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1. IDENTIFICATION

Document Category: Specific Safety Requirements

Working ID: **DS562**

Proposed Title: **Safety of Nuclear Power Plants: Design**

Proposed Action: **Full Revision of IAEA Safety Standards Series No. SSR-2/1 (Rev. 1) "Safety of Nuclear Power Plants: Design" (2016)**

Review Committee(s) or Group: NUSSC, EPReSC, RASSC, WASSC, NSGC, TRANSSC

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2. BACKGROUND

IAEA Safety Standards Series No. SSR-2/1 (Rev. 1), Safety of Nuclear Power Plants: Design (2016) was developed to establish requirements for the design of nuclear power plants (NPPs) to be met to ensure the fundamental safety objectives. The development of the requirements in SSR-2/1 (Rev. 1) was based on the initial version, published in 2012 (SSR-2/1). The requirements in SSR-2/1 were revised to incorporate the lessons learned from the Fukushima Daiichi nuclear power plant accident and available feedback from operational experience. Furthermore, the main objective of the requirements in SSR-2/1 (Rev. 1) was to strengthen the plant design basis to prevent severe accidents and to mitigate the consequences of those accidents if they were to happen.

Based on the large operating experience of water-cooled reactor technologies, and as described in the scope section of the publication, the Safety Requirements "*will be used primarily for land based stationary nuclear power plants with water cooled reactors designed for electricity generation or for other heat production applications (such as district heating or desalination). This publication may also be applied, with judgement, to other reactor types, to determine the requirements that have to be considered in developing the design*."

NPPs with non-water-cooled reactor technologies were deployed prior to the publication of the SSR-2/1 (Rev. 1), and significant additional progress has been made on those reactor technologies towards more widespread deployment. Indeed, Member States have been considering deploying these technologies in recent years, to establish or to enlarge their nuclear power programmes. Those NPPs with non-water-cooled reactor technologies differ fundamentally and incorporate innovative design features, as compared to those with water cooled reactors, and their potential deployment applications include both electricity generation and non-electrical applications. Some of the specific features considered are different neutron spectrums, different coolants, and different fuel types. Other important design features considered by advanced reactor technologies are the modularity and modularization, different power outputs and Transportable NPPs[1], including propulsion (such as

[1] TNPP - is an NPP designed to be geographically relocated as complete, or nearly complete, system. Some of such NPPs may utilize modularization for ease of assembly and deployment but are not physically attached to a transport platform during operation. These NPPs are relocated and installed at the site, however they are not designed for energy utilization during the relocation phase. Other NPPs are integrated with and remain attached to a transport platform, such as truck, or integrated with a ship, or barge, allowing the entire plant to be relocated and operated from the transport platform (or ship or barge) itself, such as floating NPPs. In this category, some NPPs (including nuclear merchant ships) may use the produced energy for propulsion. The definition is not final and will be refined during the drafting process.

nuclear merchant ships). Understanding the applicability of the current requirements in SSR-2/1 (Rev. 1) for these NPPs with different reactor technologies and designs may be challenging for stakeholders, such as design organizations, operating organizations, regulatory bodies and technical support organizations in both Member States with existing nuclear power programmes and embarking countries.

The feedback analysis is provided in the annex including a summary of relevant publications.

3. JUSTIFICATION FOR THE PRODUCTION OF THE DOCUMENT

As recalled in the background section of this DPP, SSR-2/1 (Rev. 1) was published in 2016, and since then, significant technological advancements and deployment plans for NPPs with advanced reactor technologies have emerged. Additionally, SSR-2/1 (Rev.1) does not explicitly cover NPP with non-water-cooled reactor technologies and designs, Transportable NPPs, modular NPP units within its scope. The specifics of such NPP technologies and designs, including different neutron spectrums, coolants, fuel types, and deployment options require consideration. These factors support the need for a full review of all requirements in SSR-2/1 (Rev.1) with account taken to the current level of knowledge to ensure the continued relevance and applicability of the safety requirements for the design of all NPPs.

For several years, IAEA General Conference Resolutions on nuclear and radiation safety have requested the IAEA secretariat to update the IAEA Safety Standards to incorporate specifics of advanced reactors technologies and designs, included in both NPPs with non-water-cooled reactor technologies and NPPs with water-cooled reactor designs, such as those considered for some small modular reactors[2]. Other resolutions encourage the IAEA secretariat to account for developments in transportable nuclear power plants to ensure the highest achievable level of safety[3].

Given this context, the Safety Assessment Section has been collecting feedback for several years on the applicability of safety requirements and recommendations on design safety to identify possible gaps in the application of related IAEA Safety Standards to existing NPPs and to NPPs with advanced reactor technologies and designs. This feedback has been gathered from various IAEA activities, such as technical meetings, workshops and technical safety reviews.

In response to these requests of Member States and the collected feedback, the Safety Assessment Section launched preparatory work to consider incorporating design features of NPPs with advanced reactor technologies and designs and experience feedback from existing nuclear power plants into future IAEA Safety Standards. The preparatory work involved the identification of relevant supporting publications, such as TECDOC-1569, and TECDOC-1791. Additionally, recent publications have been developed to identify the gaps and provide the basis for the review. These include the Safety Report Series on Applicability of IAEA Safety Standards to Non Water Cooled Reactors and Small Modular Reactors (SRS-123), published in 2023, along with other publications, such as TECDOC-1936, TECDOC-2010 and TECDOC-2021. The preparatory work also included consultation with international experts, from regulatory bodies and with representatives of the Generation IV International Forum (GIF). These consultations have strongly confirmed the need to consider the design features of advanced reactor designs and also the feedback from the experience in existing nuclear power plants on the relevant IAEA Safety Standards. Furthermore, the preparatory work was informed by the experience from regulatory bodies in assessing the design and safety analysis of small modular reactors (SMRs) captured in several SMR Regulators' Forum publications.[4]

The revision of SSR-2/1 (Rev.1), hereinafter called SSR-2/1 (Rev.2), is expected to enhance the clarity, applicability, and usability of the safety requirements for a broader range of reactor

[2] See Annex feedback analysis, section 4.1 paras 6 and 7 on GC resolutions for advanced reactors and small modular reactors.

[3] See Annex feedback analysis, section 4.1 paras 8 and 9 on GC resolutions for transportable NPPs.

[4] See Annex feedback analysis, section 3.1 on SMR Regulators' Forum reports.

technologies while offering more practical guidance for regulatory bodies, design organizations, and technical support organizations, especially in Member States deploying NPPs with advanced reactors technologies and designs, or Member States embarking on nuclear power programmes.

4. OBJECTIVE

The objective of the requirements in SSR-2/1 (Rev. 2) will be to establish design requirements for the structures, systems and components of a nuclear power plant, as well as for procedures and organizational processes important to the safety of the design that are required to be met for safe operation, relocation, including propulsion and for preventing events that could compromise safety, or for mitigating the consequences of such events, were they to occur. The requirements in SSR-2/1 (Rev. 2) will apply to NPPs with reactor technologies as defined in the scope section of this DPP.

In addition, the requirements in SSR-2/1 (Rev. 2) will be complemented by the requirements in SSR-1 (Rev. 1) on Site Evaluation for Nuclear Installations; and SSR-2/2 (Rev. 2) on Safety of Nuclear Power Plants: Commissioning and Operation; and provide the basis for the process of review and assessment of the design as required in GSR Part 4 (Rev.1) on Safety Assessment for Facilities and Activities.

The requirements in SSR-2/1 (Rev. 2) are expected to promote technical consistency in the level of safety among design organizations and to support regulatory authorities, technical support organizations and licensees involved in the licensing process of reactor designs. The requirements will strive to keep the extant philosophy of technology-neutral, technology-inclusive, and technology-specific requirements to support:

(a) Consideration in the design basis of the structures, systems and components in nuclear power plants to prevent accidents and mitigate their consequences, ensuring the highest level of safety reasonably achievable;

(b) The implementation of the defence in depth concept in nuclear power plant design, ensuring that the independence between their different levels, and the barriers considered at such levels, is achievable, demonstrable and maintained as far as reasonably practicable;

(c) An appropriate balance between prevention and mitigation in the design to ensure the fundamental safety functions, taking into account all safety features, including inherent safety features;

(d) Adequate safety margins to account for uncertainties and to avoid cliff-edge effects to ensure reliable performance within different plant states;

(e) The concept of practical elimination in the design of nuclear power plants to prevent plant event sequences that could lead to early radioactive releases or large radioactive releases, ensuring they are either physically impossible or they could be considered with high level of confidence to be extremely unlikely to arise.

The requirements in SSR-2/1 (Rev. 2) will aim to provide a standard framework to facilitate a regulatory review of a design or a peer review of national design safety requirements and their applications.

The requirements in SSR-2/1 (Rev. 2) are intended for use by organizations involved in design, manufacture, construction, modification, maintenance, relocation, commissioning, operation, and decommissioning for nuclear power plants with reactor technologies as described in the scope of the DPP, in analysis, verification and review, and in the provision of technical support.

The requirements in SSR-2/1 (Rev. 2) are also intended for use by regulatory authorities and technical support organizations in the review for the authorization (licensing) process for the design, manufacture, construction, modification, maintenance, relocation, commissioning, operation and decommissioning of nuclear power plants with reactor technologies as described in the scope of the DPP.

For existing (e.g. land based, floating, propulsion) nuclear power plants in operation or under construction, it might not be practicable to apply all the new or revised requirements of SSR-2/1 (Rev. 2). In addition, it might not be feasible to modify designs that have already been approved by regulatory bodies. For the safety analysis of such designs, a comparison may be, as far as relevant, made with the current IAEA Safety Standards[5], for example as part of the periodic safety review for the plant, to determine whether the safe operation of the plant could be further enhanced by means of reasonably practicable safety improvements.

5. SCOPE

The revision will expand the current scope in SSR-2/1 (Rev. 1) to consider all power producing nuclear reactors (e.g. electrical generation, process heat, desalination, marine propulsion) used for civil purposes and to integrate updated considerations for water-cooled (including advanced) and non-water-cooled reactor technologies (e.g. High Temperature Gas Cooled Reactors (HTGRs) , Liquid Metal Fast Neutron Reactors (LMFRs) and Molten Salt Reactors (MSRs)). In addition, specifics of NPPs with small modular reactors and micro reactor designs, and corresponding deployment options (e.g. NPP with multi module units (i.e. modularity[6]), remote locations, underground installation, transportable NPPs (i.e. modularization[5], and propulsion), will be considered.

Nuclear reactors for aviation or outer space applications will be out of scope of the requirements in SSR-2/1 (Rev. 2). Similarly, Accelerator-Driven System (ADS) will be out of scope of the requirements in SSR-2/1 (Rev. 2).

Appropriate consistency with the contents of all relevant Safety Standards will be maintained, in particular SSR-1 (DS557) and SSR-2/2 (Rev. 1) (DS532).

Moreover, consideration will be provided to the interaction between safety and security and safety and safeguards from the early stages of nuclear power plant design such as security by design, safeguards by design and cybersecurity aspects. This proactive approach will strengthen defence in depth, and minimize the need for later modifications or backfitting to comply with the relevant requirements related to those topics.

Therefore, the requirements in SSR-2/1 (Rev. 2) will take into account the specific characteristics of different NPPs with self-sustained nuclear fission reactor designs with account taken of the available and relevant operating experience and the status of development of the technologies, such as:

1. Water-cooled reactors, including advanced water-cooled reactors;
2. Non-water-cooled reactors, including gas cooled reactors, liquid metal cooled reactors, and molten salt cooled reactors;
3. Different neutron spectrum reactors, including thermal, and fast;
4. Different fuel types, categorized by their physical form including solid fuels and molten salt fuel;
5. Modularization[6] and modularity[7] of reactor designs, enabling geographical relocation;
6. Different power outputs, ranging from large to small or micro reactors;
7. Transportable NPPs (see proposed definition in footnote 2);
8. Nuclear power plants with different deployment options, including remote locations (off-grid) and

[5] Including, where available, existing comparisons made against SSR-2/1 (Rev.1)
[6] Modularization is as the possibility to assemble several SSCs of the NPP in the manufacturing factory, thereby facilitating subsequent transport / relocation of such assembled modules to the construction site. (TECDOC-2010)
[7] Modularity is understood as the possibility for the subsequent placing of SMR modules (i.e. reactor modules) close to each other in one NPP. (TECDOC-2010)

underground installation.

Hence, the existing requirements in SSR-2/1 (Rev. 1) will undergo full revision to incorporate the above-mentioned aspects in the related sections. The added value of the requirements in SSR-2/1 (Rev. 2) will be to provide Member States with comprehensive, consistent and up-to-date requirements for the design of structures, systems and components for all nuclear power plants. While SSR-2/1 (Rev 2) will consider the design requirements for NPPs in all states including relocation, this does not preclude the additional application of safety requirements set out in Transport Regulations. Work is ongoing to understand the implications of transportable NPPs for both NPP design safety and transport safety, and the two work programmes will reference each other to ensure the requirements are compatible.

6. PLACE IN THE OVERALL STRUCTURE OF THE RELEVANT SERIES AND INTERFACES WITH EXISTING AND/OR PLANNED PUBLICATIONS

The Safety Requirements will interface with at least the following IAEA Safety Standards Series and other publications (the list is not intended to be final or exhaustive):

1) SF-1 – Fundamental Safety Principles (2006);
2) SSR-1 – Site Evaluation in Nuclear Installations (2019) under revision as DS557;
3) GSR Part 2 – Leadership and Management for Safety (2016);
4) GSR Part 3 – Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (2014);
5) GSR Part 4 (Rev. 1) – Safety Assessment for Facilities and Activities (2016);
6) GSR Part 5 – Predisposal Management of Radioactive Waste (2009) under revision as DS548;
7) GSR Part 7 – Preparedness and Response for a Nuclear or Radiological Emergency (2015) under revision as DS558;
8) SSR-2/2 (Rev. 1) – Safety of Nuclear Power Plants: Commissioning and Operation (2016) under revision as DS532;
9) SSR-6 (Rev.1) – Regulations for the Safe Transport of Radioactive Material (2018) under revision as DS543;
10) SSG-2 (Rev.1) – Deterministic Safety Analysis for Nuclear Power Plants (2019);
11) SSG-3 (Rev.1) – Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants (2024);
12) SSG-4 (Rev.1) – Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants (2025);
13) SSG-25 – Periodic Safety Review for Nuclear Power Plants (2013) under revision as DS535;
14) SSG-30 – Safety Classification of Structures, Systems and Components in Nuclear Power Plants (2014);
15) SSG-34 – Design of Electrical Power Systems for Nuclear Power Plants (2016);
16) SSG-38 – Construction of Nuclear Installations (2015);
17) SSG-39 – Design of Instrumentation and Control Systems for Nuclear Power Plants (2016);
18) SSG-51 – Human Factors Engineering in Nuclear Power Plants (2019);
19) SSG-52 – Design of the Reactor Core for Nuclear Power Plants (2019);
20) SSG-53 – Design of the Reactor Containment and Associated Systems for Nuclear Power Plants (2019);
21) SSG-54 – Accident Management Programmes for Nuclear Power Plants (2019);

22) SSG-56 – Design of the Reactor Coolant System and Associated Systems for Nuclear Power Plants (2020);
23) SSG-61– Format and Content of the Safety Analysis Report for Nuclear Power Plants (2021);
24) SSG-62 – Design of Auxiliary and Supporting Systems for Nuclear Power Plants (2020);
25) SSG-63 – Design of Fuel Handling and Storage Systems for Nuclear Power Plants (2020);
26) SSG-64 – Protection against Internal Hazards in the Design of Nuclear Power Plants (2021);
27) SSG-67 – Seismic Design for Nuclear Installations (2021);
28) SSG-68 – Design of Nuclear Installations Against External Events Excluding Earthquakes (2021);
29) SSG-69 – Equipment Qualification for Nuclear Installations (2021);
30) SSG-88 – Design Extension Conditions and the Concept of Practical Elimination in the Design of Nuclear Power Plants (2024);
31) SSG-90 – Radiation Protection in the Design of Nuclear Power Plants (2024);
32) DS537 Safety demonstration of innovative technology in power reactor designs (in draft);
33) IAEA Nuclear Safety and Security Glossary (2022);
34) NSS 20 – Objective and Essential Elements of a State’s Nuclear Security Regime (2013);
35) NSS 42-G – Computer Security for Nuclear Security (2021);
36) NSS 33-T – Computer Security of Instrumentation and Control Systems at Nuclear Facilities (2018);
37) NSS 23-G – Security of Nuclear Information (2015);
38) NSS 17-T (Rev.1) – Computer Security Techniques for Nuclear Facilities (2021);
39) NST067 / DS533 – Management of the Interfaces Between Nuclear and Radiation Safety and Nuclear Security (in draft Step 5);
40) Legal Framework for IAEA Safeguards (2013).

Given the wide scope of the nuclear power plant design safety requirements and the interfaces with other IAEA Safety Standards listed above, revision of the various parts of SSR-2/1 (Rev. 1) will be coordinated, as relevant with NSNI/EESS, NSNI/OSS, NSRW, NSNS, IEC and the safeguards team dealing with ‘safeguards by design’ (SGCP POC). In addition, staff from NE will be invited to be members of the development team, and/or consulted for the revision of several engineering aspects of the requirements.

7. OVERVIEW

The requirements in SSR-2/1 (Rev. 2) will retain the overall structure and table of contents of the current SSR-2/1 (Rev. 1), while incorporating new sections, appendices, and/or annexes to address specific requirements for various reactor technologies and their applications.

The proposed structure is intended to preserve Sections 1 to 5 as in the current version. Requirements 1 to 42 — corresponding to Sections 3 to 5 — are expected to remain mainly technology-neutral and inclusive, serving as the foundational safety approach for the design of all nuclear power plants with different reactor technologies and designs. Where this is not possible, requirements that only apply to specific characteristics will be placed in a new section. This may also include new requirements, if necessary.

Section 6 (Design of specific plant systems: technology inclusive) and new Section 7 (Design of specific plant systems: specific characteristics) are intended to enhance the clarity and applicability of the specific requirements for specific design characteristics, mainly on the base of current

Requirements 43 to 82 (plus additional requirements, if necessary). It is also expected that a similar approach could be followed for the future revision of IAEA Safety Guides on design safety for nuclear power plants, such as SSG-52, SSG-53, SSG-56 and SSG-62.

To conduct this process, the revision of SSR-2/1 (Rev. 1) will follow the methodology outlined and applied in TECDOC-2010 and in TECDOC-1936, and the relevant results in SRS-123. This approach will guide the necessary modifications to each requirement, based on the following rationale:

1st: The requirement is technology neutral or technology inclusive and fully applicable to all reactor technologies and applications. No changes are necessary.

2nd: The requirement is not fully technology-inclusive, but only minor wording adjustments are needed to ensure broad applicability.

3rd: The requirement is technology specific to land based, water-cooled reactor technologies. It will be retained as it is. Equivalent or additional requirements should be developed for specific characteristics of other reactor types. Whether possible or applicable, the requirements will be reworded in two parts: the first one as technology neutral or technology inclusive, the second part with specific requirements for one or more technologies. To the extent possible, the current numbering will be preserved.

For example, the requirements in SSR-2/1 (Rev. 2) may have the overall structure at the section level as follows, considering that during the process of drafting, changes in the structure may be required:

1. INTRODUCTION
2. APPLYING THE SAFETY PRINCIPLES AND CONCEPTS TO THE DESIGN OF NUCLEAR POWER PLANTS
3. MANAGEMENT OF SAFETY IN DESIGN OF NUCLEAR POWER PLANTS
4. PRINCIPAL TECHNICAL REQUIREMENTS IN THE DESIGN OF NUCLEAR POWER PLANTS
5. GENERAL NUCLEAR POWER PLANT DESIGN
6. DESIGN OF SPECIFIC NUCLEAR POWER PLANT SYSTEMS: TECHNOLOGY INCLUSIVE
7. DESIGN OF SPECIFIC NUCLEAR POWER PLANT SYSTEMS: SPECIFIC CHARACTERISTICS

   (to take account of different design characteristics as presented in the Scope section of this DPP)
8. DEFINITIONS USED IN THE DESIGN OF NUCLEAR POWER PLANTS
9. APPENDICES (if needed, for instance, to provide traceability and consistency of requirements among different technologies and applications, or to explain further the interfaces between safety and security and safety safeguards)
10. REFERENCES
11. ANNEXES (IF NEEDED)
12. CONTRIBUTORS TO DRAFTING AND REVIEW

8. PRODUCTION SCHEDULE

STEP 1: Preparing a DPP	DONE
STEP 2: Approval of DPP by the Coordination Committee	July 2025
STEP 3: Approval of DPP by the relevant review Committees	November 2025
STEP 4: Approval of DPP by the CSS	March 2026
STEP 5: Preparing the draft	3Q 2026
STEP 6: Approval of draft by the Coordination Committee	3Q 2028
STEP 7: Approval by the relevant review Committees for submission to Member States for comments	4Q 2028
STEP 8: Soliciting comments by Member States	1Q 2029
STEP 9: Addressing comments by Member States	1Q 2030
STEP 10: Approval of the revised draft by the Coordination Committee Review in NSOC-SGDS (Technical Editorial review)	1Q 2030
STEP 11: Approval by the relevant review Committees	2Q 2030
STEP 12: - Submission to the CSS - Submission in parallel and approval by the Publications Committee - MTCD Editing - Endorsement of the edited version by the CSS	4Q 2030
STEP 13: Establishment by the Publications Committee and/or Board of Governors (for SF and SR only))	1Q 2031
STEP 14: Target publication date	2Q 2031

9. RESOURCES

It is estimated that the full revision of the Safety Requirements would involve approximately 400 weeks of effort by experts. This is based upon assuming 10 one-week consultancy meetings, involving no more than 20 experts and an average of one week of work per expert between meetings.

Agency resources involved are estimated at 60 weeks of effort by the Technical Officer and 50 additional weeks of other IAEA staff.

ANNEX – Feedback Analysis Report

1. Introduction

The feedback analysis for the revision of the requirements in SSR-2/1 (Rev. 1) has considered inputs from several sources, such as:

1. Feedback from IAEA initiatives to enable the deployment of nuclear reactors for power generation including water-cooled and non-water-cooled reactor technologies;
2. Requests and encouragements from the Member States collected in the resolutions of the latest IAEA General Conferences;
3. Feedback from publications related to the latest developments of nuclear reactors for power generation including water-cooled and non-water-cooled reactor technologies;
4. Feedback from technical safety review services on design safety conducted for nuclear reactors for power generation including water-cooled and non-water-cooled reactor technologies.

The following paragraphs provide an overview of the main gaps found from previously listed sources.

2. Feedback from publications

The IAEA has issued different publications in relation to advanced reactor designs, such as SMRs, to collect information about their design safety features. In particular, SRS-123 on the Applicability of IAEA Safety Standards to Non-Water Cooled Reactors and SMRs (2023), evaluated how well existing safety standards apply to emerging reactor technologies. It identified areas of novelty in SMRs, and non-water-cooled reactors compared to conventional designs and assessed their impact on the applicability and completeness of current IAEA safety standards. The report highlighted gaps and areas needing further consideration across the entire lifecycle of these technologies—from siting and design to decommissioning. It also emphasized the importance of integrating safety, security, and safeguards from the design phase to ensure an integrated approach to nuclear safety.

Other relevant publications are listed hereafter. These represent a comprehensive and up-to-date body of knowledge that directly supports the revision of SSR-2/1 (Rev. 1), particularly in light of evolving nuclear technologies, operational experience, and regulatory practices. Each publication contributes unique insights relevant to the enhancement of safety requirements for the design of NPPs, including advanced reactors and SMRs, and non-electrical applications. The justification for their inclusion is as follows:

- IAEA-TECDOC-1791 and TECDOC-2021 provide practical insights into the application and interpretation of SSR-2/1 (Rev. 1), highlighting areas where clarification or enhancement may be needed based on Member States' experiences.
- NR-T-1.18, TECDOC-1936, and TECDOC-2010 address the specific design and regulatory challenges associated with SMRs, which are increasingly relevant for near-term deployment and require tailored safety approaches.
- TECDOC-1536 and NG-T-3.5 discuss deployment models such as reactors without on-site refuelling and Transportable NPPs, which challenge traditional assumptions embedded in existing safety requirements.
- NR-T-1.19 supports the harmonization of terminology and classification of advanced NPPs, which is essential for consistent application of safety standards across diverse technologies.

- NP-T-4.1, NP-T-4.2, and TECDOC-1753 provide technical and economic perspectives on non-electrical applications of nuclear energy, such as hydrogen production and desalination, which may influence design safety considerations and plant configurations.
- TECDOC-1674, NF-T-4.1, and NP-T-1.6 contribute detailed technical knowledge on fuel and coolant technologies for advanced reactors, particularly sodium-cooled fast reactors (SFRs), which are central to many innovative designs.
- TECDOC-1569, TECDOC-1406, and TECDOC-1912 offer historical and technical insights into the design, operation, and safety challenges of liquid metal cooled reactors, informing the robustness of safety requirements for these systems.
- TECDOC-2079 presents the latest international efforts in modelling and analysing severe accidents in fast reactors, which may support the development of risk-informed and performance-based safety requirements.

Together, these publications ensure that the revision of SSR-2/1 (Rev. 1) is informed by the latest technological developments, operational feedback, and regulatory innovations, thereby enhancing the relevance, clarity, and applicability of the safety requirements for current and future nuclear power plant designs. An overview of each publication is provided below.

2.1. General

- TECDOC 1791 Considerations on the application of IAEA Safety Requirements for the design of NPPs (2016), provides detailed considerations to support the understanding and consistent application of the revised IAEA Safety Requirements SSR-2/1 (Rev. 1) for the design of nuclear power plants, particularly addressing new concepts introduced after the accident at the Fukushima Daiichi nuclear power plant and aiming to harmonize interpretations among Member States.
- NR-T-1.18 Technology Roadmap for SMR Deployment (2021) provides Member States with a set of generic technology roadmaps to support the planning and implementation of small modular reactor deployment. It outlines roles for key stakeholders (owners/operators, designers, regulators), presents a methodology for roadmap development, and discusses emerging opportunities and challenges in SMR technology based on inputs from countries actively pursuing SMRs.
- TECDOC-1536 Status of Small Reactor Designs Without On-Site Refuelling (2007) provides comprehensive information on the development trends, design status, and potential applications of small reactors that do not require on-site refueling. It targets a broad range of stakeholders and includes detailed annexes describing specific reactor designs, highlighting their potential to address future nuclear energy system challenges.
- TECDOC-2010 Approach and Methodology for the Development of Regulatory Safety Requirements for the Design of Advanced Nuclear Power Reactors. Case Study on Small Modular Reactors (2022) presents a stepwise, technology-neutral methodology to help national regulatory authorities adapt or develop safety requirements for advanced nuclear power reactors, with a specific case study on SMRs. It emphasizes a risk-informed, objective-oriented, and performance-based approach, incorporating lessons from Member States and highlighting key SMR design features.
- TECDOC-2021 Experience in Applying IAEA Principles for Design Safety to New Nuclear Power Plants (2023) compiles Member States' experiences in implementing the requirements of SSR-2/1 (Rev. 1) for the design and safety assessment of nuclear power plants equipped with advanced reactor designs. It highlights common practices,

differences in interpretation, and implementation of safety requirements, aiming to foster a shared understanding among regulators, designers, and other stakeholders.

- NR-T-1.19 Terms for Describing Advanced NPPs (2023, NPTDS) provides updated terminology for describing advanced nuclear power plant designs. It revises and expands upon IAEA-TECDOC-936, clarifying distinctions between design phases, and standardizing terms related to evolutionary, innovative, and passive designs, consistent with current IAEA safety standards and glossaries.

- Technical Report No. NG-T-3.5, Legal and Institutional Issues of Transportable Nuclear Power Plants: A Preliminary Study (2013) explores the legal, regulatory, and institutional challenges associated with deploying transportable nuclear power plants (TNPPs), particularly in countries other than the supplier state. It examines ownership models, licensing, safeguards, liability, and international legal frameworks, and outlines potential solutions for safe and secure deployment of TNPPs under various technical and operational scenarios.

- The IAEA publication NW-T-1.14 (Rev.1), Status and Trends in Spent Fuel and Radioactive Waste Management, provides a comprehensive overview of global practices, inventories, and strategies related to the management of spent fuel and radioactive waste. It outlines national programmes, current technologies, and future projections, and emphasizes the importance of integrating waste and decommissioning considerations into the early stages of nuclear programme development. The document also addresses emerging challenges associated with new reactor technologies, offering insights to support Member States in developing effective and sustainable waste management approaches.

2.2. HTGRs (both pebble bed and prismatic fuel types):

- TECDOC 1936: Applicability of Design Safety Requirements to SMR Technologies Intended for Near Term Deployment (2020) evaluates how the requirements in SSR-2/1 (Rev. 1) apply to SMR designs, specifically light water and high temperature gas cooled reactors. It provides engineering-based insights on adapting existing safety requirements to SMRs and aims to support harmonization of safety approaches among Member States for near-term SMR deployment.

- TECDOC 1674 Advances in High Temperature Gas Cooled Reactor Fuel Technology (2012) presents the outcomes of a coordinated research project focused on coated particle fuel developments for HTGRs. It includes benchmark exercises using fuel performance and fission product release codes, experimental comparisons of fuel properties from the Republic of Korea, South Africa, and the USA, and advances in fuel characterization and quality control techniques.

- NP-T-4.1 Opportunities for Cogeneration with Nuclear Energy (2017), provides a comprehensive overview of cogeneration applications using nuclear energy, such as district heating, desalination, and industrial process heat. It outlines technical, economic, and environmental benefits, presents international case studies, and offers guidance for Member States — especially newcomers — on integrating cogeneration into nuclear energy planning.

- TECDOC: Considerations on the Safety of HTGRs (expected to start internal Q&A process early in 2026) primarily focused on the design safety features of HTGRs, with particular attention to the implementation of DiD, the fulfilment of fundamental safety functions, in particular the confinement and shielding safety function, the consideration of Design Extension Conditions, including severe accidents.

2.3. Hydrogen Production:

- IAEA NE Series NP-T-4.2 Hydrogen Production Using Nuclear Energy (2013) presents the state of the art in nuclear-based hydrogen production, and addresses the technical challenges and research needs for establishing a hydrogen economy. It reviews international R&D efforts, outlines various hydrogen production methods using nuclear energy (including thermochemical and electrochemical processes), and introduces economic evaluation tools and infrastructure considerations for future deployment.

2.4. Desalination:

- TECDOC-1753 New Technologies for Sea Water Desalination Using Nuclear Energy (2015) compiles research and development findings on emerging technologies for seawater desalination using nuclear energy, with a focus on low temperature and hybrid desalination systems. It includes a techno-economic feasibility study, evaluates sustainability and competitiveness, and explores innovative coupling configurations between nuclear reactors and desalination systems to improve efficiency and reduce costs.

2.5. Fast reactors (or Fast Neutron Spectrum Systems):

- TECDOC-1912 Challenges for Coolants in Fast Neutron Spectrum Systems (2020) evaluates various coolant options — such as light and heavy liquid metals, molten salts, gases, and water — for nuclear systems operating in a fast neutron spectrum, including fusion, fission, and accelerator applications. It compiles current knowledge, identifies technical challenges and knowledge gaps, and outlines near-term R&D needs based on experimental data and operational experience.

- NP-T-1.6 Liquid Metal Coolants for FRs Cooled by Na, Lead and Lead-Bi Eutectic (2013) provides a comprehensive overview of the technological status, challenges, and R&D needs related to liquid metal coolants in fast reactors. It covers the physical and chemical properties of sodium, lead, and lead-bismuth eutectic; coolant quality control, thermal-hydraulics, and radioactivity management; and summarizes past experiences and current projects, particularly in the Russian Federation.

- NF-T-4.1 Status and Trends of Nuclear Fuels Technology for Na cooled FRs (2011) reviews the technological status and development trends of nuclear fuels for sodium-cooled fast reactors (SFRs), focusing on manufacturing processes, irradiation behavior, and out-of-pile properties of fuels such as mixed uranium–plutonium oxide, monocarbide, mononitride, and metallic U–Zr and U–Pu–Zr. It also addresses fuels containing minor actinides (Np, Am, Cm), providing a valuable reference for fuel developers and materials scientists working on fast reactor systems.

- TECDOC-1569 Liquid Metal Cooled Reactors: Experience in Design and Operation (2007) presents a survey over five decades of global experience with LMFRs, focusing on design, operation, and decommissioning. It covers sodium and lead-bismuth-cooled systems, including demonstration and commercial reactors, and addresses technical topics such as coolant behaviour, safety issues, fuel development, and decontamination. The publication supports knowledge preservation and international collaboration in fast reactor technology development.

- TECDOC-1406 Primary Coolant Pipe Rupture Event in Liquid Metal Cooled Reactors. (2003) presents the proceedings of a technical meeting focused on the safety implications, structural integrity, and thermohydraulic consequences of primary coolant pipe rupture events in LMFRs. It includes national assessments from China, France, India, Japan, Republic of Korea, and Russia, and discusses design philosophies, leakbefore-break approaches, and innovative mitigation strategies to minimize core damage and enhance reactor safety.

- TECDOC-2079: Analysis and Modelling of Severe Accidents for Liquid Metal Cooled Fast Reactors: Proceedings of a Technical Meeting (2025) compiles the outcomes of a 2023 IAEA Technical Meeting focused on the analysis and modelling of severe accidents in LMFRs. It presents current knowledge on physical phenomena, the development and validation of numerical tools, and experimental data related to accident progression. The publication is intended for designers, operating organizations, regulatory bodies, and researchers involved in LMFR development and safety assessment;

- TECDOC: Considerations on the Safety of Liquid Metal Cooled Fast Reactors (expected to start the internal Q&A process in September 2025) provides an overview of the safety design features incorporated in LFMR designs. It also outlines the approaches adopted by Member States in the design safety and safety assessment of LMFR, with particular emphasis on the Design Extension Conditions, including the severe accidents.

2.6. Molten Salt Reactors:

- TECDOC-1912 Challenges for Coolants in Fast Neutron Spectrum Systems (2020) (see above);

- TECDOC: Considerations on the Safety of Molten Salt Reactors (expected to start internal Q&A process in Q4 2025) primarily focused on the main safety-related characteristic of MSRs, the fulfillment of the fundamental safety functions, the implementation of DiD, and the consideration of design extension conditions, including severe accidents.

2.7. Other publications

In addition, other relevant publications related to SMRs are listed below, highlighting the importance of addressing the key specific features of SMRs. These publications provide detailed insights into the safety design criteria, proliferation resistance, and deployment considerations for Generation IV systems, which are relevant to SMRs and TNPPs.

Cross-Cutting Safety and Design Reports from GIF:

- A Risk-Informed Framework for Safety Design of Generation IV Systems (2023);

- Safety Design Guidelines on Structures, Systems and Components for Generation IV Sodium-cooled Fast Reactor Systems (2024);

- Safety Design Criteria for Generation IV Very High Temperature Reactor System (2023);

- Safety Design Criteria for Generation IV Gas-Cooled Fast Reactor System (2022);

- Gas-Cooled Fast Reactor System Safety Assessment (2022);

- Safety Design Criteria for Generation IV Sodium cooled Fast Reactor System, Rev. 1 (2017);

- Safety Design Criteria for Generation IV Lead-cooled Fast Reactor System (2021);

- Safety Design Guidelines on Safety Approach and Design Conditions for Generation IV Sodium-cooled Fast Reactor Systems (2016).

Proliferation Resistance & Physical Protection (PR&PP) Reports from GIF:

- Molten Salt Reactors – PR&PP White Paper (2023);
- Very High Temperature Reactors – PR&PP White Paper (2022);
- Gas Fast Reactors – PR&PP White Paper (2022);
- Supercritical Water Reactors – PR&PP White Paper (2022);
- Lead Fast Reactors – PR&PP White Paper (2021);
- Sodium Fast Reactors – PR&PP White Paper (2021);
- PR&PP Bibliography – Revisions 9 to 11 (2022–2024).

Non-Electric Applications from GIF:

- Position Paper on Non-Electric Applications of Nuclear Heat – A GIF Priority (2022).

International Maritime Conventions and other related documents:

- United Nations Convention on the Law of the Sea (UNCLOS): Adopted in 1982;
- International Convention for the Safety of Life at Sea (SOLAS): The current version was adopted in 1974;
- International Convention for the Prevention of Pollution from Ships (MARPOL 73/78): Adopted in 1973, with a modifying Protocol in 1978;
- International Regulations for Preventing Collisions at Sea (COLREGs): Adopted in 1972;
- International Maritime Dangerous Goods (IMDG) Code: First adopted in 1965;
- International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on board Ships (INF Code): Became mandatory in 2001;
- Code of Safety for Nuclear Merchant Ships: Adopted in 1981.

Finally, several regulatory bodies have started considering how their current regulations could be adapted to advanced reactor designs, including SMRs and TNPPs, such CNSC, US NRC and Rostechnadzor:

- CANADIAN NUCLEAR SAFETY COMMISSION, Physical Design - Design of Reactor Facilities, REGDOC-2.5.2, Version 2.1, Ottawa (2023);
- UNITED STATES NUCLEAR REGULATORY COMMISSION, Guidance for Developing Principal Design Criteria for Non-Light Water Reactors, Regulatory Guide 1.232, Revision 0, US NRC, Washington, DC, (2018);
- NP-022-17: General Safety Assurance Provisions for Ships and Other Floating Craft with Nuclear Reactors. Rostechnadzor (2017);
- NP-029-17: Nuclear Safety Rules for Ships and Other Floating Craft with Nuclear Reactors. Rostechnadzor (2017).

3. Feedback from IAEA initiatives

3.1. SMR Regulators' Forum

The IAEA SMR Regulators' Forum has published a series of reports that identify and address several key safety-related gaps for both water cooled and non-water-cooled SMR designs. These reports, developed during the Forum's three phases of work (2015–2023), reflect the collective insights of regulatory bodies in different States and focus on cross-cutting, technology-neutral issues. The Forum emphasizes that while existing IAEA safety standards are broadly applicable, SMRs introduce novel features—such as modularity, compactness, and factory-based construction—that challenge traditional safety assessment methodologies.

For water-cooled SMRs, the Forum has underscored the importance of re-evaluating the safety implications associated with shared systems and components across multiple reactor modules. These designs frequently depend on interconnected support systems — such as power supply, cooling, and control — which, if not adequately isolated, can introduce vulnerabilities and potential common-cause failures. The compact design of SMRs, while advantageous for factory-based fabrication and transport, poses challenges for in-service inspection, maintenance accessibility, and emergency response planning. The Forum also noted that conventional safety analysis methodologies may not fully account for the complex interactions between modules, particularly in scenarios involving internal or external hazards.

In the case of non-water-cooled SMRs — such as gas-cooled, liquid metal-cooled, or molten salt reactors — the Forum identified additional challenges not only due to the limited operational experience, but mainly due to the novel phenomena associated with different physics and materials involved. These designs often feature high operating temperatures, alternative coolants with unique thermophysical properties (such as liquid metals or molten salts), special fuel type, and compact core geometries, all of which introduce novel challenges for thermal-hydraulic behavior, material performance, and system integration.

Additionally, extensive reliance on passive safety systems, which operate based on driving forces like natural circulation or gravity, raises concerns about their robustness under adverse conditions. The Forum stressed the importance of validating these systems through rigorous testing and modeling.

Another major area of concern is the application of defence in depth (DiD), particularly design extension conditions, including severe accidents. The Forum found that many SMR designs propose alternative approaches to severe accident mitigation, including the concept of "practical elimination" of certain accident scenarios.

In summary and in alignment with the Forum's objectives, the working phases have focused on addressing the safety issues most impacted by innovations in SMRs, thereby enabling the future revision and development of IAEA Safety Standards. Additionally, the Forum emphasizes the critical importance of integrating safety, security, and safeguards from the earliest stage of design. (ref. SMR Regulators' Forum Pilot Project Report: Considering the Application of a Graded Approach, Defence-in-Depth and Emergency Planning Zone Size for Small Modular Reactors, January 2018, Microsoft Word - SMR RF Report_29.01.2018.pdf; SMR Regulators' Forum Phase 2 Summary Report Covering Activities from November 2017 to December 2020 for Small Modular Reactors, June 2021, smr_regulators_forum_phase_2_summary_report.pdf; SMR Regulators' Forum Phase 3 Summary Report, December 2023, smr_rf_phase_3_summary_report.pdf, SMR Regulators' Forum Phase 3 Report on Containment Systems (2023); and SMR Regulators' Forum Phase 3 Report on Safety, Security and Safeguards from a Regulatory Perspective: An Integrated Approach (2023); There are two additional reports under development expected to be published in 2026 Working Group on Design and Safety Analysis Phase 4 Report: Mechanistic Source Term and Working Group on Design and Safety Analysis Phase 4 Report: Remote Locations).

3.2. NHSI initiative

Similar to the SMR Regulators' Forum, the IAEA's Nuclear Harmonization and Standardization Initiative (NHSI) provides a platform to enable collaborative efforts between regulators, technology developers, and industry stakeholders, aiming to facilitate the safe and efficient global deployment of advanced nuclear reactors. A key aspect in this initiative is the need for harmonized regulatory approaches that uphold high safety standards, such as those established by the IAEA. This harmonization is essential to addressing identified challenges in the licensing process that are closely connected to the innovations in advanced reactor designs.

While the IAEA Safety Standards are broadly applicable, NHSI found that certain assumptions embedded in these standards that are related to large, water cooled reactors, may not hold for advanced nuclear reactors, and SMRs. For example: the application of defence in depth, the use of passive safety systems, the application of the single failure criterion and common cause failure protections.

In summary, the NHSI recommends that the IAEA consider revising its Safety Standards to reflect the unique characteristics of advanced reactor designs and SMRs, especially non-water-cooled designs. This revision will support the aspiration of the regulatory track to develop a global framework for the regulatory reviews of advanced reactor with a consistent and informed application of IAEA Safety Standards along with other codes and standards (ref. Summary of NHSI Second Plenary Meeting, 27 June 2023, Summary of NHSI Plenary Meeting Material June 2023.pdf)

3.3. Atomic Technologies Licensed for Applications at Sea (ATLAS)

Considering that the Atomic Technologies Licensed for Applications at Sea (ATLAS) project has just started, the drafting of the revised version of SSR-2/1 (Rev. 1) will consider the progress performed by the ATLAS project, as appropriate.

4. IAEA General Conferences' Resolutions

4.1. IAEA General Conferences' Resolutions

Recent IAEA General Conference resolutions have highlighted several important gaps and priorities related to the design safety of advanced reactors, including SMRs and TNPPs.

The IAEA General Conference has acknowledged that while current Safety Standards provide a strong foundation, they may not fully address the novel design features of advanced reactors and SMRs and need further revision for their applicability. (ref. Nuclear Safety Review 2023, GC(67)/INF/2, GC67-inf2.pdf).

For TNPPs and factory-fueled SMRs, there are publications (e.g. from INPRO) identifying gaps in applying existing safety standards to mobile, sealed reactors (see Technical Report No. NG-T-3.5). These designs challenge traditional assumptions about site- specific safety, emergency planning, and regulatory oversight. The publications emphasized the need for clear allocation of responsibilities between supplier and host states, especially regarding safety, security, and liability.

The General Conference resolutions have called for greater harmonization of safety requirements and regulatory cooperation to avoid duplication and facilitate international deployment. This includes developing common expectations for safety cases, pre-licensing design reviews, and mutual recognition of regulatory assessments which can be expressed by updated IAEA safety standards on design safety, safety assessment and regulations.

The 67th and 68th IAEA General Conferences have reaffirmed the importance of updating safety standards to reflect these emerging technologies. The following are the relevant IAEA resolutions from Member States:

> GC(67)/RES/7, para 49: Encourages the Secretariat to continue updating the Safety Standards based on the results of the applicability study to small modular reactors, most notably through the CSS as well as affiliated and relevant Agency committees, and to keep abreast of any new developments and challenges in this regard.

GC(68)/RES/8, para 51: Requests the Secretariat to continue updating the Agency's Safety Standards following the process of the CSS and Safety Standards Committees, including updates based on the results of the applicability study to small modular reactors and advanced reactors, and to keep abreast of any new developments and challenges in this regard.

GC(67)/RES/7, para 76: Calls upon the Secretariat to continue considering the safety and security aspects, including emergency preparedness and response, of TNPPs and SMRs throughout their life cycle, including through the Small Modular Reactor Regulators' Forum, the NHSI and its regulatory track and, where relevant, the NHSI industry track and the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), and to draw upon the knowledge and experience of other international organizations and Member States, and renews its request to the Secretariat to continue to organize meetings and activities on TNPPs and SMRs, with a view to using their findings to consider, under the common existing requirements and legal instruments, the various safety aspects of such power plants, including their transport, as well as identifying, understanding and addressing regulatory challenges related to their lifecycles.

GC(68)/RES/8, para 78: Calls upon the Secretariat to continue considering the safety and security aspects, including emergency preparedness and response, of TNPPs and SMRs throughout their life cycle, including through the Small Modular Reactor Regulators' Forum, the NHSI and its regulatory track and, where relevant, the NHSI industry track and the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), and to draw upon the knowledge and work of other international organizations, initiatives and Member States, on nuclear safety improvements, and renews its request to the Secretariat to continue to organize meetings and activities on TNPPs and SMRs, with a view to using their findings to consider, under the common existing requirements and legal instruments, the various safety aspects of such power plants, including their transport, as well as identifying, understanding and addressing regulatory challenges related to their lifecycles.

5. Feedback from technical safety review missions on design safety and safety assessment

In 2024-2025 the Safety Assessment Section conducted technical safety review (TSR) missions focused on the design safety of three small modular reactors, i.e., Rolls Royce SMR, NuScale SMR and SALUS SMR. The main feedback from those TSRs is that the IAEA Safety Requirements are generally applicable to SMR designs. However, some interpretations and adjustments are needed depending on the reactor technology and the level of detail of the design to be evaluated. Therefore, updating the IAEA Safety Standards considering the key design safety features of such reactor designs will ensure wider applicability of the design safety standards, enhancing their usage and increasing safety globally.