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Small Modular Reactors: **Overcoming the Licensing Dilemma**

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Introduction

Small modular nuclear reactors (SMR) are unique, not simply miniature versions of large nuclear reactors. As such, they have unique licensing requirements. Nuclear regulatory agencies around the world thus face a new situation: licensing a smaller-scale reactor, different first-of-a-kind designs, factory production of units, innovative safety measures, multiple-unit plants with one control center, and a smaller site footprint.

All these factors require designers, vendors, operators, and regulators to work out new approaches and regulations for licensing.

The promise of SMRs in a world that has pledged to cut carbon emissions is vast. As fossil fuels are phased out, SMR proponents intend to be ready to fill the power void. For the last decade, the World Nuclear Association (WNA), the International Atomic Energy Agency (IAEA), and many governmental and industry groups have been discussing and planning how to overcome potential SMR licensing hurdles.

The goals of these groups include:

- Working collaboratively to harmonize licensing regulations worldwide
- Highlighting advanced SMR safety features that require less regulatory attention
- Standardizing types of SMR designs to ease regulation in different countries

The overall aim is to streamline the licensing process and ease the introduction of commercial SMRs into both new and old nuclear nations within a decade.

A concept whose time has come

SMRs are not a new concept. Historically the idea dates back to the beginning of the nuclear age, when the United States considered using small reactors in remote military outposts and rural areas, and for powering ships, planes, and submarines. The U.S. Nuclear Navy was the most successful. The U.S. Navy at present has 83 nuclear-powered ships, including 72 submarines--all pressurized water reactors.

The U.S. Army is currently considering very small modular reactors for remote military bases and forward positions. Additionally, the U.S. Department of Defense is looking at small mobile nuclear reactors for use in disaster relief situations, including attacks on an electrical grid.

Some critics point out that historically, small reactors were not a financial success, and that today's SMR optimism is misplaced. First of all, this this isn't completely true, but more importantly, today's political situation is very different. Per-kilowatt power comparisons with other power sources are not necessarily the deciding factor, when looked at through the lens of climate change.

In addition, current experience has shown that renewables (wind and solar) are intermittent and cannot meet today's power demand without back-up power sources. SMRs are uniquely capable of being that backup, and efficiently supplementing renewables' connection to power grids.

The SMR Promise ... and Challenges

SMR designs have many unique advantages.

Ironically, the SMR innovations that make these reactors so appealing are the same that pose licensing challenges, simply because they are new, and will require new or modified regulatory approaches.

Here are some of the advantages and the new challenges posed.

Many different designs
SMRs proposed worldwide include PWRs, BWRs, HTRs (high-temperature gas-cooled), FNRs (fast neutron reactors), MSR (molten salt reactors), and heat pipe micro-reactors. In 2020, the Organization for European Cooperation and Development reported that there were 72 SMR concepts under development, about half of them PWRs. Others are first-of-a-kind (FOAK) designs, although the concepts may have been tested.

New types of safety systems
Passive safety systems increase safety margins and vastly reduce the risk of reactor core damage. There's also a smaller nuclear fuel inventory. New rules are required to accommodate the need for less safety redundancy.

Modular factory production
Most designs are intended to be factory-produced in series and pre-assembled and delivered to the reactor site. The serial production is expected to replace the economy of scale of traditional large plants. Factory sites, transportation, and assembly need to be regulated.

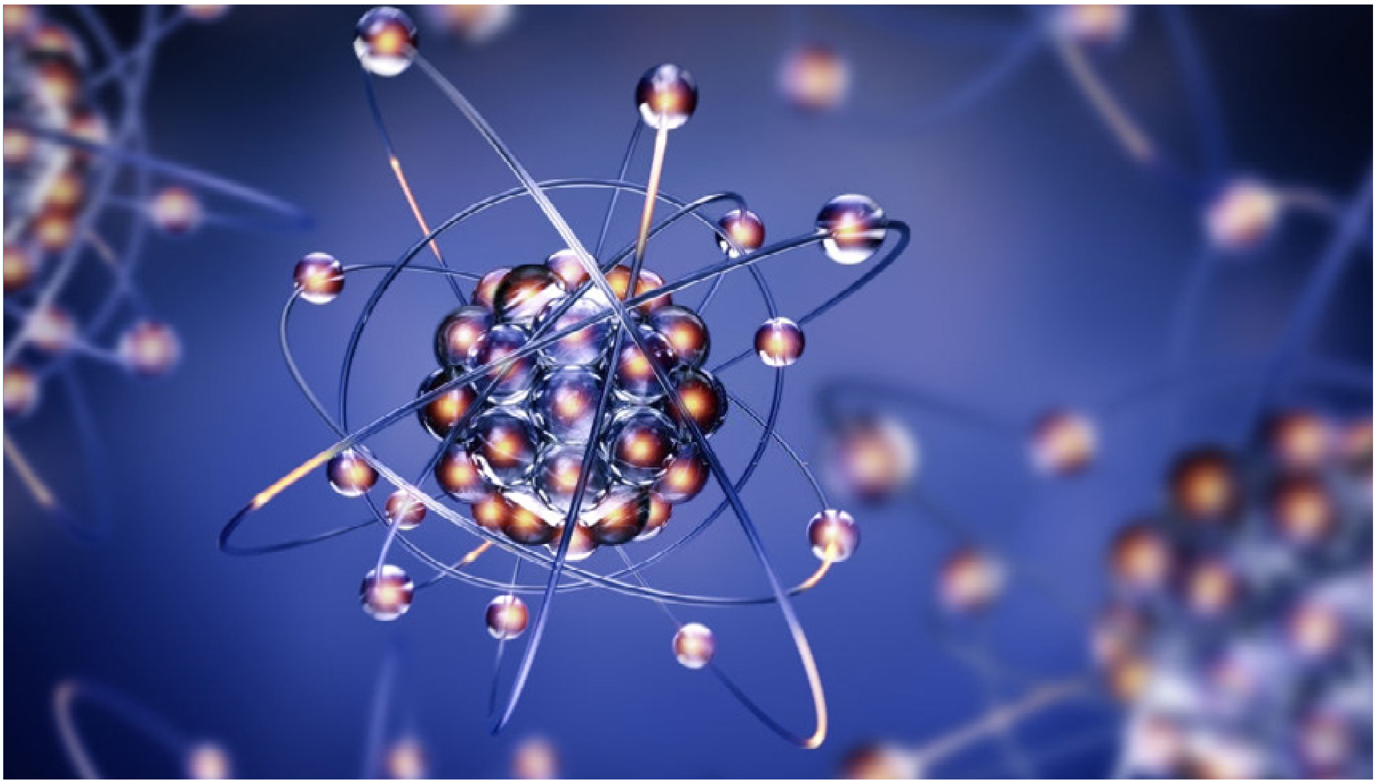
Smaller size and new plant configurations
The smaller reactor size allows for additional units to be added and connected to a central control facility as a small power grid grows. New regulatory situations include adding units or refueling while other units are operating, joint control rooms, joint personnel.

Versatility
SMRs are designed to have a smaller footprint, and some can be located below ground, on ships, or underseas. Some are suitable for brownfield locations, or to be trucked to remote locations. Some may be remote-controlled. Regulations need to be adapted to these new conditions.

New deployment choices
The smaller size and advanced reactor designs can be more easily and efficiently coupled with renewables or with industrial applications like desalination, co-generation, hydrogen production, or mining. These new end-use tasks require regulating.

New types of fuels
Some designs use different types of fuels--self-contained TRISO pebbles and high assay low-enriched uranium (HALEU)-- that may require different or additional regulations.

A variety of sponsors
Private investors, small companies, and academic organizations are taking the lead in developing SMRs. Their relative inexperience with nuclear compared with government and large commercial firms may require additional licensing requirements.



Meeting New Regulatory Challenges

Although SMRs are simpler in design than the traditional light water reactors, their innovative attributes present new licensing situations to accommodate FOAK as well as NOAK (nth of a kind) SMRs.

Nuclear regulatory agencies worldwide now have different national laws and different approaches to licensing:

- a rules-based approach, where an applicant must meet very specific requirements
- a goals-based approach, where an applicant demonstrates that it meets specific risk assessment targets
- a hybrid system

Fortunately, there is an unprecedented level of collaboration among all concerned that is helping bring about the necessary changes to facilitate SMR deployment. Such collaboration is needed, particularly to help applicants navigate regulatory conditions in new or less-experienced nuclear nations.

As the introduction to a July 28, 2021 World Nuclear Association webinar on SMR licensing pointed out, it is critical "to reduce uncertainty and risk in in the licensing process when reactor designs move between countries."

In the same webinar, Anna Bradford, Division Director for the Division of New and Renewed Licenses in Office of Nuclear Reactor Regulation at the U.S. Nuclear Regulatory Commission (NRC), outlined some of the licensing challenges for SMRs. The NRC safety requirements are purposely not easy, she stressed, and SMR companies are not experienced, and not used to the regulatory rigor required. Additionally, the wide variety of designs makes it more complicated. Plus, she noted, public acceptance is still a hurdle.

On the positive side, both new and experienced licensing applicants can rely on substantial groundwork on SMR licensing: Nuclear organizations have worked for several years to detail each possible scenario for SMR licensing and propose guidelines and solutions. There is ongoing international collaboration in these projects, and many resources for developers, regulators, and vendors. (See References).

SMR Licensing Groundwork

Here's a brief look at the work to date on easing SMR licensing:

- A 2010 report issued by the American Nuclear Society devotes a chapter to the applicability of the NRC light water reactor licensing process to SMRs. Two approaches to the problem are discussed. The first is the exemption process, where a licensee "is exempted from meeting a requirement based on a demonstration of low public risk and the presence of `special circumstances' regarding minimal safety impact."

  The second approach, which the report concludes is better for innovative designs that differ from the LWR, is the parity option, "which allows an applicant to gain license approval by demonstrating the inherent safety qualities of the design." In other words, the applicant should show how the design can protect public health and safety in a way that is better or equivalent to the current regulations.

- The World Nuclear Association organized a Working Group in 2007 called the Cooperation in Reactor Design and Licensing (CORDEL), which aimed to foster dialogue between various sectors of the nuclear industry and nuclear regulators. In 2013, CORDEL launched the Small Modular Reactor Ad-hoc Group (SMRAG), which issued a report in 2015 laying out the main SMR licensing issues and how to move forward.

SMRAG notes at the outset that safety levels determined by national laws "do not differ in relation to the size or type of a plant." It also strikes an optimistic note, that there is a "valid way forward, if there is a willingness" among those involved to accept a new licensing process for SMRs.

To optimize the licensing process, the SMRAG report recommends a Module Design Certification as a first step, including the primary safety systems. The rationale here is to separate the design certification from site-specific and operational approvals to make it easier for international adoption of the design.

The report also notes that the concept of standardized does not mean "completely identical." But standardized reactors would share "the same global architecture and the same specifications

for the nuclear steam supply system design and components and associated safety systems."

- The International Atomic Energy Agency's SMR Regulators' Forum, created in March 2015, established working groups to study aspects of SMR regulations, including defense in depth, emergency planning zones, and design and safety.

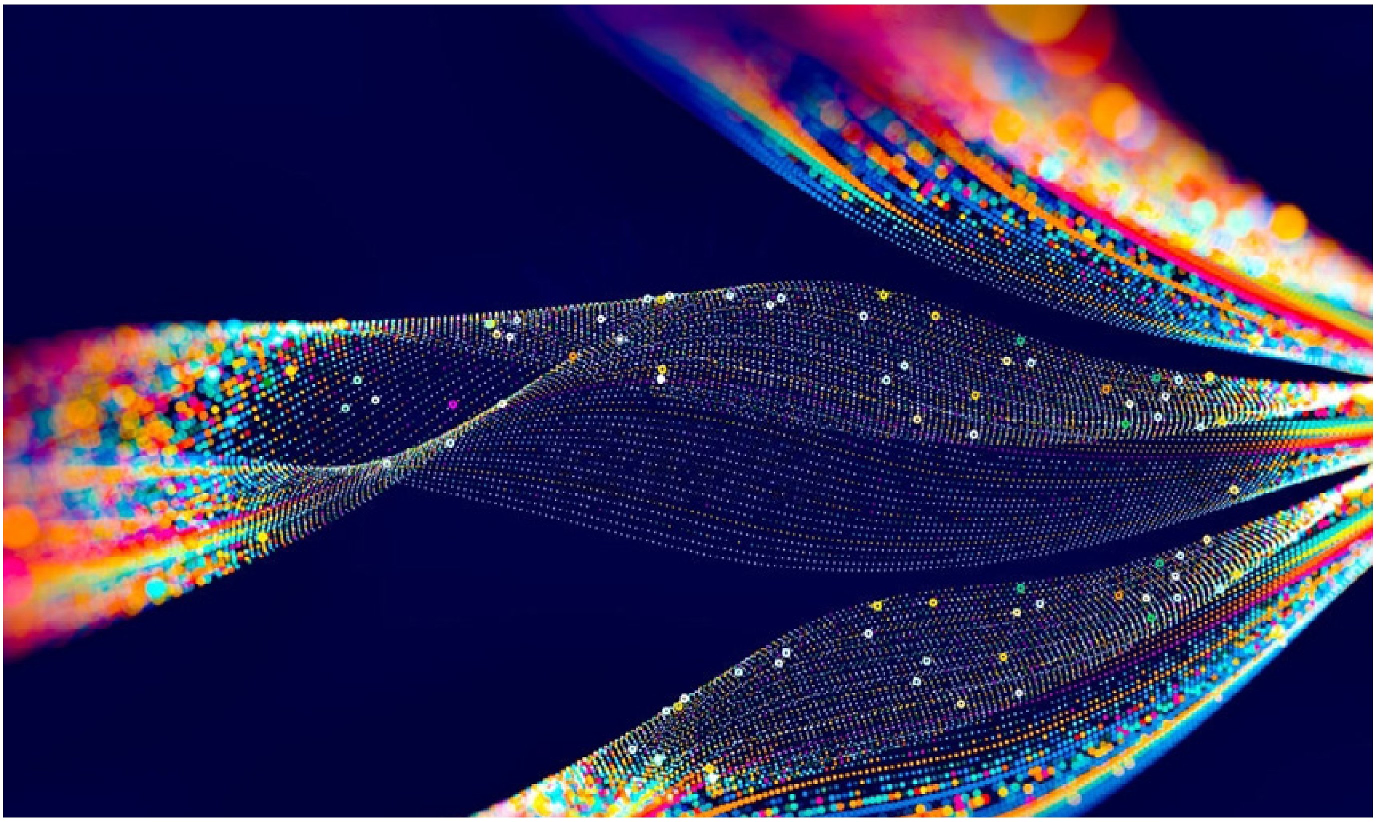
  The SMR Regulators' Forum Licensing Issues Working Group issued a comprehensive report in June 2021, which provides specific guidelines for regulators. These include key regulatory intervention points across all aspects of SMR licensing, issues related to FOAK vs NOAK designs, and licensing of multiple unit facilities.

  The guidelines encourage regulator pre-licensing interactions with vendors, establishing additional features for FOAKs to "provide enough margin to overcome unknowns in their design," and allowing designs to evolve during the regulatory process. They also suggest guidelines for overseeing off-site commissioning and transportation, for factory-built modules with specific guidelines for multiple modules.

  The report lays out a logical progression of licensing steps. It also urges all involved in the process to work together and share knowledge about any problems that FOAK designs may have.

  The report advises regulators to use alternative approaches or consider modifying existing requirements while keeping "high-level safety principles" used in a graded approach, that is, commensurate with the level of risk.

- In 2015, the World Nuclear Association's SMRAG evolved into the Small Modular Reactor Task Force



(SMRTF) to further efficient licensing of SMRs. A June 2021 report, “Design Maturity and Regulatory Expectations for Small Modular Reactors,” surveys the state of SMR design and regulation in nine countries in Asia, Europe, and North America.

The objective of two surveys and ongoing discussions with applicants, vendors, and regulators involved in the licensing process was to specify challenges, categorize each country’s regulations, review maturity of designs, and suggest effective practices to streamline licensing.

Results are presented in a series of tables and figures that give a comprehensive picture of all aspects of SMR regulation, the differences among countries, and a description of licensing and design progress in each. The report maps out, among other things, the “technological readiness” of fast-reactor, high-temperature-gas-reactor, and molten-salt-reactor designs by country.

Among its conclusions, the report notes that “a greater level of design maturity prior to” engaging with regulators will yield more predictable timescales and costs for the pre-licensing and licensing process. The report recommends completion of major research and development before pre-licensing, “early engagement” of applicants with regulators before the formal process begin, and active dialogue with regulators internationally.

Appendices categorize national organizations and regulatory resources for Belgium, Canada, China, France, the Republic of Korea, Russia, UK, Ukraine, and the USA.

Licensing Progress to Date

Nothing succeeds like success, and participants in the WNA webinar on streamlining SMR licensing, affirmed that progress was ongoing in meeting the challenges of regulation in several countries. As each design advances in the regulatory process, it is helping to pave the way for other SMRs to follow.

NuScale, an American company founded in 2007, became the first SMR to receive a standard design approval from the NRC, in 2020 for its LWR design. This means that NuScale customers have assurance that the design's safety aspects are approved by the NRC.

Last year, NuScale opened a simulation laboratory in Idaho Falls, Idaho, at the Center for Advanced Energy Studies, about 50 miles from the Idaho National Laboratory site planned for its first SMR. The target date for full SMR operation is 2030.

NuScale has submitted a pre-licensing vendor design review to the Canadian Nuclear Safety Commission and has signed a Memorandum of Understanding (MOU) with Ukraine's State Scientific and Technical Center for Nuclear and Radiation Safety, with the Kazakstan company KNPP, and with several European companies.

The company has private investors as well as government funding.

"At some point we will get there; it's just going to take a little time … and resources."

-Anna Bradford, Director, Division of New and Renewed Licenses, NRC, in WNA webinar

"We are all a little bit poisoned by old nuclear thinking that everything takes decades … over-pessimistic.

-Rafal Kasprow, CEO, Synthos Green Energy, in WNA webinar

SMR Progress Worldwide

Many SMR designs are advancing through the licensing process worldwide.

Some highlights:

- Belgium has an FNR research reactor in pre-licensing.
- China has an operating experimental fast reactor, and Chinergy is constructing two small HTRs, while a floating SMR is in preliminary licensing stage.
- Canada has several SMRs in pre-licensing, including HTGRs, an FNR, an MSR, and three LWRs. Global First Power Ltd. announced in May 2021 that its SMR design had moved to the technical review phase, with plans to build a Micro SMR by 2026.
- France is in preliminary discussions for a PWR.
- The Republic of Korea has a PWR in pre-licensing.
- Russia has a floating PWR in operation, a lead-cooled FNR with a construction license, and early licenses for LWR reactors.
- In the UK, Rolls Royce announced in November 2021 that it had received a government grant of $285 million for its PWR design, plus more in private funding, and is moving forward with preliminary government discussions. Additionally, in December 2021 the Qatar Investment Authority made an investment of GBP85 million ($112 million) to secure a 10% shareholding in Rolls-Royce SMR Ltd.
- The USA has several SMR designs in pre-licensing with the NRC.

Conclusion

A brief review of SMR licensing progress worldwide is encouraging. Many projects are advancing, and intend to operate or be near to operating in the next 10 years. More experienced SMR vendors are in preliminary licensing discussions with less experienced or first-time nuclear nations.

An unprecedented level of international collaboration with nuclear vendors and regulators has created a new, more favorable situation. The detailed reports of the IAEA, WNA, and other industry groups have prepared a deep foundation for applicants to rely on. Companies more advanced in SMR licensing have provided specific recommendations for newer companies.

Challenges remain for SMR designs, including the hurdle of public acceptance, especially if plants are located near cities. But the market is there, the governments are willing, and the prospects for realizing the promise of SMRs are good and getting better.

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