo, 2022].

5 Safeguards and Security Measures

Safeguards and security measures play a crucial role in mitigating proliferation risks associated with Small Modular Reactors (SMRs). Robust international safeguards agreements, such as those implemented by the International Atomic Energy Agency (IAEA), are essential for ensuring the peaceful use of nuclear energy and preventing the diversion of SMRs for military purposes. International safeguards agreements provide a framework for verifying compliance with non-proliferation commitments. These agreements require states to implement comprehensive safeguards measures, including inspections, monitoring, and reporting, to ensure that nuclear materials and facilities are used solely for peaceful purposes. The IAEA plays a central role in conducting inspections and verifying the compliance of states with their obligations under these agreements. [Carbanas, 2021]

In addition to safeguards, effective export controls, strict regulations, and enhanced security are necessary to prevent unauthorized access to SMRs and their associated technologies. Export controls ensure that sensitive nuclear materials, equipment, and technologies related to SMRs are not transferred to unauthorized recipients. Strict regulations governing the export and import of SMRs help prevent their diversion to illicit purposes and ensure that their deployment is in line with non-proliferation objectives. Enhanced security measures are essential to protect SMR facilities and materials from theft, sabotage, and unauthorized access. This includes physical security measures, such as secure perimeters, access controls, and alarm systems, as well as cybersecurity measures to safeguard against digital threats. Strengthening the physical protection and cybersecurity of SMRs contributes to the overall non-proliferation regime and helps maintain the integrity and security of nuclear facilities.

Collaboration among states, international organizations, and industry stakeholders is crucial for implementing effective safeguards and security measures for SMRs. Sharing best practices, technical expertise, and information on emerging threats can enhance the effectiveness of these measures and ensure a comprehensive approach to addressing proliferation risks. The Global SMR Regulatory Forum serves as a platform for regulatory authorities, industry stakeholders, and technical experts to exchange knowledge and harmonize regulatory approaches. Collaborative research and development programs among SMR-producing countries foster innovation while minimizing proliferation risks. Transparency, information sharing, and peer review mechanisms contribute to building trust and confidence among participating nations. The Global SMR Regulatory Forum facilitates cooperation by enabling the sharing of best practices, harmonizing safety and security guidelines, and enhancing understanding of SMR technologies. Through this forum, participating countries can collectively address proliferation concerns, assess the safety and security aspects of SMR deployment, and develop common standards for global implementation. [IAEA, 2022]

By implementing robust safeguards agreements, enforcing export controls, and enhancing security measures, the international community can enhance the non-proliferation regime and minimize the risks associated with the global spread of SMRs. These measures contribute to the safe and secure use of nuclear energy for peaceful purposes while deterring the misuse of SMRs for military or clandestine purposes.

6 Case Studies and Instances

Case studies and examples of countries or regions that have implemented Small Modular Reactors (SMRs) can shed light on their approaches to nuclear non-proliferation. One such example is the United Arab Emirates (UAE), which has embarked on a nuclear power program that includes the deployment of SMRs. The UAE's commitment to non-proliferation is demonstrated through its adherence to comprehensive safeguards agreements with the International Atomic Energy Agency (IAEA) and its ratification of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). The country's nuclear program is subject to rigorous international inspections and verification measures, ensuring transparency and accountability [UAE, 2023].

Another noteworthy example is the United States, where several SMR designs are under development. The U.S. Nuclear Regulatory Commission (NRC) oversees the licensing and regulation of these advanced reactors, incorporating stringent safety and security requirements. The NRC's oversight, combined with the country's robust export control regime and adherence to non-proliferation commitments, demonstrates a comprehensive approach to preventing the proliferation of nuclear materials and technologies associated with SMRs [USNRC, 2022].

Examining the impact of SMRs on regional security dynamics is also important. For instance, in the case of Central and Eastern European countries, the deployment of SMRs could enhance energy security and reduce dependence on foreign energy sources. This, in turn, may contribute to regional stability by reducing vulnerabilities and potential geopolitical tensions associated with energy supply. However, it is crucial to ensure that these deployments are accompanied by robust safeguards, control mechanisms, and international cooperation to prevent any potential misuse or diversion of SMRs for military purposes [Herrera, 2022]. The effectiveness of safeguards and control mechanisms in preventing proliferation in the context of SMRs can be assessed by analyzing the experience of countries with existing nuclear power programs. Countries like Canada and Sweden, which have a long history of operating nuclear power plants, have well-established systems in place for nuclear materials management, strict export controls, and international cooperation on non-proliferation. These examples demonstrate the importance of comprehensive and robust safeguards agreements, effective export controls, and close collaboration with international organizations such as the IAEA [Wealer et al, 2018]. By analysing case studies and examples, insights into the approaches taken by countries and regions in implementing SMRs while ensuring nuclear non-proliferation are gained. Understanding the effectiveness of safeguards, control mechanisms, and international cooperation is vital for addressing proliferation concerns and ensuring the safe and responsible deployment of SMRs globally.

7 Conclusions

In summary, the complex relationship between Small Modular Reactors (SMRs) and nuclear non-proliferation have been explored. The growing popularity of SMRs in the nuclear energy sector and their potential impact on nuclear proliferation has also been discused. It was highlighted that while SMRs offer several benefits, their dual-use nature and the possibility of clandestine construction or diversion raise concerns about their potential misuse for military purposes. It is emphasized - the importance of safeguards and security measures in mitigating proliferation risks associated with SMRs. Robust international safeguards agreements, such as those implemented by the International Atomic Energy Agency (IAEA), play a crucial role in ensuring the safe and secure deployment of SMRs. Additionally, effective export controls, strict regulations, and enhanced security measures are essential to prevent unauthorized access to SMRs and their associated technologies. International cooperation and responsible governance were identified as key factors in addressing proliferation concerns. Multilateral initiatives, like the Global SMR Regulatory Forum, facilitate information sharing, transparency, and peer review mechanisms among SMR-producing countries. Collaborative research and development programs also contribute to addressing proliferation risks by promoting the adoption of best practices and standardized safety and security measures. Case studies were presented to examine countries' approaches to nuclear non-proliferation in the context of SMRs. Examples such as the UAE and the United States demonstrated their commitment to non-proliferation through adherence to comprehensive safeguards agreements, rigorous regulatory oversight, and robust export control regimes. It was acknowledged that while SMRs can enhance regional energy security and stability, their deployment must be accompanied by stringent safeguards, control mechanisms, and international cooperation to prevent any misuse or diversion for military purposes.

In conclusion, the global spread of SMRs presents both opportunities and challenges regarding nuclear non-proliferation. Continuous evaluation, monitoring, and strengthening of international non-proliferation measures are crucial to mitigate risks and ensure the safe and responsible use of SMRs. Ongoing research and international cooperation are needed to further understand the potential impact of SMRs on nuclear proliferation and to develop effective strategies to address these concerns. By doing so, we can harness the benefits of SMRs while upholding global security and non-proliferation goals.

Policy recommendations for the deployment of small modular reactors (SMRs) include resolving uncertainties regarding economic feasibility and proliferation risks, addressing legal restrictions on uranium enrichment and spent fuel reprocessing, increasing funding for inspections and collaboration between inspection authorities and SMR developers, improving governance in deployment regions, and proactively addressing SMR-specific safeguard issues. the risks associated with widespread deployment of SMRs, including in nuclear aspiring regions with lower governance capabilities, could be comparable to conventional large nuclear power plants, requiring measures to address proliferation resistance, safety standards, risk quantification, and regulation.

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