Small Modular Reactors Regulators' Forum

Working Group on

Licensing Issues

<u>Phase 2 REPORT</u>

June 2021

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EXECUTIVE SUMMARY

There is a sustained global interest in small modular reactors (SMRs), which have the potential to play an important role in globally sustainable energy development as part of an optimal energy mix. Such reactors have the potential to enhance energy availability and security of supply in both countries expanding their nuclear energy programs and those embarking on a nuclear energy program for the first time.

The SMR Regulators Forum was formed in 2014 to identify, enhance understanding of and address key regulatory challenges that may emerge in future SMR regulatory discussions. This is expected to help enhance safety, efficiency in SMR regulation, including licensing, and to enable regulators to inform changes, if necessary, to their requirements and regulatory practices.

The Forum entered its second phase in 2017, following up on the work carried out in previous years. This document is the Phase 2 Final report of the Licensing Issues Working Group. Appendix A shows the list of the contributors to the report.

The following three topics are being covered in the second phase which was completed at the end of 2020:

- Key regulatory interventions
- First Of a Kind vs Nth Of a Kind
- Licensing of multiple module/unit facilities

This report was developed based on information, insights, and experience gained from the regulatory activities of the SMR Regulators' Forum members. It is considered to be generally consistent with existing IAEA documents but may deviate in some cases. This report is intended to provide useful information to regulators and industry in the development, deployment and oversight of SMRs.

Introduction

Content of the report

This report is divided into a high-level description of the main common positions of the authors of the report and three main technical chapters:

Chapter 1: Key regulatory interventions

This chapter discusses the licensing processes and regulatory challenges arising from the various potential SMR deployment models as well as the potential key regulatory interventions within the process for the regulatory oversight of the said deployment.

Chapter 2: FOAK vs NOAK Designs

This chapter discusses potential issues related to the licensing process within a Member State for a first of a kind (FOAK) SMR project, and how the safety case may differ from that of a Nth of a kind (NOAK) SMR projects (serial production).

Chapter 3: Licensing of multiple module/unit facilities

This chapter discusses how multi-unit/modules potential features such as a) ownership model, b) single license for several nuclear cores , c) sharing of systems important to safety, d) sharing of personnel, e) common control rooms, may or may not have an impact on the licensing process of an SMR.

Common positions

Common Positions for Chapter 1 - Key Regulatory Interventions

- "key regulatory intervention" (KRI) is a term which describes a strategic regulatory point of interest during the lifecycle of an SMR. A KRI could range from a higher level of regulatory involvement or scrutiny to pauses in the licensee's activities (hold point) until the regulatory authority has issued an authorization to continue work.
- Regulators need to ensure the licensing process facilitates efficient and effective validation of the safety case, which in turn facilitates efficient progression of regulatory activities. The steps (e.g., construction, operation, decommissioning) of the licensing process should be discrete and follow a logical order.
- Experience has shown that licensing stages (as described in IAEA Safety Guide SSG-12. [1]) may overlap; i.e., one stage may start before the previous one is fully completed.
- Regulators have shown that effective pre-licensing interactions can be a positive experience for both reactor vendors and regulators.
- Regulators should ensure that applicants/licensees have the capabilities to work with vendors to understand where KRIs may emerge.
- Regulators should consider implementing KRIs for areas known to be of higher safety significance. That is, if not completed properly by the licensee, they could present as safety issues or latent flaws that could challenge licensing and operational safety

- The modularity, transportability, and modularity of SMRs may result in a regulator needing to implement KRIs that might not be considered or relevant in traditional nuclear power plant facilities

Common Positions for Chapter 2 - FOAK vs NOAK designs

- Regulators need considering the deployment of SMRs would benefit by understanding what is different about FOAK designs and how they would evolve towards NOAK designs. This is especially true for emerging countries
- Regulators need to be mindful that there are many new players in the SMR market, some of whom might not have the experience (both vendors and licensees) expected of more mature nuclear proponents (experienced nuclear plant operators).
- Additional demonstration requirements are expected for FOAK designs due to lack of operating experience of the design.
- Regulators must also consider the amount of experience they have with respect to technologies that are being assessed/deployed. Targeted training programs to help develop regulatory knowledge should be considered if needed.
- Regulatory bodies need to have enough flexibility to ensure safety throughout the lifecycle of any design type – especially for FOAK SMRs design and evolving into NOAK design.
- Regulators need to be able to take into account lessons learned across all SMR licensing stages (e.g., design, construction, operation, decommissioning) in a manner which keeps pace with evolving techniques
- Regulatory bodies need to provide stability in their regulatory frameworks as a design evolves from FOAK to NOAK, and enforcing high level safety principles and the application of a graded approach
- Regulators should emphasize that FOAK designs might have to employ additional features in order to provide enough margin to overcome unknowns in their design. These may include additional instrumentation, start-up control, operational controls, commissioning tests, or controls during early operations.
- regulators need to carefully consider how incremental design changes module by module can impact safety as an FOAK design evolves to an NOAK design
- Regulators need to strike a balance between pragmatically allowing designs to evolve while maintaining or improving safety.

Common Positions for Chapter 3 - Licensing of new build projects with multiple module/unit facilities

<u>SMR ownership / licensee models</u>:

- Regulators should ensure that the Licensee has relevant capability and competence as defined in the licence.
- Regulators need to ensure that any adjacent facilities / sites have a co-operation agreement in-place for the management arrangements covering emergency response or security, etc.
- The Regulatory Body would expect a single licensee, even though the ownership of a number of reactors (or % share) could be owned / funded by different organisations.

- Regulators need to have means in place to ensure that the licensee have appropriate control and oversight of their staff and key contractors.
- Regulators need to ensure that licensees have clear contractual arrangements in place for shared personnel in order to ensure that shared personnel do not compromise the safety of a licensed facility.

Multi-module/unit licensing, - shared safety systems:

- Regulatory bodies must ensure safety functions are demonstrated to be available for all modules/units when needed.
- When an SSC important for safety is shared, regulatory bodies must ensure that the risk contribution to the aggregated risk of the overall plant is considered.
- Regulators must ensure that the safety case demonstrates that there is enough ultimate heat sink capacity to perform required safety functions for abnormal and accident conditions for the combined heat loads from all modules/units.

Shared personnel:

- Regulatory bodies must require that processes are in place to ensure that shared personnel or services are available when required for safety reasons.
- Regulators must verify that controls are in place to ensure shared personnel are familiar with all the different designs and procedures they work with (i.e. be competent in what they do).
- Regulatory bodies should require demonstration that emergency plans cover the entire site and include multi-unit events.
- Regulatory bodies should require demonstration that security plans cover the entire site and consider multiple reactor designs.
- Regulatory bodies should ensure there are provisions for site-wide drills for security and emergency response that are graded to the overall safety case for the site.

Shared control rooms:

- Regulators should assess in the licensing process the justification for the amount of control room staff, sufficient consideration of HFE, and the licensee's configuration control process (including training of staff or updating procedures when the configuration changes).
- Regulators must ensure that licensees demonstrate that the proposed operating models are capable of meeting all safety requirements.
- The regulatory body should include configuration control in its inspection program.
- Regulators should encourage training utilizing a simulator and be flexible on the location of such simulator facilities.
- Regulators should ensure that the loss of the common control room is considered in the licencing basis.
- Regulators must ensure that operator error is accounted for in the licensing basis.

1. Chapter 1: Key regulatory interventions

1.1 Objectives

This focus of this Chapter is to:

- identify the potential licensing stages unique to the lifecycle of an SMR
- describe the considerations that support the choice of key regulatory interventions (KRIs)
- propose KRIs in the lifecycle of an SMR

1.2 Introduction

1.2.1 Context

For the most part, traditional nuclear power plant lifecycles have been fairly consistent, with a facility generally going through the following high-level stages of activities, as defined in IAEA SSG-12, Licensing Process for Nuclear Installations [1].

Lifecycle stage per IAEA SSG-12, *Licensing Process for Nuclear Installations*	Typical activities conducted during lifecycle stage
Siting and site evaluation	Site characterization and comparison of generic design(s) to the site characteristics
Design	Site-specific reconciliation against a chosen specific design
Construction	Construction that could include cold (fuel-out) commissioning activities
Commissioning	Fuel-in commissioning with a critical reactor
Operation	Commercial operation and maintenance evolutions – includes ongoing radiological and hazardous waste management
Decommissioning	Facility disassembly and site remediation
Release from regulatory control	Site hazards below threshold that merit control by the licensee – transfer to long-term monitoring under institutional control

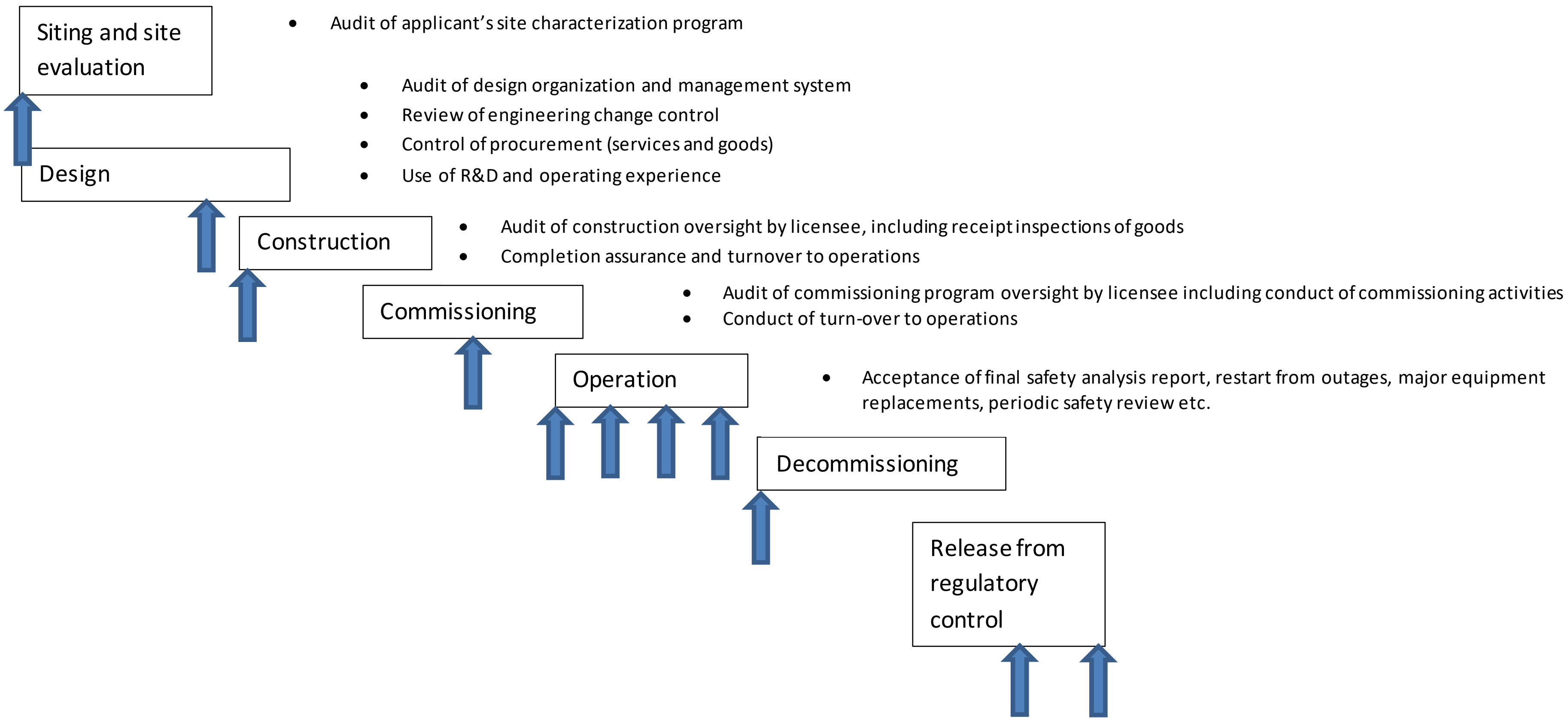
In accordance to the set of IAEA Safety Standards and Guides, regulators strive to implement licensing processes that are clearly defined and communicated, systematically performed, transparent and traceable through proper records management. The licensing process should be established to facilitate effective and efficient validation of safety, which in turn facilitates efficient progression of regulatory activities. The steps of the licensing process should be discrete and follow a logical order.

Figure 1 shows the main stages dealt with in the licensing process for traditional nuclear power plants according to SSG-12 [1]. Experience has shown that stages may overlap; i.e., one stage may start before the previous one is fully completed. The blue arrows represent potential key regulatory interventions (KRIs) along the process, for illustrative purposes only.

The above approach has been proven for traditional nuclear power plant licensing. SMR proponents are proposing some different and unique approaches to plant lifecycles, and this may pose challenges to the traditional view of the licensing approach.

The modularity inherent to SMRs introduces new challenges to the SMR lifecycle, mainly associated with the construction, commissioning, operation and maintenance (OM), and decommissioning stages.

Figure 1: Lifecycle steps for a traditional reactor (new build) – Taken from SSG12 [1]



1.3 Key regulatory interventions

For the purpose of this document, the Licensing Issues WG proposes introducing the term "key regulatory intervention" (KRI) to describe a strategic regulatory point of interest during the lifecycle of an SMR. A KRI could range from a higher level of regulatory involvement or scrutiny to pause the licensee's activities until the regulatory authority has issued an authorization to continue work.

The WG initially considered using the term "hold point" since the IAEA also uses it. However, since this term is not defined in the IAEA's Safety Glossary [2], not all countries use it during the licensing process of a reactor and its meaning could vary from one country to another. Therefore, the WG decided to use the term "key regulatory intervention", as it is more generally applicable than "hold point".

In a given lifecycle stage, there may be several KRIs set by national legislation and regulatory requirements. These KRIs give the regulatory body the power, aside from the typical oversight program, to ensure that risks to the health and safety of people and to the environment from nuclear installations and their activities are properly controlled by the persons or organizations responsible for the nuclear installations and their activities. The arrows in Figure 1 represent points in the licensing process where a regulator may choose to have or impose KRIs. The arrows are for illustrative purposes only and do not necessarily represent recommended KRIs. KRIs can be intrinsically built into a licensing process, by way of distinct licensing stages or regulatory process steps. KRIs may also be included within a licence and managed under compliance for that licence.

A KRI may originate from 2 different places, the first is KRI presented by the licence applicants' future conduct of activities and over which the licensees will have control over (for example requesting authorisation for specific commissioning activities). These are generally selected by the applicant to reduce regulatory uncertainty.

The second ones may be originated by the regulators or the designer based on the design activities. There may be outstanding issues from the design which would result in KRIs. For example, - evidence around FOAK design issues may need to be substantiated. In this case it is the responsibility of the applicant/licensee to identify those areas and address the potential risk to their specific new built project.

While it is recognized that disparity exists amongst member states on how pre-licensing interactions between regulators and reactor vendors should be held, experience has shown that pre-licensing interactions can be a positive and constructive approach for both reactor vendors and regulators. An optional design review certification process or non-binding pre-licensing review, which is normally conducted with a vendor, may not be able to predict all of the specific KRIs that a licensee would encounter in a new build project – but it can be helpful for KRI identification.

Applicants/licensees should have the capabilities to work with designers/vendors to understand where KRIs may emerge. From the beginning the applicant should provide a description of the different phases of the project and the proposed potential KRIs. The regulator should evaluate the KRIs to determine whether they are appropriate, keeping in mind that discussion of KRIs with vendors, licensees, and regulatory bodies is recognized as a good practice. Another good practice is recognizing that KRIs can and should be identified during all design and licensing phases (i.e. for the full lifecycle of the facility).

1.3.1 Methodology for determining KRIs

It is not feasible to define specific KRIs that would apply to all types of SMR facilities. However, some generic considerations may be useful in determining KRIs, such as:

- the level of risk or the safety significance of the lifecycle step being considered
- the level of complexity of the design or part of design subject of a potential KRI (e.g. integrated designs)
- the novelty or lack of proven-ness of the design or part of design subject to a potential KRI, in recognition of the need for operating experience to inform decision making
- design constraints (e.g., access limitations after a certain stage of construction)
- operational constraints (e.g., in-service inspection and maintenance constraints)
- other constraints (e.g., impossibility or difficulty to repeat the activity if not successful at first attempt)
- stage of lifecycle (e.g., manufacturing, fabrication, transportation, offsite commissioning) In some cases, potential KRIs may coincide with significant licensee project milestones, such as:
- turnovers of major project activities from one organization to another
- completion of excavation prior to first pour of nuclear concrete
- substantive completion of a portion of the project prior to onset of a major evolution for the next portion
- initiation of major commissioning milestones (particularly for a first plant)
- fuel arrival onsite
- loading of fuel into the reactor core

In other cases, KRIs may be at points where the regulator is seeking to confirm that sufficient confidence is demonstrated by the licensee (including licensee contractors and subcontractors) so that activities may proceed based on work-as-done. These areas of interest may be focused on:

- the need to confirm completion of activities important to the successful completion of future activities (e.g., safety analyses, designs, and specific studies – including required calculations, experiments and demonstrations)
- verifying that quality requirements have been met for work as-done (e.g., rebar position or quality of cured concrete)
- the licensee's program and process readiness for the activities to come

The common element of these considerations is that they are known to be areas of higher risk. That is, if not completed properly by the licensee, they could present as safety issues or latent flaws that could challenge the licensing and operational safety. For example, if concrete was not cured properly, this could reduce the capacity of the concrete to perform its function, and additional analysis and/or testing would be required to verify the concrete's ability to perform its intended function.

1.4 Potential stages for the lifecycle of an SMR

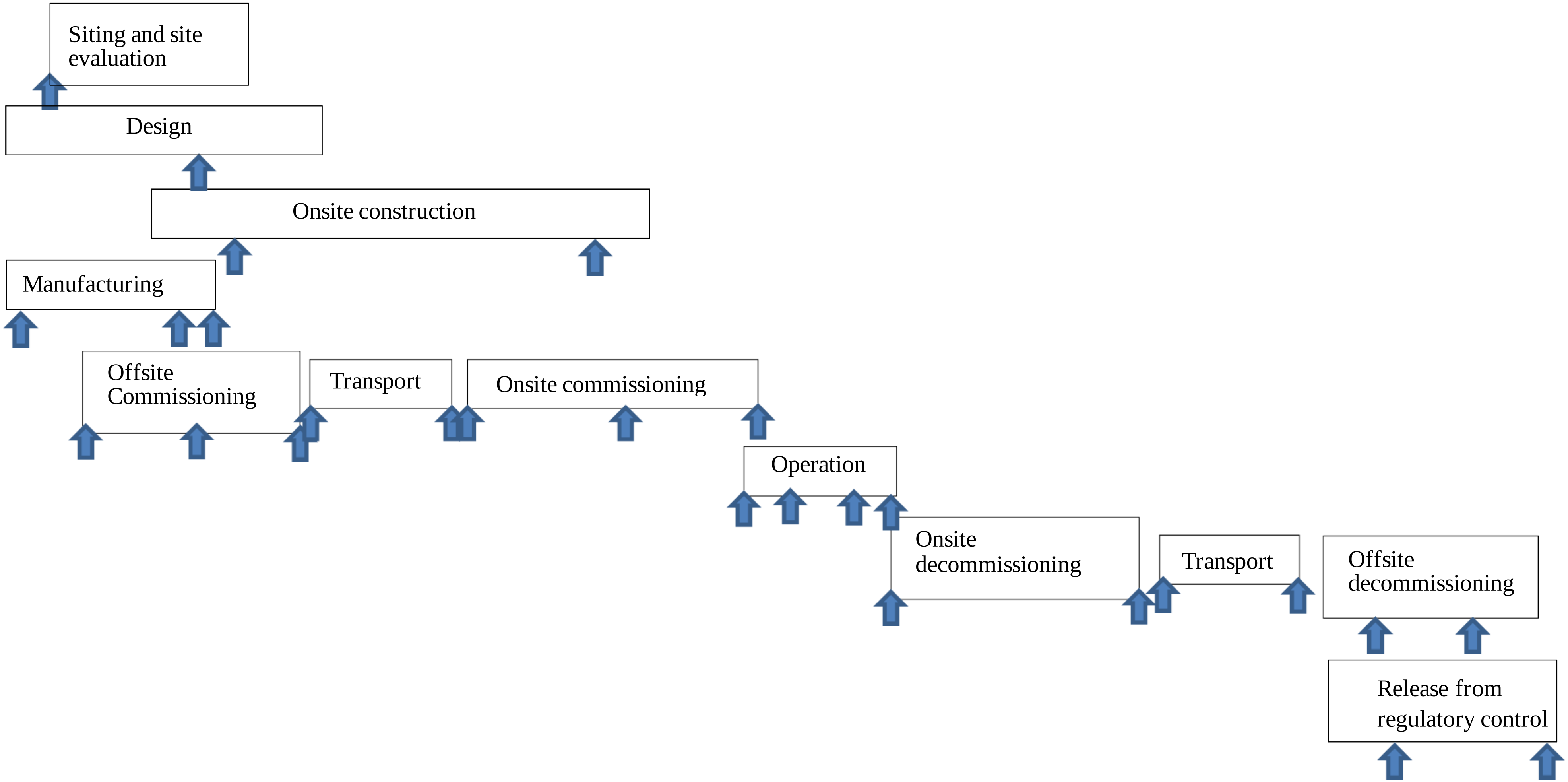
In addition to novel design features and approaches, SMR projects may introduce a number of differences to a new-build project – ranging from factory manufacturing and testing, to new construction and commissioning methods, to new programs for long-term operation and maintenance. These, in turn, may impact potential stages (as defined in IAEA SSG-12 [1]) for SMR licensing process and where KRIs might be based on the levels of risk introduced. As a first plant project has no operational experience, additional KRIs may be identified once the plant starts to operate.

The following are potential stages in the lifecycle of a SMR:

- siting and site evaluation
- design
- construction
- manufacturing
- offsite commissioning
- transportation (both to and from facility)
- onsite commissioning
- operation
- onsite decommissioning
- offsite decommissioning
- release from regulatory control

These stages are illustrated in figure 2. It is worth noting that each of these stages, which are further detailed in chapter 2 of this document, may not be needed for all SMR designs. The purpose of this diagram is to pictorially show how an SMR's lifecycle might be different than that of a traditional reactor shown in Figure 1. Spent Fuel and radioactive waste management may be an activity in the lifecycle of an SMR that is handled both during the above lifecycle stages of an SMR, and after a site is released from regulatory control. It is also worth noting that the regulatory body would seek assurances on the licensee's organizational capability to effectively oversee safety considerations at all stages of the lifecycle. This will be a subject of a dedicated report.

Figure 2: Sample SMR licensing process



1.5 Key regulatory interventions expected for each stage of the SMR lifecycle

Each potential licensing stage is discussed in this chapter in view of how KRIs might be introduced due to the unique licensing features of some SMR designs. This discussion is summarized in the table in Section 2.6.

1.5.1 Siting and site evaluation

All activities associated with the proposal, including the impact of construction and operation of multiple modules (or units) on a single site, should be considered in the licence application.

Where multiple modules are considered for a single site, the planned activities (i.e., construction, operation, maintenance and decommissioning) should be considered during site evaluation to ensure that it is possible to implement them on the site. This could include, for example, a preliminary aging management program for common services shared among modules – including civil structures, electrical systems, compressed air systems, pools, security, and emergency arrangements. This would be particularly important for cases such as:

- multiple-module SMRs where a licensee proposes to put only a few modules into service at the onset, with an option to install and operate more units in the future
- spent modules that may be removed and replaced with newer modules, which could differ technically from the original unit

The impact of adjacent units planned on a site, along with the proximity to population, also should be considered. In some cases, more than one licensee may be present on a site – and any possible interactions would need to be considered by all potential or current licensees. Impact of other facilities should also be considered as applicable – for example industrial facilities used for hydrogen production or water desalination.

Note: Similar considerations should be applied for floating reactors (for the facility where the reactor is fuelled) or any other novel approaches

1.5.1.1 KRIs for siting and site evaluation

Potential KRIs for siting and site evaluation could include:

- overall approval of plans for activities on the site
- environmental impact assessment results
- common workshop for maintenance and repair
- spent fuel and radwaste storage & management facilities

1.5.2 Design

There is no fundamental change in the design review process for an SMR vs. a large-scale design. However, due consideration should be given to first-of-a-kind (FOAK) designs, since these will differ in the type of evidence and operating experience available to support their safety cases.

In addition, regulatory agencies may need to adopt new guidelines/approaches adapted to SMRs in order to meet the underlying requirements or regulations.

Another challenge that arises with SMRs is the level of maturity of design organizations and licence applicants, some of them being industry newcomers with little to no experience in nuclear safety.

Regulators also should ensure that processes are in place to ensure efficient and effective knowledge transfer and an implementation of appropriate design authority scheme, from the designer to the licence applicant. This should be done together with the early engagement of regulators from the design phase and regulation process and strive to be as common as possible in all stakeholders' countries.

Finally, the design of onsite supporting systems should be evaluated in terms of overall plant safety.

1.5.2.1 KRIs for design

Potential KRIs for design include:

- approval that the reactor design is capable of meeting safety requirements
- approval that the balance of site would not negatively impact the safety of the facility

1.5.3 Manufacturing

There may be many different manufacturing models for SMRs. While these models vary widely, the goal of many SMR designs is to manufacture SMR modules offsite and then transport them to a site for installation and use. The engineered modules could be manufactured serially in a controlled factory environment. The premise is that factory manufacturing results in high-quality construction, short manufacturing times, and economies of scale. These engineered modules would be delivered from production factories to be assembled on the plant site, with the assumption that construction time would be significantly reduced. It is also claimed that some of the commissioning work could be done during manufacturing, reducing the onsite time to bring the plant to commercial operation. This concept has been proven in the shipbuilding and aerospace industries. Traditional reactor construction has also utilized this approach; however, some proposed SMR designs would use it on a wider scale – with some proposing to build, fuel and commission reactors before delivering them to site.

With the manufacturing model described above, there are two major differences compared to traditional reactors in that:

- assembly is mostly performed at the factory
- manufacturing and assembly may take place before the future licensee has decided to build the facility; i.e., prior to the beginning of any licensing process (reactor modules could be built and be available for immediate sale/use as part of manufacturing inventory)

There is a need to establish regulatory oversight for safety-related systems that are built and assembled in a factory. The level of regulatory oversight should be proportionate to the safety significance of the systems being assembled at the factory, and it should also consider the availability of onsite system inspection. The scope of regulatory oversight may be limited to the licensee's procurement process for systems that might be verified after onsite installation.

Additional consideration should be given to a manufacturing facility involved in fuel loading; these considerations should recognize safety, transportation, security and safeguards aspects.

For factory sites that are not licensed, or even for factory sites outside of the regulator's control, regulatory oversight should still be maintained through the availability of regulatory inspections. The type and depth of regulatory inspections should be commensurate with the importance of the components being assembled, as well as the ability to inspect them once installed at a site.

Another option for regulatory oversight might also include the qualification or certification of a manufacturer. This can be especially beneficial if reactor modules are manufactured by different manufacturers at different facilities, or if modules are held in inventory for long periods of time. As previously mentioned, it is conceivable that some modules may be manufactured before a site is chosen or prepared.

Finally, an additional challenge arises for components or modules that have been manufactured abroad. Regulators may consider developing processes for approval of components whose manufacturing they (or the licence applicant) have not been able to oversee. It may be worthwhile to consider exchanging knowledge with counterparts and applying the experience of other regulators, if available, to support the review. A common review amongst regulators should be considered where applicable.

1.5.3.1 KRIs for manufacturing

Potential KRIs for manufacturing include:

- licence or QA approval for manufacturers
- inspections of items before a point at which they cannot be further inspected (for example, after assembly)
- approval of modules before they are shipped to site (for modules manufactured before the current licensee and regulator were involved).

1.5.4 Construction

Construction time is expected to be shorter for SMRs than for traditional nuclear power plants. This is due to their smaller footprint, and the possibility that many key components might be manufactured offsite and then transported to the site for final inspection and installation (greater use of modularization).

For sites with multiple modules, the simultaneous construction of modules in parallel while other modules are operating should be considered. Any construction activity could pose an additional hazard to existing operating units in terms of safety and security and these must be considered in advance.

1.5.4.1 KRIs for construction

Potential KRIs for construction include:

- issuing a construction licence
- key construction activities (e.g., pouring of first concrete, adding new modules adjacent to operating modules)
- modification to the design of functionally safety-significant equipment or components during the construction phase

1.5.5 Offsite commissioning

Commissioning tests should be performed to confirm that design requirements have been achieved. The design should include the acceptance criteria of commissioning activities that are necessary and sufficient to provide reasonable assurance that, if these commissioning activities are performed and the acceptance criteria met, the as-built components will conform to the approved plant design and applicable regulations.

For some SMRs, offsite commissioning consists of the commissioning tests that are performed on a module (or other equipment) before it leaves the offsite assembly facility. Offsite commissioning activities are especially important when inspection of modules or parts of modules is not possible due to some components not being accessible. Some offsite commissioning might also represent the last opportunity a regulator has to inspect some portions of a module. Offsite commissioning may replace some onsite commissioning tests.

It may be easier to perform some commissioning offsite versus onsite – especially if the commissioning equipment needed to perform certain tests is not portable. The commissioning equipment can stay at the assembly facility, where it can be used for multiple reactor modules.

Offsite commissioning plans should also take into consideration possible damage during transportation – and also should consider the time between testing and module use; if there is a prolonged period between a piece of equipment or module is tested and its use, an appropriate asset care program should be set in place.

Regulatory agencies may expect the licensee's personnel to conduct or supervise offsite commissioning to ensure that appropriate commissioning standards are being adhered to, hence ensuring proper transfer of knowledge and responsibility to the licensee.

As for manufacturing, additional challenges may arise when offsite commissioning has been completed earlier, meaning that the regulator and the licence applicant would not have had the opportunity to observe the tests. A thorough and transparent documentation of the test performance (not only the results, but also test conditions, possible modifications to testing procedures, etc.) is crucial in these cases (for additional information, see MDEP Common Position CP-STC-01, Common Position addressing First-Plant-Only-Tests (FPOT) [3].

1.5.5.1 KRIs for offsite commissioning

Potential KRIs for offsite commissioning include:

- testing of items before they cannot be tested any more (for example, after assembly)
  - needs to be done supported by appropriate documentation
- the possible need for design specific KRIs (tests performed to demonstrate design requirements or commitments)
- fuel loading (if done off site)

- transportation (both to and from facility)

1.5.6 Transportation

Transportation of modules that are fuelled onsite is not expected to differ from transportation for large-scale reactors. However, additional checks may be expected once the module arrives at the designated location to ensure that no damage has been incurred during transportation.

For modules that are fuelled offsite, transportation introduces additional challenges, especially with respect to safety, security and safeguards and compliance with the transport regulations [4]. The complexity of the transport will increase if the transportation is done through different countries or international waters see.

The traditional model of reactor refuelling currently used at nuclear power plants around the world is to perform individual fuel element replacements at the facility site. Fresh fuel is delivered to the site in suitable packaging, and spent fuel is kept onsite in safe storage following removal from the reactor.

A number of SMR concepts consider using a compact nuclear core vessel that would either be entirely replaceable or that would have its entire fuel inventory replaced in a manner similar to a fuel cartridge. Using this approach, operators intend to reduce or even eliminate lengthy refuelling operations at the deployment site and possibly facilitate quicker removal from the deployment site. The spent fuel inventory might then either be stored onsite or shipped to another location (e.g., for refurbishment or disposal). Transporting reactor vessels is especially challenging, as there is no certified packaging that is large enough for most (or all) reactor cores. Proposals exist for shipping reactor cores that:

- are always defueled (for delivery to site, or removal from a site),
- are fuelled with fresh fuel (for delivery to a site)
- contain spent fuel (when removed from a site)

For regulating the transport of reactor modules that contain fuel, it is recognized that many safety, security and legal challenges arise, both on nationally and internationally. These challenges should be addressed separately.

1.5.6.1 KRIs for transportation

Potential KRIs for transportation include:

- licence/authorization for transportation
- verification that there is capability to transport large items
- inspection and configuration management before and after transportation
- module completion – before packaging for shipment
- after packaging for shipment
- before transport if the module is fuelled
    - safe and stable configuration
    - package certification
- acceptance at final destination

1.5.7 Onsite commissioning

Onsite commissioning consists of the commissioning tests performed on a module after it arrives from the assembly facility. There may be onsite commissioning both before and after the module is installed in its facility location.

Onsite commissioning plans should also take into consideration possible damage during transportation – and also should consider the time between any offsite commissioning testing and module use. KRIs might be transferred from the site to offsite – or from offsite to the site itself.

Continuity from offsite commission to onsite commissioning should be ensured.

Onsite commissioning should consider difficulties that may be introduced as new modules are added. Integration testing of all modules and systems also should to be taken into account.

1.5.7.1 KRIs for onsite commissioning

Potential KRIs for onsite commissioning include:

- commissioning without nuclear fuel
- fuel loading
- start of active commissioning (for each module or only first one)

1.5.8 Operation

Some SMR designs propose to have multiple smaller reactors operating on a single site.

The multiple reactor modules may have common services that are shared between modules, such as common control rooms, electrical systems, compressed air systems or civil structures.

For facilities with multiple modules, additional consideration should be given to the impact of activities involving some modules on the operation of the other modules. Such activities may include:

- bringing new modules onsite or installing a new module in the facility
- refuelling operations
- maintenance (which may include replacing a module)

When licensing an SMR site or facility, regulators should also consider:

- that some novel designs may need additional regulatory controls for operation
- that many operating concepts can be different from traditional reactors:
    - remotely operated facilities, no operators onsite
    - multiple modules operated from common control room by same operators
    - different companies for different actions (refuelling, maintenance.)
- security arrangements of remote sites
- accident response of remote sites
- multiple operators on one site
- length of the operating licence, interval of periodic safety reviews

1.5.8.1 KRIs for operation

Potential KRIs for operation include:

- first criticality / power ascension (several KRIs corresponding to ramp-up thresholds for the first module, as needed for subsequent modules, including shared systems)
- first-of-a-kind activities (e.g. refuelling, maintenance)
- possible regulatory controls during early operation
- major component replacements

1.5.9 Onsite decommissioning

Regulators should ensure that SMRs have credible decommissioning plans and that they consider any novel technologies in use. Some SMR facilities could have sequenced decommissioning, i.e., some modules may still be operating while some are decommissioned. This could lead to decommissioning personnel working close to operating modules. Security and safety issues should consider these cases.

1.5.9.1 KRIs for onsite decommissioning

Potential KRIs for onsite decommissioning include:

- establishment of the spent fuel and radioactive materials management plans
- site clearance or reuse for new plants
- permit/licence to start decommissioning activities
- establishment of fuel disposal plans

1.5.10 Offsite decommissioning

if offsite decommissioning is necessary for a specific design, it could include defueling, decontamination and disassembly of components. The licensee of an offsite decommissioning facility may be different than the licensee that operated the reactor, with a transfer of ownership and liability from the operator to the decommissioning facility.

Unique regulatory perspectives for offsite commissioning can include disposal considerations for unconventional fuels, and various reuse or refurbishment possibilities for modules. For example, a reactor module may just need to be refuelled and key components inspected before redeploying at the same or different site where it came from. Decommissioning in an offsite facility would likely be more controlled than traditional onsite decommissioning activities.

1.5.10.1 KRIs for offsite decommissioning

Potential KRIs for offsite decommissioning include:

- the issuing of a licence for an offsite decommissioning facility
- before departure from the operating site
- on arrival at the offsite decommissioning facility
- in case of refurbishment, before departure from the decommissioning facility

- establishment and approval of waste disposal routes

1.5.11 Release from regulatory control

This stage is unlikely to present any significant difference from traditional reactors.

1.6 Overview of the licensing stages of an SMR lifecycle and proposed KRIs

The table below summarizes how KRIs might be introduced due to the unique licensing features of some SMR designs. Some sample questions are included in the table below.

Licensing stage	Questions to consider for development of KRIs for SMRs	Potential KRIs
Siting and site evaluation	• What is the maximum number of units proposed for the site? • Would there be any adjacent units? • Are there any shared facilities (pools, electricity, emergency arrangements)? • What is the proximity to population? • What is the size of the EPZ? • Will there be several licensees to one site?	• Overall approval of plans to do activities on the site • Environmental impact assessment results
Design	• What additional regulatory oversight should there be due to the novelty of the design? • How confident is the regulator with the transfer of knowledge from the designer to the operator?	• Approval that the reactor design meets safety requirements • Approval that the balance of site does not negatively impact the safety of a facility

Manufacturing	• How much factory testing and regulatory involvement is needed at the factory? • Is fuel loading taking place at a factory? If so, a license is likely to be needed (who would be the licensee in this case?) • Are more inspections at the manufacturer's premises needed? o What if the Manufacturing of modules is done overseas? • What is the maturity of the manufacturers? Is additional oversight necessary? • Will modules be held in inventory for a long time? What would be the impact? • Have modules been manufactured by different suppliers at different facilities?	• license or QA approval for manufacturers • Inspections of items before they cannot be inspected any more (after assembly…) • approval of modules before they are shipped to site (for modules manufactured before the current licensee and regulator were involved).
Construction	• What if construction of modules happens simultaneously with operation? • Is construction an external hazard to existing units?	• Issuing a construction licence • Key construction activities (e.g. pouring of first concrete) • modification to the design of functionally safety significant equipment or components during the construction phase
Off-site commissioning	• Are Inspections possible after assembly and commissioning? Are all components accessible? • Are any on site commissioning tests being replaced by offsite work? • Are tests being performed in a controlled environment (positive aspect)? • Are any outstanding KRIs being transferred to later in the build schedule? • Can some KRIs be conducted during on-site versus off-site commissioning?	• Testing of items before they cannot be tested any more (after assembly…) • Design specific KRIs might be needed (tests performed to demonstrate design requirements or commitments) • Fuel loading

Transportation	• Who is responsible during transport?
	• Are the modules fuelled?
	• What are the recovery scenarios for unplanned events during transport of fuelled modules?
	• What are the transfer routes and methods?
	• Are there any transborder (national or international) transfers?
	• What security arrangements need to be implemented?
	• What is the inspection routine?
		• Licence / authorization for transportation
		• Module completion – before packaging for shipment
		• After packaging for shipment
		• Before transport if the module is fuelled
		  o safe and stable configuration
		  o package certification
		• Acceptance at final destination

On-site commissioning	• What is the impact of reduced on-site commissioning due to modularization and off-site commissioning? o E.g., for battery type reactors only minimum on-site testing may be proposed • Are the impacts of possible transportation damage being considered? • What is the impact of serial commissioning as new modules are added?	• Commissioning without nuclear fuel • Fuel loading • Start of active commissioning (for each module or only first one)

Operation	• What are the multi-module considerations? E.g., in the same building, can there be modules in different phases
	• Should there be any KRIs due to novel designs?
	• Should there be any KRIs based on different operating concept? E.g.,
	  o remote control, no operators on site
	  o multiple modules operated from common control room by same operators
	  o different companies for different actions (refuelling, maintenance.)
	• Should there be any KRIs as a result of the site being remote – particularly related to security arrangements and/or emergency response?
		• First criticality / power ascension (several KRIs corresponding to ramp-up thresholds for the first module, as needed for subsequent modules - including shared systems)
		• First of a kind activities (e.g. refuelling, maintenance)
		• Possible regulatory controls during early operation
		• Major component replacements

	• Are there multiple licensees on one site? • What is the length of the operating license? Interval of periodic safety reviews?	
On-site decommissioning	• Is there sequenced decommissioning? i.e., some modules may still be operating while some are decommissioned o Are decommissioning personnel working close to operating modules? Does this introduce security issues etc. • Is there a credible decommissioning plan considering novel technologies?	• Permit/license to start decommissioning activities • Establishment of fuel disposal plans
Off-site decommissioning	• Would there be a different licensee for off-site decommissioning? • Are there considerations needed for the disposal of unconventional fuels? • Are there any refurbishment intentions for components or modules?	• Issuing a license for an off-site decommissioning facility • Before leaving the operating site • On arrival at the off-site decommissioning facility • In case of refurbishment, before leaving the decommissioning facility • Establishment and approval of waste disposal routes
Release from regulatory control	• N/A	• N/A

2. Chapter 2 - First Of a Kind vs Nth Of a Kind

2.1 Objectives

The focus of this Chapter is on the considerations for a licensing process within a Member State for a first of a kind (FOAK) SMR project and where a safety case may differ from that of Nth of a kind (NOAK) SMR projects (serial production) from a licensing perspective. In general, safety regulations and guidance do not differentiate between FOAK facilities and NOAK facilities. Regulators need to strike a balance between pragmatically licensing SMR activities while maintaining safety as SMRs evolve from FOAK to NOAK designs.

2.2 Introduction

The IAEA Safety Glossary {2] defines a **licence** as:

1. A legal document issued by the regulatory body granting authorization to perform specified activities relating to a facility or activity.
    a. A licence is a product of the authorization process (although the term licensing process is sometimes used), and a practice with a current licence is an authorized practice.
    b. Authorization may take other forms, such as registration or certification.
2. Any authorization granted by the regulatory body to the applicant to have the responsibility for the siting, design, construction, commissioning, operation or decommissioning of a nuclear installation.
3. Any authorization, permission or certification granted by a regulatory body to carry out any activity related to management of spent fuel or of radioactive waste.
    a. The definitions (2) and (3) from the Conventions [5, 6] are somewhat more general in scope than the usual IAEA usage in definition (1).
    b. In IAEA usage, a licence is a particular type of authorization, normally representing the primary authorization for the operation of a whole facility or activity.
    c. The conditions attached to the licence may require that further, more specific, authorization or approval be obtained by the licensee before carrying out particular activities.

Licensing basis is defined by the IAEA as:

- A set of regulatory requirements applicable to a nuclear installation.
    - The licensing basis, in addition to a set of regulatory requirements, may also include agreements and commitments made between the regulatory body and the licensee (e.g., in the form of letters exchanged or of statements made in technical meetings).

Regulators are either engaging or are preparing to engage with proponents who are preparing safety cases (A safety case is a general term which encompasses all of the items which an SMR proponent would prepare to demonstrate safety in support a licence application to a regulatory body. This is often summarized in [7]) that will involve the demonstration of safety to support the use of an SM [8] technology(ies). These proposals may pose challenges to some aspects of the licensing process that has been followed for traditional nuclear power plants. This is because of the use of novel approaches in the design and the safety demonstration of these technologies. It has been recognized that regulators need to strike a balance between pragmatically allowing designs to evolve while maintaining safety. Although graded approaches could in principle be used to overcome some of these issues, the SMR Regulators' Forum agreed that clarification is needed on the regulatory view of grading and what this means in the context of addressing novel approaches being proposed for SMRs in the area of licensing.

Within this context, the Licensing Issues Working Group was instructed to:

- Understand how the participating Member States address FOAK facilities, as opposed to NOAK facilities, in their regulatory frameworks for licensing
- Illustrate how technology readiness levels for different SMR technologies may impact the information needed to support safety claims in the licensing process
- Develop common position statements and discuss how enhanced cooperation could be undertaken by this working group in areas such as:
    - the application of the graded approach in technical assessment and the overall regulatory inspection program
    - the nature of evidence available and impacts on the use of a graded approach when supporting safety claims in decision making
    - the impacts on licensing and regulatory approaches to address uncertainties associated with the outsourcing of activities, considering the modular design approach and the fact that significant decentralization of design and safety analysis activities is occurring in SMR development

Interest in SMRs has surged worldwide. All new SMR designs share one characteristic: they all are first of a kind (FOAK) with innovative technologies and systems. The licensing of such reactors requires additional care, which has to be balanced against the theoretical safety benefits of SMRs as opposed to traditional nuclear power plants.

This Chapter aims to examine the licensing issues for FOAK versus NOAK designs, by:

- discussing the extent of licensing review for FOAK as compared to NOAK designs
- examining what level of proven-ness, credibility, margins are needed for FOAK designs
- discussing what additional R&D will be needed to provide credibility for NOAK plants
- identifying strategies and best practices for licensing designs with different maturity levels

2.3 What is an FOAK reactor?

Every Member State may have a different understanding of what constitutes an FOAK reactor. In some countries, an FOAK may be associated with a scaled prototype for the purpose of gathering scientific knowledge as part of a coordinated research and development program. In others, an FOAK may simply be a first new-build project of a design already established in another country, where a state of technology proven-ness may already have been established but needs to be evaluated against the importing country's regulatory requirements.

For the purposes of this report, an FOAK reactor facility is considered to be in between the above two scenarios and has the following characteristics:

- a fully functional integrated facility which may include additional features built in to support any technological demonstration activities
- Experience in the construction and operation of this specific design is non-existent or very limited
- The design contains a number of new technological features or operating approaches that have not yet been fully proven in an integrated manner and in commercial use
- Experience with the application of industrial standards for these specific approaches remains new for both licensees and regulators
- Operation of the FOAK plant may be used to develop operational experience and complete integrated specific R&D and engineering optimization activities to address technology uncertainties and support a future domestic or international fleet
- It is manufactured and constructed in a more traditional manner, contrary to the long-term objective of factory manufacturing, until construction and manufacturing practices are optimized for mass production
- Deployment approaches may vary from traditional methodologies, requiring a more novel approach to licensing

In addition to the above, an FOAK may be a commercial facility projected to operate over a full lifecycle. Alternatively, depending on the licensees' objectives, the FOAK reactor may see earlier removal from service and alternate decommissioning strategies. This must be factored into the overall licensing program, but the licensing process ultimately remains the same as for a commercial facility.

An FOAK design may not yet be completely proven. As such, information (including operational experience) from the FOAK reactor may prove useful when licensing the Nth of a kind (NOAK) design. Information gathered by the licensee may include such things as:

- understanding of nuclear core performance under different operating conditions
- demonstration of operating concept (e.g., human machine interface validation)
- new materials and chemistry environments (understanding aging mechanisms)
- final stage of new fuel qualification testing
- testing of alternative product streams, the facility may produce (e.g., hydrogen)

Typically, FOAK facilities integrate prototypical systems from independent engineering efforts. As a result, integrated testing and operational evolutions may be performed in the FOAK facility to gather additional information on overall behaviours and performance of the complete design under real nuclear conditions.

The intent of many SMR manufacturers is to end up with a final, proven design which can be built repeatedly. It is recognized that the 2nd of a kind of a facility may not be the final design, and minor design variances may emerge in a multiple-unit facility based on manufacturing, construction and commissioning experience. NOAK design stability may vary from design to design.

2.4 Levels of design maturity, proven-ness, credibility and margins for FOAK

FOAK designs will differ in the type of evidence and operating experience available to support their safety case. While regulatory perspectives or expectations may be different for different member countries, a FOAK licensing review is expected to be a review where the design is not completely proven (eg. a design that has previously been proven in equivalent applications or based on items of high quality and of a technology that has been qualified and tested). There may not be specific national or international standards in place to support all engineering approaches for the technology. More unknowns in the design are expected for FOAK.

The IAEA Safety of Nuclear Power Plants: Design (SSR-2/1), Rev 1 [9], Requirement 9 indicates that "where an unproven design or feature is introduced or where there is a departure from an established engineering practice, safety shall be demonstrated by means of appropriate supporting research programmes, performance tests with specific acceptance criteria or the examination of operating experience from other relevant applications. The new design or feature or new practice shall also be adequately tested to the extent practicable before being brought into service and shall be monitored in service to verify that the behaviour of the plant is as expected."

The licencing WG recommends that an additional approach to offset any design uncertainties in a FOAK reactor, may imply a safety case which is more comprehensive and conservative than one for a NOAK reactor, including:

- more conservatism in the design, increased design margins (e.g., thicker concrete, more margins in reactivity control, more heat removal capacity, etc.)
- an emphasis on simulations
- additional safety features (e.g., supplementary active shutdown means)
- more stringent/conservative operational limits (e.g., limiting operation to something less than full power)

Information supporting the application must be of high quality and describe in sufficient detail how proposed approaches in lieu of evidence and operating experience will ensure safety. Credibility and fidelity of data and test results that are relevant to SMR design is needed. This information should be used as part of a regulatory discussion on the applicant's use of informed engineering judgment.

Successful approaches may include the use of available codes and standards coupled with:

- experimental information
- supplementary safety analyses (including analyses of uncertainties)
- conservative approaches

By their nature, FOAK facilities can present additional risks as a result of the uncertainties being resolved through testing under realistic conditions. In addition, many SMR designs rely on passive design features and functions, which present an additional layer of uncertainties due to their innovative character. Best practices related to regulatory design or licensing review of passive features and functions should be applied.

The licensing process should be designed to confirm that these risks are being addressed in all areas to ensure that the activities conducted using the FOAK facilities are done so safely. Applicants should be encouraged to leverage relevant information from other Member States who have licensed FOAKs.

In the deployment of FOAK SMR designs, it is expected that many new players will be involved that may not have a lot of experience in the nuclear industry. These might include suppliers, SMR designers, licensees and even regulators. Conservative regulatory approaches must take into consideration all unknowns – including those of regulators, suppliers or licensees. SMR proponents and regulators need to work together to share knowledge in an effort to help overcome FOAK issues that many SMR designs might bring.

As SMR designs evolve towards NOAK designs, many SMR proponents plan on exporting their designs for licensing in other countries. In such cases, it is often the regulator that may need some training or additional help in order to better assess a licence application. In such cases, regulator to regulator training and, or IAEA support in the application of the safety standards to SMR technologies should be utilized to help facilitate regulator learning. A well-informed regulatory body helps ensure safety.

2.5 Use of a graded approach in licensing an activity using an FOAK design

Graded approach is defined by the IAEA Safety Glossary [2] as a process or method in which the stringency of the control measures and conditions to be applied is commensurate, to the extent practicable, with the likelihood and possible consequences of, and the level of risk associated with, a loss of control. The use of a graded approach is intended to ensure that the necessary levels of analysis, documentation and actions are commensurate with the magnitudes of any radiological hazards and non-radiological hazards, the nature and the particular characteristics of a facility, and the stage in the lifetime of a facility. A graded approach should be used in order to place an appropriate amount of regulatory scrutiny on activities, depending on the level of risk. Primary considerations for the extent and depth of application are the degree of novelty, complexity and potential harm posed by the proposed activity or facility. The degree of scrutiny, which may vary either upward or downward, is further informed by:

- technical assessments of submissions
- relevant research
- information supplied by proponents

Extra care should be taken when reviewing the safety case to ensure that the impact of failures of any system is sufficiently understood. As an FOAK design evolves, it may be expected for safety classifications of SSCs to change (i.e. as the design becomes more proven in one area, extra conservatism in other areas may be removed). When considering activities which use FOAK designs that may not be fully proven, more detail is needed for safety-significant systems and equipment, while less design detail might be needed for systems and equipment that are relatively less safety significant.

The use of a graded approach is not limited to regulators – proponents or licensees may be expected to use it when exercising prudent engineering judgement. A licensee must have competencies and processes in place to apply the graded approach when issuing specifications to procurement and evaluating the evidence in support of their licensing safety claims.

The objective of using a graded approach should be to limit to a reasonable level the risks associated with any licensed nuclear activity. How the graded approach is used for meeting commonly understood requirements and guidance may change as the design of an FOAK facility is better understood, R&D and operational experience is gathered or as the design of a facility evolves.

In cases where the existing regulatory framework does not sufficiently cover a unique situation or novel case, regulators should consider modifying the requirements and guidance or allowing the use of alternative approaches to meeting regulatory requirements or following guidance. If an alternative approach is used, it should result in an equivalent or superior level of safety. High level requirements and safety principles help regulators to safely and fairly evaluate a wide variety of FOAK design challenges that SMRs are potentially introducing. The best way to keep pace with evolving SMR technology is to apply high level safety principles in a manner which utilizes a graded approach.

As in the case above, if technical evaluations conclude that an activity which meets requirements and follows guidance in the regulatory framework does not provide adequate protection in an area, a graded approach should be used to ensure that a facility has more protection in place to ensure safety (i.e., grading should be used to ensure that a facility is grading in the direction of greater safety).

The magnitude of the safety margin should be considered when evaluating the overall safety of an activity. Activities or proposed activities that would cause safety margins to be thin need to be demonstrated with greater reliability and precision than activities that have larger safety margins.

All regulatory decisions, including those using a graded approach, need to be well documented through formal management system processes.

Graded approach methodologies are used to 'right-size' the review scope of licensing efforts to ensure safety objectives of member states are met in a manner that is appropriate for the level of risk an SMR presents, with enough consideration of associated uncertainties. More design detail should be expected for safety-significant systems and equipment, and less for less safety-significant For example, depending on a system's provenness and contribution to safety, an analysis alone may be sufficient instead of imposing a test for validation. A graded approach should be used to determine the level of substantiation in design needed for regulatory findings or decisions.

2.6 Research and development

As mentioned, FOAK design are expected to have areas of their technology and design which are not completely proven. Research and Development is the work undertaken on a systematic basis to increase the stock of scientific and technical knowledge to help address proven-ness gaps.

In some cases, there is a wealth of information available on technical approaches from other industry sectors or research efforts. This information may be leveraged to support safety claims but supporting information must also address any specific considerations of the proposed activity that may influence the R&D results. For example, materials exposed to the environment inside a nuclear reactor must be able to remain fit for service in that environment for the reactor's service life. This means that additional analysis or R&D activities may be necessary to complete already existing information, especially for FOAK undertakings.

SMR developers are also conducting their own R&D to help address uncertainties, including the use of an FOAK plant to perform the R&D activities necessary to support licensing of future projects (i.e., address uncertainties associated with various new technological approaches). Licensing lessons, operating experience, and benefits from FOAK experiences should be applied to activities involving NOAK designs. Uncertainties in the design, construction, and operation of an FOAK facility need to be systematically identified and planned for. The plans developed for FOAK may need to perpetuate through NOAK via operating experience. This includes the likelihood that FOAK designs will require additional instrumentation, start-up control, operational controls, commissioning tests, and controls during early operations. As R&D help build the knowledge base around an SMR, lessons learned can be used for NOAK designs. As SMR deployments evolve from FOAK to NOAK designs, regulators and licensees must carefully consider how incremental design changes module by module can impact safety.

R&D plays a major role to help prove the safety case of FOAK designs – and eventually the information gleaned should also helps inform NOAK licensing efforts. Regulators should recognize that R&D may also be needed for continuous improvement of safety through commissioning and operation of both FOAK and NOAK plants.

3. Chapter 3: Licensing of multiple module/unit facilities

Modularity is a defining concept of SMRs. However, it can be understood in several ways. In a similar way, the terms 'module' and 'unit' do not seem to have a unified meaning between SMRs designers. It may refer to a part of a reactor, to a core and its bare confinement, to several cores in a single plant. For instance, the 'module' may or may not be autonomous and does not include individual safety systems and safety support systems such as separate heat sinks or AC power. It was observed in some designs that the control room, reactor building and ultimate heat sink, as examples, can be common to several modules/units. In addition, some SMRs may use a single confinement common to several modules/units.

The Licensing Issue Working Group has decided to not try forcing a harmonized definition of those terms; as of today, they are too dependent on countries, reactor types, technologies and designer languages. However, it is worth pointing out the Pilot Project Report from phase 1 [10] of the Forum states Small Modular Reactors are "designed to allow addition of multiple reactors in close proximity to the same infrastructure". This close proximity of multiple reactors and the challenges it raises is the focus of this Chapter.

3.1 Objectives

This chapter aims at investigating how the following topics may or may not have an impact on the licensing process of an SMR, as well as providing recommended best practices for regulators on each:

- Ownership model: SMRs offer a potential for having several designs and several operators of different reactor cores on a single site. This may lead to additional challenges regarding emergency planning and response, strict liability, the use of common services and a conflict of support groups (shared maintenance…).
- Considerations of a single license for several cores/modules/units: some countries are pondering the benefits of issuing a single license for several reactor cores/modules/units, acknowledging for the necessity of incrementally bringing units/modules/cores online. The impact on the license of replacing an SMR once the fuel is spent (for relevant designs) is also worth considering.
- Shared systems important to safety: some designs propose systems important to safety be shared between several SMRs. It is worth examining how this specificity may have an impact on safety and on the type of license that could be issued to the SMR. Special attention should be paid to not overlap with the work of the Design and Safety Analysis working group.
- Shared personnel (exclusion control rooms): several teams, such as maintenance, emergency response, or training, are expected for some situations (design and country dependent) to be shared. It could be a maintenance team owned by a separate organization, or an emergency response team common to several owners on a same site. Each of these unique situations might raise a new challenge and has to be examined from a licensing perspective.

- Control room: some designers propose control rooms shared between several SMRs, a reduced number of operators in the control room per reactor core compared to large-scale plants, or even remotely operated facilities. Since these specificities are new for most countries, challenges arise when it comes to their acceptability.

3.2 Small Modular Reactor Ownership / Licensee models

3.2.1 Objectives for Ownership / Licensee models for Small Modular Reactors

SMRs offer a potential for having a variety of ownership models with, for example, several designs and several operators on a single site. This may lead to additional challenges regarding emergency planning and response, the use of common services and a conflict of support groups (shared maintenance, etc.).

3.2.2 Problem

SMRs may present some challenges in respect of new and novel ownership models, with the potential introduction of new organizations / investment bodies with limited experience in the nuclear sector. The Regulatory Body of the Member State should be mindful of the potential impact of these organizations and their relationship with the licensee(s). SMRs may follow an ownership / licensing model which is broadly understood internationally, with a single licensee, owned by a corporate body with relevant nuclear experience. Alternatively there could be models at the other end of the spectrum that could create fresh challenges to consider; for example different ownership / licensees models within a single facility, which would need careful consideration by the regulators to ensure the focus on safety or security is appropriately maintained through all phases of the lifecycle.

As part of ownership there is also the considerations around shared personnel (further discussed in Section 3.5 on Shared Personnel), notably around emergency planning and response, security and maintenance. Note that the SMR Regulators forum has expressed reservations around the shared use of operating personnel.

3.2.3 Considerations

To further examine this topic, the section below offers a series of potential scenarios to enable further understanding of some of the potential challenges, these scenarios are underpinned with some key considerations for the Regulatory Body:

Scenarios:

1. One nuclear facility with a number of reactor modules/units (e.g. 12 reactors), operated by a single licensee; under the ownership of an experienced nuclear operating organization. Key considerations:
    - A traditional model, similar to the large-scale reactors, understood internationally.
    - All relevant capability under the control of the licensee.

- Low risk of undue influence from the owner on the licensee.
- Adjacent facilities / sites should have a co-operations agreement in-place for the management arrangements covering emergency response or security, etc.

2. One nuclear facility with a number of reactor modules/units (e.g. 12 reactors), operated by a single licensee, under the ownership of a consortium of different companies / investors. Key considerations:

    - The Regulatory Body would expect a single licensee, even though the ownership of a number of reactors (or % share) could be owned / funded by different organizations.
    - In this case, from a regulatory perspective the % shares ownership model would be preferred, which brings collective responsibility for the safety of the facility as a whole.
    - The Regulatory Body should consider the Board make-up in order to ensure no undue influence could be exercised on the decision making that would undermine safety.
    - A single licensee approach would have the appropriate control of their staff and key contractors.

3. One nuclear facility with a number of reactor modules/units (e.g. 12 reactors), subgroup of reactors operated by different licensees, under different ownership models. Key considerations:

    - Different licensees within one facility would cause Regulatory challenges with respect to capability and control of staff and shared services.
    - Appropriate Safeguard control could be challenging to demonstrate.
    - The provision of an integrated Security capability would need to be adequately demonstrated.
    - Each Member State would have to consider the implications of their legal framework.
    - In general, this would not be the preferred model from a regulatory perspective.

4. Two adjacent nuclear facilities with a number of reactor modules/units (e.g. 12 reactors in each facility), with separate licensees for each facility, but use shared services and some personnel utilized by both facilities. Key considerations:

    - Contractual arrangements for shared services to ensure safety can be maintained.

- Contractual arrangements should also be established for shared personnel.
- Prioritizations protocol for staff during peak workload.
- Provision for the ongoing maintenance of shared services, and recognition of the need to invest in future requirements for shared services.
- Arrangements for sharing common infrastructure – emergency response etc.
- Identification and management of interdependent risk contributors.
- Co-ordination agreements in-place for key services relating to safety and security.

3.2.4 Common positions for SMR Ownership / Licensee models

- Regulators should ensure that the licensee has relevant capability as defined in the licence.
- Regulators need to ensure that any adjacent facilities / sites have a co-operation agreement in-place for the management arrangements covering emergency response, security, etc.
- The Regulatory Body would expect a single licensee, even though the ownership of a number of reactors (or % share) could be owned / funded by different organisations.
- Regulators need to have means in place to ensure that the licensee have appropriate control and oversight of their staff and key contractors.
- Regulators need to ensure that licensees have clear contractual arrangements in place for shared personnel in order to ensure that shared personnel do not compromise the safety of a licensed facility.

3.3 Multi-module/unit Licensing

3.3.1 Objective

Considerations of a single license for several modules/units: some countries are pondering the benefits of issuing a single license for several modules/units, acknowledging for the necessity of incrementally bringing modules/units online. The impact on the licence of the entire lifecycle of a reactor (e.g., replacing an SMR once the fuel is spent (for relevant designs)) is also worth considering.

3.3.2 Problem

The licensing process for many countries has only involved issuing a licence for single module/unit on a site. Licensing reactors that have multiple modules/units on a single site, or sometimes multiple modules/units in a single building creates challenges for the regulatory frameworks of some countries.

3.3.3 Considerations

The entire lifecycle of a module/unit needs to be considered as part of licensing considerations. Some challenges that need to be considered when developing licensing approaches might include:

- A reactor module/unit may be moved around a facility for maintenance or refuelling.
- A reactor module/unit may not always be in the same place when it is operating. For example, a module/unit may be removed from its bay for refuelling, another module put back in its place, and then when refuelling is complete the module/unit would be put in a different bay.
- A reactor module/unit might be sent back to a factory for maintenance.
- A reactor module/unit may be moved around to different sites within its lifecycle.

If an applicant proposes to construct and operate a facility, all of the activities` associated with the proposal should be considered in the licence application, including construction and operation of multiple modules/units on a single site.

Proposed SMR designs have a wide range of plans for handling their modules/units. Some reactor designs are moveable for maintenance or refuelling, while other designs do not have provisions for moving a module until it is decommissioned. Some reactor designs do not refuel their reactor core over its lifetime. Some other designs do not refuel, but rather replace the entire module/unit at regular intervals.

Also being developed are marine-based floating and submersible power plants, with multiple modules/units that could be relocated from one potential site to another. Land-based reactors are also being proposed that may have the ability to move sites in their operating lifetimes. Currently most licensing processes consider only a single deployment site. Precedence for licensing marine-based reactors, or reactors that relocate during their lifecycle is very limited.

Licensees need to consider how they will manage the differences between modules/units in terms of:

- Potential configuration differences between modules/units.
- Units of different vintage (age differences).
- Modules/units in a station that are in various lifecycle stages, for example, modules/units operating, modules/units under construction or commissioning, in refurbishment and modules/units in safe storage state awaiting decommissioning.

Licensees need to consider the above points in all of their programs for operating and maintaining the facility as a whole. Differences between modules/units needs to be carefully accounted for during maintenance and operation. This is especially important if modules/units are moved from one location to another during their lifetime. A very common proposal is that new modules/units might be under construction while other modules/units are operating. The attributes of all modules/units need to be considered as part of licensing to ensure there are appropriate measures in place to ensure safety of the entire plant. This would include, for example, an aging management program for "common services", features that are shared between modules/units – including civil structures, common electrical systems and compressed air systems. Licensing of a facility should consider the entire lifecycle, including cases such as:

- multiple- module/unit SMRs where a utility proposes to put only a few modules/units into service at the onset, with an option to install and operate more modules/units in the future.
- spent modules/units that may be removed and replaced with newer modules/units, which could differ technically from the original modules/units.

For a proposal for a multiple- module/unit licence to construct or operate a facility, it is important for the applicant to consider the facility's ultimate total capacity over its life and the timelines for deploying the modules/units.

For licensing scenarios where all of the modules/units are expected to be constructed and operated around the same time, a high level of consistency in the design and construction of the modules/units is also expected. However, for scenarios where modules/units are expected to be constructed, and operated at different times, maintaining consistency in how the modules/units are designed and constructed, in reality, could be a challenge; therefore, this potential evolution of design differences among the modules/units could impact their ability to maintain a high level of consistency between modules/units.

For this latter scenario, the licensing process could be relied on to accommodate the changes for subsequent modules/units to be constructed and operated.

This will play a role in, for example the safety analyses that will support the facility's safety case. It is important that the applicant describe their programs and processes which control how multiple- module/unit activities will be managed under all programmatic areas. For example:

- configuration management – ensuring accurate records are maintained which capture any specific differences between modules/units
  - thorough configuration management helps reduce increasing risk over time
- human performance – personnel training and preventing errors such as performing maintenance on the wrong module/unit

While many regulators are leaning towards having a single licence for a site, some regulators are choosing to have multiple licences on a site (one for each reactor module.). Having a blanket licence for many units being deployed in a wide variety of geographical locations is not a best regulatory practice.

3.3.4 Common positions for multi-module/unit licensing

- Regulators need to set clear expectations to ensure that all activities associated with a proposal are considered in the licence application.
- Regulators need to ensure that configuration differences between modules/units are properly accounted for.
- Regulators need to set expectations to ensure that modules/units in different states (construction, operation, decommissioning), and the possible interactions between modules/units are considered.

- Regulators must set out strong human performance expectations specifically designed to handle workers at multiple module/unit facilities.

3.4 Shared Safety Systems

3.4.1 Objective

The sharing of safety systems should not negatively impact safety as a whole. Safety functions are expected to be available for all operational scenarios, from normal operation through to Beyond Design Basis Accidents (BDBAs). The sharing of any systems should not degrade the safety function which the system provides.

3.4.2 Problem

From a licensing perspective, regulators need to ensure that safety functions are available for all modules/units when needed.

3.4.3 Considerations

When licensing a facility, regulators need to ensure that safety functions are available for all modules/units when needed. One way to do this is by ensuring there is sufficient capacity of safety functions to serve the needs of all modules/units.

When considering a licence for an SMR consisting of multiple modules/units - structures, systems, and components (SSCs) important to safety should not be shared among SMR modules/units unless a proponent can show in their licensing approach that such sharing will not significantly impair their ability to perform their safety functions. This includes, in the event of an accident in one module/unit, an orderly shutdown and cool down of the remaining modules/units.

One way to demonstrate how sharing will not significantly impair all of the reactor modules/units is by ensuring that only one module/unit at a time can use or be used by the shared SSC, either via design limitation that would make it physically not possible to use the system for more than one module/unit at a time or by physical limitation via operator action and control.

It is also important that a license consider the risk contribution from a shared SSC relative to the overall plant aggregated risk in a systematic and quantitative way since a presumed failure of a shared SSC would render its functionality to be lost for all of the modules/units. The shared SSC's risk contribution should be appropriately modelled and accounted for in the overall risk assessment of an SMR design in order to verify that its risk contribution to the aggregated risk is sufficiently low. This does not necessarily mean that its relative risk contribution, among the ranks of all the SSCs in the design, should be at a low end, but that its actual or absolute risk contribution, for example in terms of core damage frequency contribution, should be sufficiently low. This is especially important to verify for a shared SSC that provides a safety function or supports a safety function. On the other hand, even if a shared SSC or a feature or may not appear to have a significant safety impact from a qualitative standpoint, such as the plant grid, a plant probabilistic assessment can help to provide a more objective perspective on its risk significance and contribution and allow for its appropriate disposition for licensing.

3.4.3.1 Example 1: Overhead Heavy Load Handling System (OHLHS)

An example of a shared SSC featured in an SMR design with multiple modules/units within a common reactor building could be its overhead heavy load handling system. If such system is designed to support refuelling only one module/unit at a time, then that would minimize or eliminate impact on the operation of other modules/units, including potential shutdown and cooldown. There should be a good understanding of the interactions between refuelling activities on one module/unit and the normal operation of the remaining modules/units with respect to the use of the OHLHS as well as the sustained safety-related cooling capability or accident mitigation capability of all of the modules/units.

Another way to demonstrate how sharing an SSC will not significantly impair the modules/units is by ensuring that the capability and the capacity of the shared SSC can be relied on to meet the needs of all of the modules/units concurrently for conditions that may require highest demand from the shared SSC. An example of this type of arrangement is shown in Example 2 below.

3.4.3.2 Example 2: Ultimate Heat Sink (UHS)

An example of a shared SSC featured in an SMR design with multiple modules/units for which there is common reliance on the shared SSC by all of the modules/units at the same time could be a shared UHS. The shared SSC in this case, the UHS, should in such case be capable of providing sufficient cooling to dissipate the heat from an accident in one module/unit and permitting the simultaneous and safe shutdown of the remaining modules/units and maintaining them in a safe shutdown condition. In such case the UHS capacity for abnormal and accident conditions should include the combined heat loads from all modules/units to perform required safety functions.

3.4.4 Common positions for shared safety systems

- Regulatory bodies must ensure safety functions are demonstrated to be available for all modules/units when needed.
- When an SSC important for safety is shared, regulatory bodies must ensure that the risk contribution to the aggregated risk of the whole plant is considered.
- Regulators must ensure that the safety case demonstrates that there is enough ultimate heat sink capacity to perform required safety functions for abnormal and accident conditions for the combined heat loads from all modules/units.

3.5 Shared Personnel

3.5.1 Objective

Shared personnel - outside of the control room – may consist of several teams in specialized areas. Licensing of facilities utilizing shared personnel need to consider any additional risks that may be introduced and also ensure those risks are appropriately mitigated.

3.5.2 Problem

The concept of shared teams is attractive, especially from a financial perspective. While not having personnel dedicated to a single site or modules/units may be attractive from an efficiency or financial perspective, shared personnel can introduce situations which have the potential to raise unique licensing challenges.

3.5.3 Considerations

Shared personnel - outside of the control room – may consist of several teams in specialized areas. Each set of shared personnel have a potential of introducing complexities which might raise unique licensing challenges and has to be examined during the licensing process. As mentioned earlier, the concept of shared teams is attractive, especially from efficiency and financial perspectives. Some examples of shared teams might include:

- Shared maintenance teams – specialized for various SSCs.
- Shared or centralized emergency and fire response teams
  - Emergency management could be shared amongst facilities.
  - Emergency and fire equipment could be shared if facilities are close enough.
  - Sharing might be with facilities using the same or different designs.
- Security response teams may be shared amongst facilities.
  - Sharing might be with facilities using the same or different designs.
- Training, administration, radiation protection, and other services might be shared with many facilities

Some general considerations for shared personnel are as follows:

- Licensees must ensure shared personnel or services are available when required for safety reasons.
- All personnel need to be competent on what they do
  - Applicable for all reactors but achieving and maintaining competence may be more challenging in case of multi-module/unit sites (different designs, different practices and procedures between the licensees).
- Maintenance on different reactor designs
  - e.g., Working on design 'A' on Monday, then design 'B' on Tuesday challenges the competence of a shared team.
- Shared operators
  - Operators could be shared for the same reactor type.
  - Operators might be proposed to be shared between licensees – but would be a challenge from a licensing perspective.
    - As an example, operating procedures and levels of decision-making authority may vary between licensees
    - Configuration management may also differ – which has the potential to alter the way a reactor behaves.
    - Operator certification processes may differ between licensees.
- Likewise, as configuration management drift occurs amongst modules/units, personnel need to adjust for this.

    - E.g., I&C replacements due to obsolescence.
    - Need to ensure personnel are adequately oriented to any unique features of a module/unit/site/licensee.
    - Procedures should be in place to help reduce confusion of units (human factors issue).
- Emergency plans must be implemented for the entire site
    - An emergency at any facility needs to be considered.
    - Need to consider multi-module/unit events (e.g., Fukushima).
    - Would emergency response be provided by an external provider
        - Might be more achievable for smaller reactors with multiple sites.
    - For multi-module/unit sites with different licensees, emergency response needs to be coordinated for the site.
    - Ultimately, from a licensing perspective, regulators need to ensure emergency response for any site is adequate both on and off site.
    - Needs to be commensurate with the scope of the largest possible emergency response proposed.
    - As emergency plans are updated, it needs to be done for the entire site.
- Security personnel need to be sensitized to sensitive areas for all areas they are responsible for.
    - I.e., include all the facilities for which they would be exposed.
    - Security by design plays a large role in SMR security – may not be that much different for multi-module/unit sites.
    - Shared systems may be more vulnerable to sabotage-based attacks.
    - Security should be commensurate with the vulnerability of the design.
    - Security needs to take the entire site into account.
        - Consider where multiple reactor designs are present at the same site.
    - Fuel storage (or other nuclear material stored on site) needs to be considered.
    - Security should consider the off-site radiation exposure potential.
    - Security may need to be enhanced for some operations, for example transport or refuelling.
- Security and emergency response drills should be considered for the entire site.
    - Need to do site-wide drills but graded to overall risk of the site.
    - Minimum complement needs to consider not only individual units or reactors sites, but also the whole site (e.g., when there is more than one design on a site).

3.5.4 Common positions for shared personnel

- Regulatory bodies must require that processes are in place to ensure that shared personnel or services are available when required for safety reasons.
- Regulators must verify that controls are in place to ensure shared personnel are familiar with all the different designs and procedures they work with (i.e. be competent in what they do).
- Regulatory bodies should require demonstration that emergency plans cover the entire site and include multi-unit events.

- Regulatory bodies should require demonstration that security plans cover the entire site and consider multiple reactor designs.
- Regulatory bodies should ensure there are provisions for site-wide drills for security and emergency response that are graded to the overall risk of the site.

3.6 Shared control rooms

3.6.1 Objective

Different SMRs apply various approaches for control room and operating concepts. They vary from traditional approach where one reactor is operated from one control room to operating several reactors from a shared control room by one team, and the control room may be located remotely from the reactors.

Countries have different licensing approaches to control rooms. Some countries may require regulatory approvals related to control rooms, the approvals can consider, for example, control room equipment, the persons working as operators or validation of the chosen concept. When licensing a new facility, the control room and HFE aspects, as well as the operating concept in general, are reviewed when reviewing the Preliminary Safety Analysis Report/Final Safety Analysis Report of the facility. Even if no approvals are required, typically the regulatory body expects to see some demonstration that the facility can be safely operated; ideally the demonstration covers the whole entity formed by the control room space, equipment, procedures, and personnel. The regulatory body may wish to observe some activities demonstrating the safety of the control room and operation, like validation of procedures with a simulator or Integrated System Validation (ISV) of the control room entity.

The purpose of this section is not to define the best regulatory approach for licensing activities related to control rooms, but to identify aspects of multi-module SMRs that may deserve special attention in the licensing process.

3.6.2 Licensing a shared control room

The main differences related to control rooms of multi-module/unit facilities compared to traditional NPPs are 1) operating several reactors from a common control room, 2) operating several reactors by one team and 3) non-fixed configuration: adding new modules/units later on or changing the location of the modules/units within the facility (as discussed above in the previous chapter).

Some experience already exists of shared control rooms – in Canada some CANDU reactors are operated from a shared control room. Also, in process industry, experience from controlling several processes by one team from one main control room could probably be found. It may be worthwhile - not only for the designers but also for potential utilities and regulators - to familiarize themselves with the existing operating experience and lessons learned.

Still, as the amount of operating experience is limited, licensing multi-module facility with a shared control room for the first time may require a more profound justification and demonstration of safety than the later facilities. Licensing of First-Of-A-Kind (FOAK) facilities has been discussed in Chapter 2.

In order to become convinced of the safety of the shared control room, the regulator should assess in the licensing process the justification for the number of control room staff, sufficient consideration of HFE, licensee's configuration control process (including training of staff or updating procedures when the configuration changes). These topics are typically supported by the use of full-scope simulator.

3.6.3 Number and role of control room staff

The number of operating personnel in the control room depends, among other things, on the operating concept and the distribution of work between plant automation and personnel.

The operating concepts of multi-module/unit facilities may be different from each other. The operating concept is defined for example by the purpose of the facility (electricity production with or without load following, district heating, process heat for industry…), by the refuelling strategy (continuous or not), by the degree of automation, maintenance strategy, tolerance of design to faults, etc. There can also be variation on how independent the different modules/units are. They might be relatively independent of each other, sharing only some support systems, or they might be dynamically linked by feeding the same process (e.g. turbine) and sharing several essential systems.

One objective of SMR concepts is to reduce staffing to be more cost effective. Proponents of new designs are proposing that they can reduce staffing levels while maintaining high levels of safety. To accomplish this, many SMR operating concepts are proposing to automate further than the operation of traditional NPPs. Inherently safer design features, such as for example, passive system designs for reactors, and highly intelligent control systems may be used to reduce the need for operator action. Due to the increased role of automation, the duties of the control room operators may change, and they may be focused more on monitoring the performance of the I&C, instead of monitoring and controlling the whole plant. Lessons learned from conventional power plants have shown that increasing the role of automation may change the operators' role in fundamental ways, for example towards optimizing the production and following the electricity market. Thus, the role of the operators in a highly automated facility may be very different from what is typical at present-day nuclear facilities.

Some vendors are also proposing unmanned facilities that are operated and monitored remotely. There are several challenges related to remote operation (monitoring), like ensuring cyber security and physical protection. The concept of remote operation/monitoring is not discussed further in this report.

Due to different approach, the lessons learned from the operation of present NPPs may not be directly applicable to operating SMRs. The chosen solutions should be based on operator task analyses, taking into account all considered operating modes of the multi-module/unit facility, as well as abnormal situations and accidents and transients. Whatever the solution, the licensee must demonstrate to the regulator that the proposed operating models are capable of meeting all safety requirements.

3.6.4 Human Factors Engineering (HFE)

One topic the regulator may wish to verify is the strong role of HFE-program considerations since the early design. Multi-module/unit facilities pose some unique challenges for human factor engineering, like how to avoid confusing different modules/units with each other or the work-load and situational awareness of the team operating several reactors simultaneously.

As many of the SMRs are still in conceptual design phase, all the control room concepts are not yet known. It might be possible that some concepts, especially in remote operation, share not only the control room space between the reactors, but also the operator working stations could be common, and not dedicated to one reactor. This may be an additional challenge especially in abnormal operation or transient/accident situations.

Multi-module/unit facilities may have modules/units in different operational states or in different phases of the lifetime. Depending on the sequencing of construction, there might at the same time be modules/units in commissioning, construction, refurbishment, operation and even in decommissioning states. Even if all the modules/units are in operation phase, there probably are simultaneously modules/units in power operation and in refuelling or in maintenance. This emphasizes further the importance of not confusing different modules/units with each other.

3.6.5 Configuration control

It is important that the operators are aware or possible differences between the modules/units. Especially, if new modules/units are added later on, it might be that the design has evolved from the original.

If it is possible to add more modules/units later on, or relocate modules/units, this must be considered in the licensing activities related to MCR and operation from the onset. The MCR and operating procedures must at all times be up-to-date and suitable for safe operation, and when changes are made, the necessary validation actions, training etc. must be repeated. During the recent years, a concept called Multi-Stage-Validation has been under development by the OECD Nuclear Energy Agency [11]. It would enable performing validation in several stages, taking into account modifications during operation. Such an approach would be better suited to multi-module/unit facilities than one-time ISV, which only provides a pointwise base for evaluation of the control room entity.

When adding new modules/units, it should also be ensured that the refurbishment of the control room does not disturb the safe operation of the existing modules/units.

The regulatory body should include configuration control in its inspection program or approach it by other means, as appropriate in the national regulatory approach.

3.6.6 Use of simulators

Full-scope simulators are widely used in nuclear industry for training of operating staff and for different purposes. These include, for example, validating the sufficient number of operators, training of operating staff, validating operating procedures and the integrated validation of the control room entity. For FOAK facilities, the use of a simulator can play a critical role in helping validate the proposed number of operators, as well as validating operational procedures. For designs with existing OPEX, a simulator can help validate new operational procedures before being implemented. This is especially helpful for multi-unit facilities where operators are often responsible for more than one unit. The use of simulators should be noted as a best practice. These activities are needed not only in the beginning of operation but also later when modifications are made. For SMR facilities, having and maintaining a facility specific simulator may be considered too expensive. The vendor may have a simulator that is used for all the customers for example to train their staff. The simulator time available for one customer may be limited. With this kind of solution, it is challenging to take into account facility specific features and needs, for example validating procedures or training the personnel when new modules/units are added or the interconnections between the modules/units are modified. The utility and the regulatory body should find a common understanding how to ensure for example sufficient training of the staff in such a case.

With the adoption of more digital I&C in newer designs, simulators are becoming smaller and more portable. It should be noted that simulator training may take place in both the host country, as well as in a centralized facility. Regulators focus on the quality of training a simulator can provide and be flexible on the location of simulator facilities. Fidelity of simulators should be encouraged.

3.6.7 Failure or loss of the MCR

During design phase, it should be evaluated if a shared control room can be a source of common failure that would affect the safety functions of several modules/units at the same time. Operator errors should be considered likewise. If necessary, appropriate measures should be implemented to prevent unacceptable consequences of such a failure or operator error.

The facility should also be prepared for the loss of the common control room, for example due to fire.

3.6.8 Common positions for shared control rooms

- Regulators should assess in the licensing process the justification for the amount of control room staff, sufficient consideration of HFE, and the licensee's configuration control process (including training of staff or updating procedures when the configuration changes).
- Regulators must ensure that licensees demonstrate that the proposed operating models are capable of meeting all safety requirements.
- The regulatory body should include configuration control in its inspection program.
- Regulators should encourage training utilizing a simulator, and be flexible on the location of such simulator facilities.
- Regulators should ensure that the loss of the common control room is considered in the licencing basis.
- Regulators must ensure that operator error is accounted for in the licensing basis.

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Appendix A: Contributors to the Report

The Licensing WG was established to develop common position statements and areas of enhanced cooperation where practicable to inform near term SMR projects being undertaken by member states. This working group is composed of volunteer representatives from the following IAEA member states who are also members of the SMR Regulators' Forum:

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