

**ANSN - Regional Workshop on Safety
Benefits and Challenges in the
Development of the Adoption of Small
Modular Reactors (EVT2404165)
31 March - 4 April 2025
Daejeon, Rep of Korea**

Day 2: Tuesday, 1 April 2025

P11. Safety consideration on the SMR Siting - 1

Name: Paolo Contri

Section: External Events Safety Section (EESS)

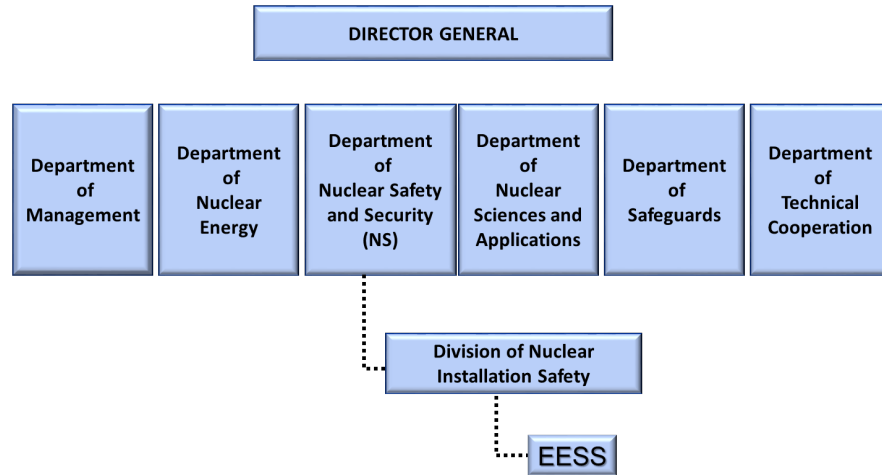
Division of Nuclear Installation Safety (NSNI)

International Atomic Energy Agency (IAEA)

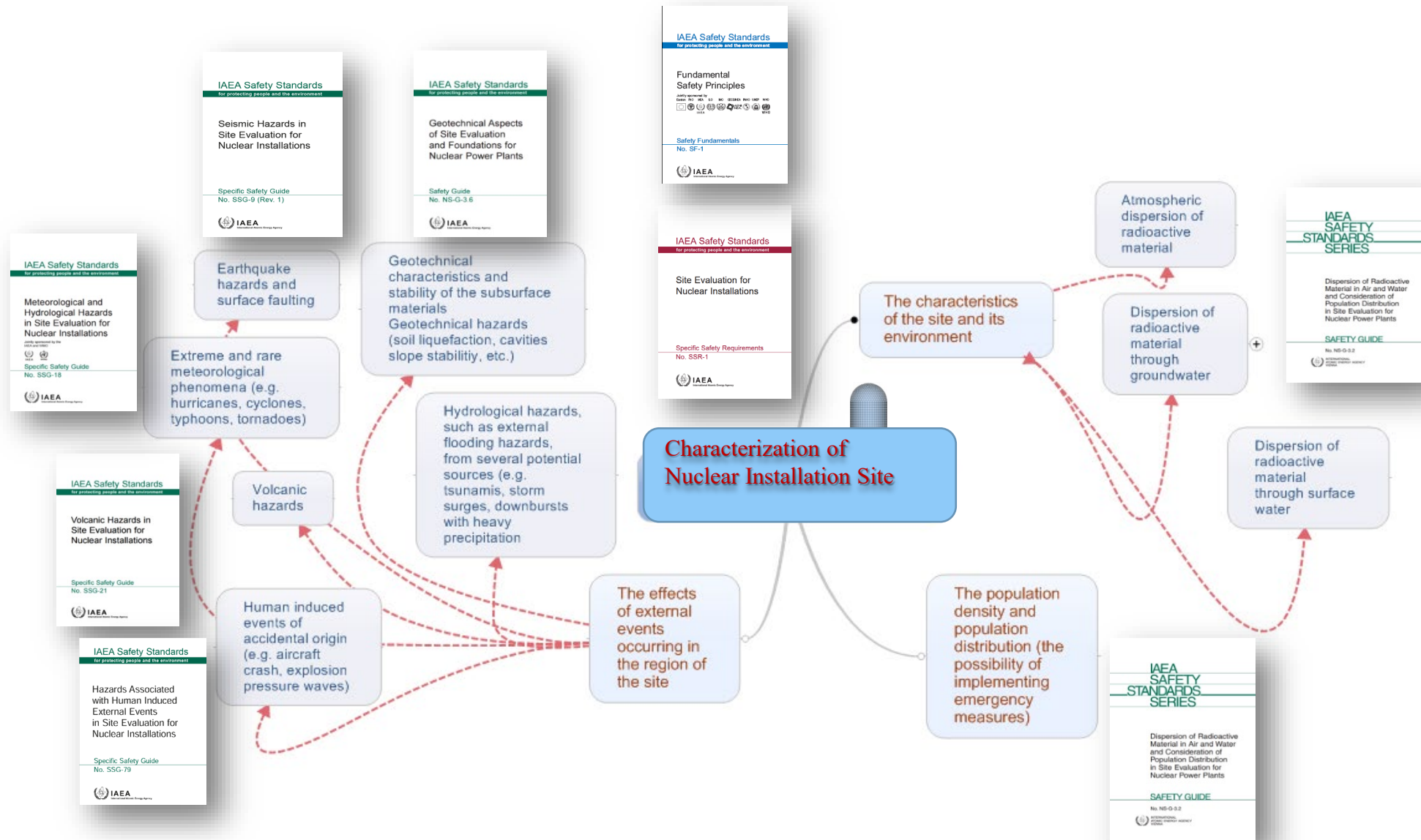
Contents of Presentation

- Introduction of External Events Safety Section (EESS);
- IAEA Safety Standards for Site Evaluation;
- External Events related issues for SMRs;
- Challenges to Plant Safety against Impacts of Climate Change;
- EESS Publications related to Advanced NPPs including SMRs;
- EESS SEED Review Mission for Site Selection of SMRS;
- EESS Activities for Capacity Building of Embarking Countries;
- EESS Upcoming Events related to SMRs;
- Application of IAEA Safety Standards to External Hazards Assessment for Advanced NPPs, Including SMRs;
- Possible Approaches for Applying Graded Approach to Site Evaluation of Advanced NPPs
- Final remarks on Graded Approach for Site Evaluation of SMRs;

The External Events Safety Section



IAEA Safety Standards for Site Evaluation of Nuclear Installations





Technical issues related to siting and design of SMRs in relation to EEs

External Hazard related issues for SMRs

Siting

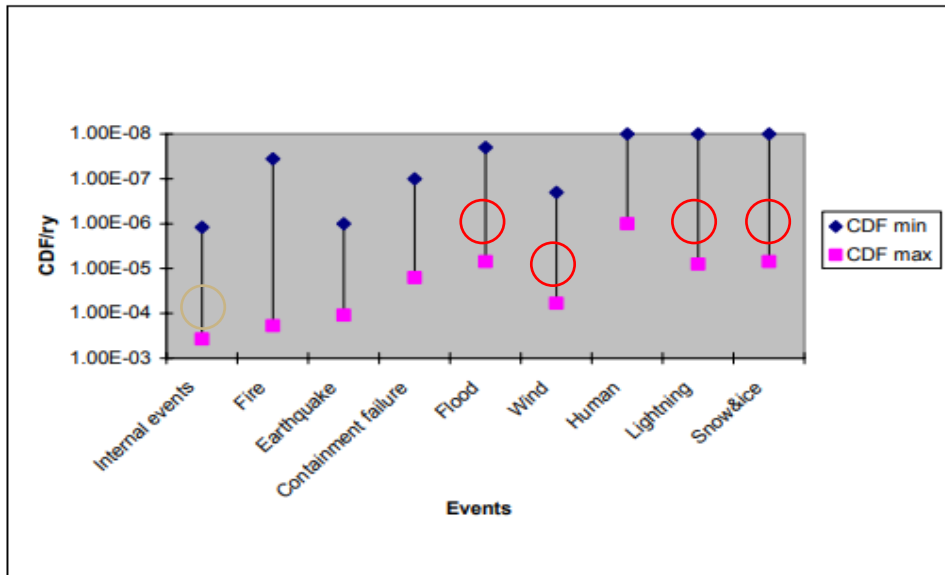
- SMRs are typically certified with “standard” EE design basis, but the site license should refer to a **site specific** assessment, requiring dedicated site investigation and hazard assessment
- SMR siting is not compatible with costs and time typical of NPP siting: a suitable **graded approach** should be applied
- The graded approach cannot be based on power inventory: reference to the **safety features** of SMRs should be applied
- **Screening** of EEs may take advantage of the special configuration of SMRs
- **Off site emergency planning** may take advantage of SMR design features
- **Multi Unit interaction** should be addressed since siting and design phases
- Interactions with **co/located facilities** should be addressed
- **Capacity building for Regulators** in site licensing is important

Design

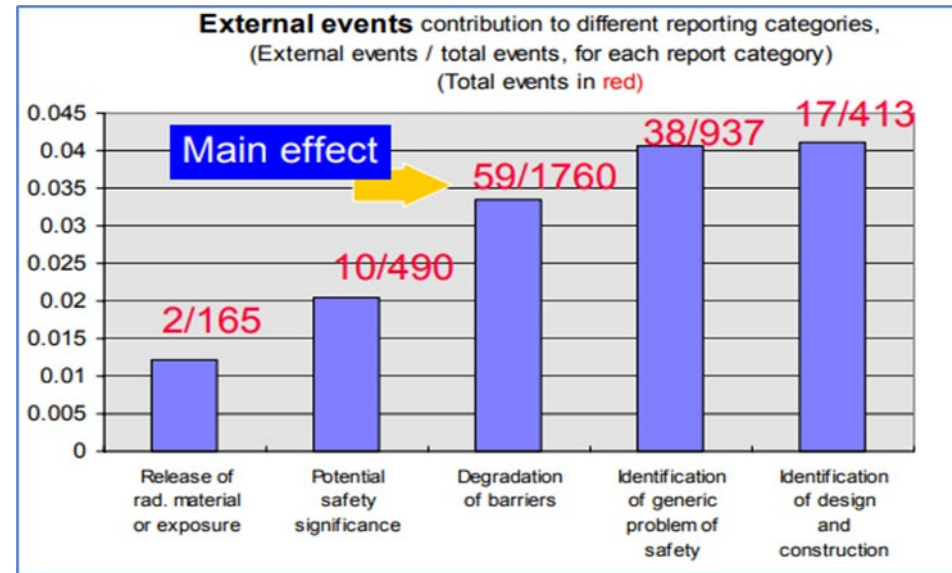
- **EE safety margins** should be reassessed with reference to actual site hazards
- **Embedment, footprint and low elevation** of superstructure may show different vulnerability to EEs
- **Component qualification** to EE may be optimized following a risk based approach
- The overall risk assessment to EE may suggest simplified approach to siting and design

Challenges to plant safety from climate change

Very significant contribution is expected by climate-change related scenarios on CDF and safety significant scenarios



US/NRC, Perspectives gained from the individual plant examination of external events (IPEEE) programme, NUREG-1742, NRC, Washington, April 2001



IAEA, Tecdoc 1341, Extreme external events in the design and assessment of nuclear power plants, March 2003 – A new assessment of external events in the period 2000-2020 is in progress at EESS

Effects of climate change affected scenarios are quite similar and relevant among all plant types. Preliminary studies show that similar impact is expected for **SMRs**

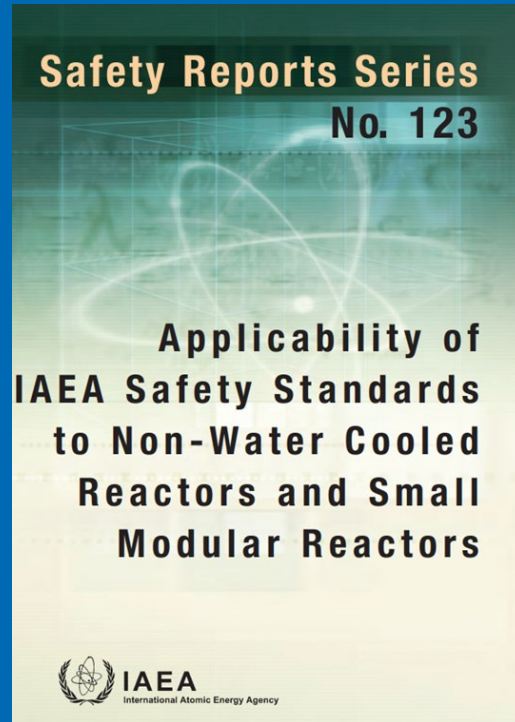
The main siting issue: graded Approach in Site and Design Safety

- The governing principle is provided by the IAEA Safety Fundamentals, Principle 5: *‘The resources devoted to safety by the licensee, and the scope and stringency of regulations and their application, have to be commensurate with the magnitude of the radiation risks...’*.
- The application of a graded approach is a **proportional application** of the safety requirements, while keeping the focus on achieving the overall safety objectives, rather than a relaxation of the requirements themselves.
- **Risk-informed and performance-based** strategy integrating site-installation interactions used for new advanced reactor designs (such as SMRs) for achieving an adequate design robustness against external hazards.
- This approach enables the application of a graded approach to site specific hazards characterization, thereby making the engineering effort more efficient and cost effective.



IAEA Support to SMR deployment

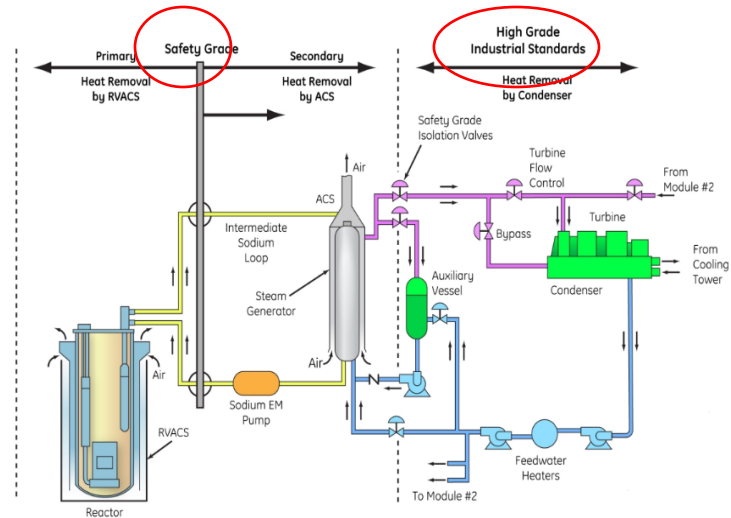
The EESS support to SMR deployment



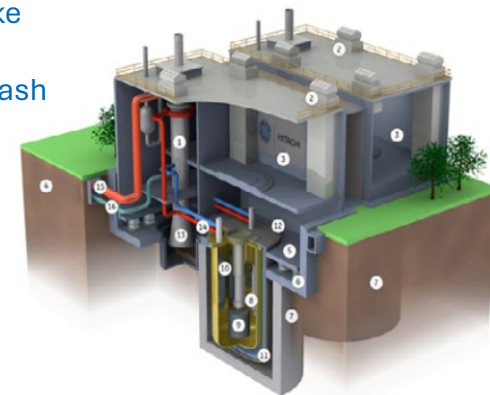
1. Extra Budgetary Projects on SMR related issues
2. Development of technical documents to support the application of Safety Guides, often technology dependent
3. Capacity building: e-learning material and training hub, training manuals
4. Review services: SEED, Technical Safety Review services, IRRS, etc.
5. Event analysis and lesson learnt for continuous learning (EENS)
6. Scanning the research network for updates and dissemination

IAEA/EESS Ongoing Projects Supporting SMRs

- **Design Robustness against External Hazards:**
 - Assessment of the adequacy of the EH safety Margins through performance based strategies
- **Optimization of Protection against EH:**
 - Establish graded approach rules for siting and design, based upon the safety features of the SMRs
- **Handbook for Site Selection and Evaluation**
 - Apply a graded approach to the site investigation effort and meet time and cost objectives
 - Minimise the site specific investigation effort wrt to the enveloping hazard used for unified design of SMRs
- **Safety assessment of site and design of Multi Unit installations**
- **Seismic qualification of SSCs by similarity**
- **Capacity building for regulators in SMR site licensing**



Earthquake
Flooding
Aircraft crash
Etc.



Technical documents in SMR (External Event) areas

Site Safety – Areas of work for Guidelines

Safety Report "Application of Graded Approach for Site Evaluation of Nuclear Installations including Small Modular Reactors"

Tecdoc "Handbook for Site Survey and Site Evaluation for Nuclear Installations"

Tecdoc "Protection of nuclear installations from the effects of climate change"

Safety Report "Effect of Climate Change on Assessment of Meteorological and Hydrological Hazards for Nuclear Installations"

Tecdoc on "Operational Measures, Adaptation Strategies, Pre- and Post-event Actions for Climate Events"

Safety Assessment - Areas of work for Guidelines

Tecdoc 2043 "Assessment of Design Robustness against external hazards"

Tecdoc 2042 "Optimization of safety measures for protection of nuclear installations against external hazards (Framework for siting SMRs)"

Tecdoc "Siting and Design aspects of SMRs in relation to External Hazards: special issues in the application of Safety Standards (seismic isolation, steel plated structures and EPZ)"

Tecdoc on "Seismic performance of structures, systems and components; their qualification based on seismic experience"

Technical documents (Cont'd)

Design Safety – Areas of work for Guidelines

Safety considerations of HTGRs, LFRs, SFRs, MSR

Passive safety

Safety of non water cooled reactor fuels and cores

Advanced manufacturing and new materials: safety considerations

Safety implications of using AI in NPPs

Design safety of floating NPPs

Safety, Security and Safeguards by design

Safety Assessment - Areas of work for Guidelines

Safety assessment for SMRs and non water cooled reactors

Severe accident analysis and management for non water cooled reactors

Safety demonstration of innovative technology in power reactor designs

Demonstration of defence in depth using deterministic and probabilistic approaches

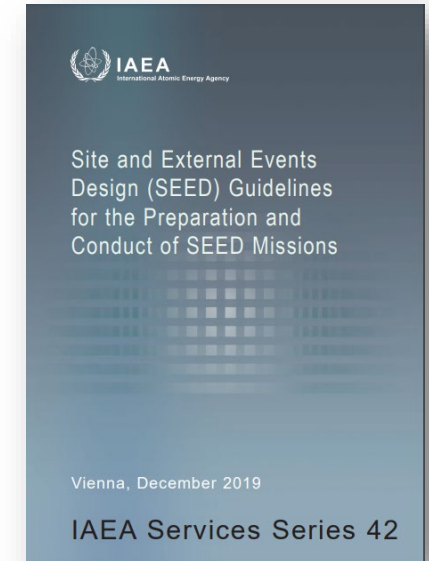
EESS SEED Review Mission for Site Selection of SMRS

SITE AND EXTERNAL EVENTS DESIGN (SEED) REVIEW MISSION:

- Site Selection for Deployment of Small Modular Reactors in Uzbekistan, Jan 2022
- Site Selection for Deployment of Small Modular Reactors in Romania, 22-24 Aug 2022;
- Follow-up Review Mission on Site Selection for Deployment of Small Modular Reactors in Romania, April 3, 2024;
- Review of Site Selection Process for Nuclear Installations in Canada (Saskpower) 23 – 27 September 2024, Regina, Canada

1. Site and Design Safety Regulations;
2. Site Selection Process;
3. Site Evaluation;
4. Environmental Impact Assessment;
5. Site Monitoring; and
6. Safety of Structures, Systems and Components against External Hazards

SEED Review Modules



Working Areas

1. External Hazards Assessment
2. Designs Against External Hazards
3. Safety Assessments Against External Hazards
4. Seismic Experience Database Project
5. Capacity Building Project

Methodologies

1. IAEA SSs and Technical Documentations
2. Research Projects
3. Technical Meetings, CSs and Workshops
4. Advisory Missions and Trainings
5. External Event Monitoring and Alert
6. Knowledge Management

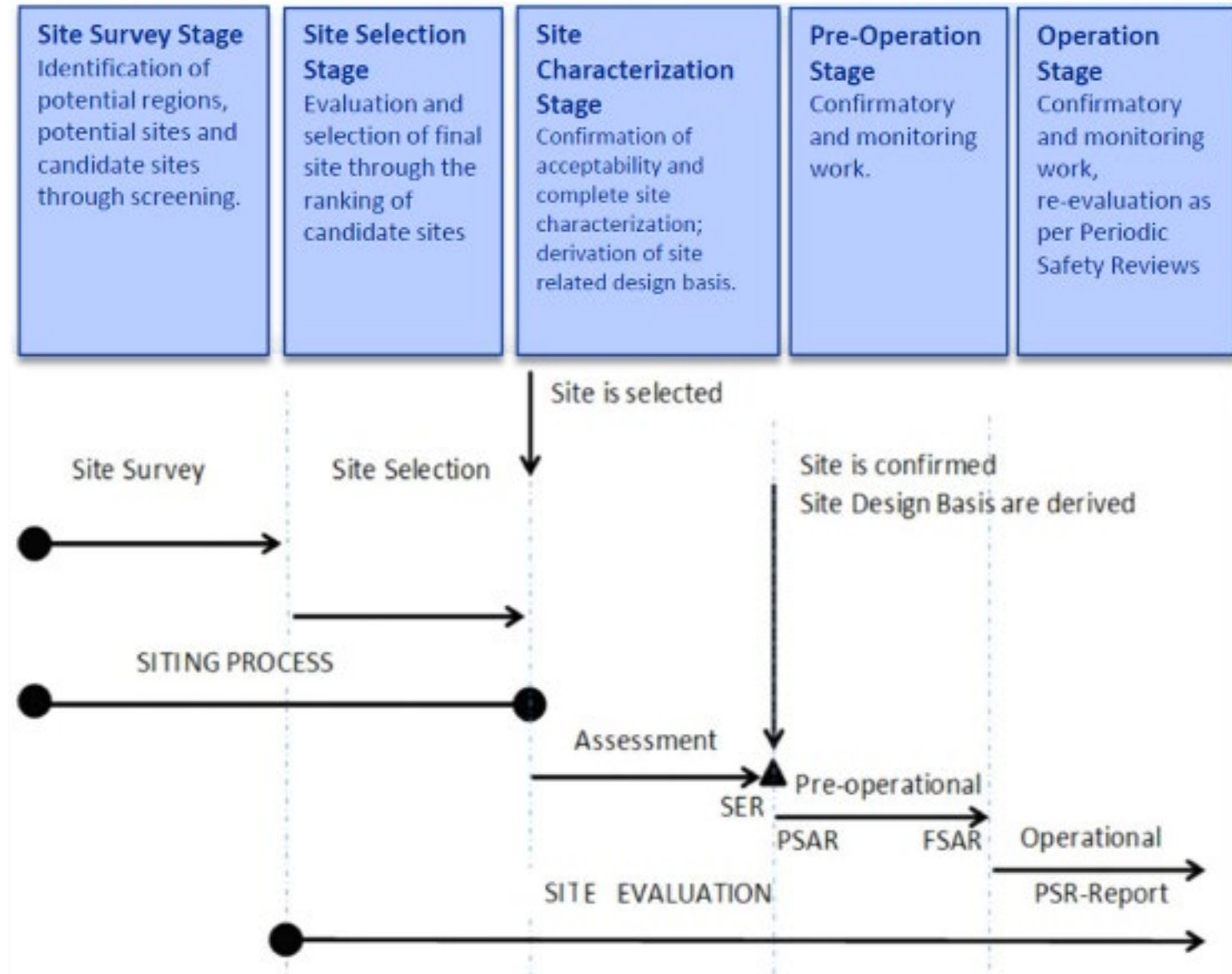
SEED review modules

Working Areas

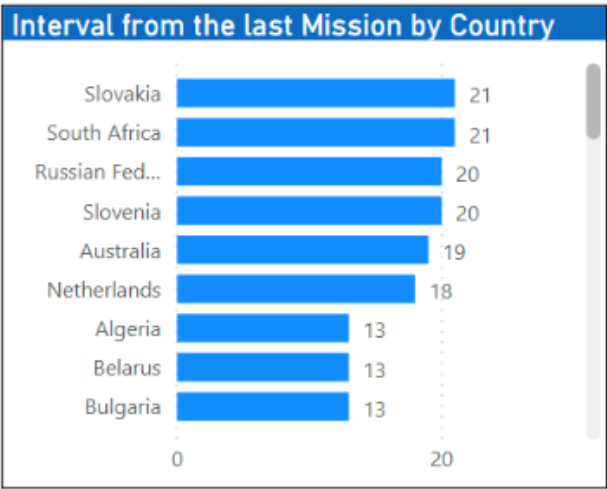
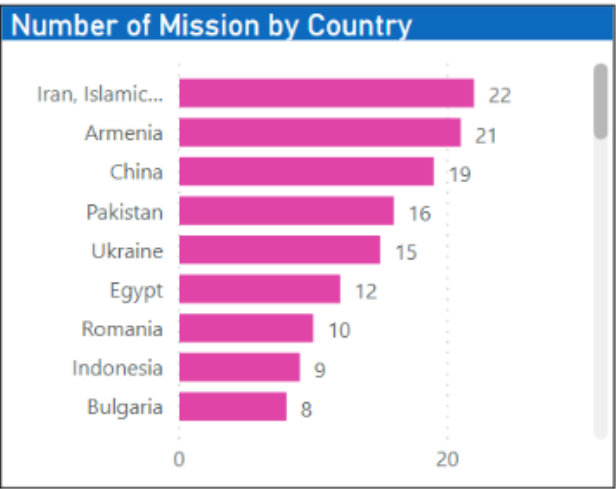
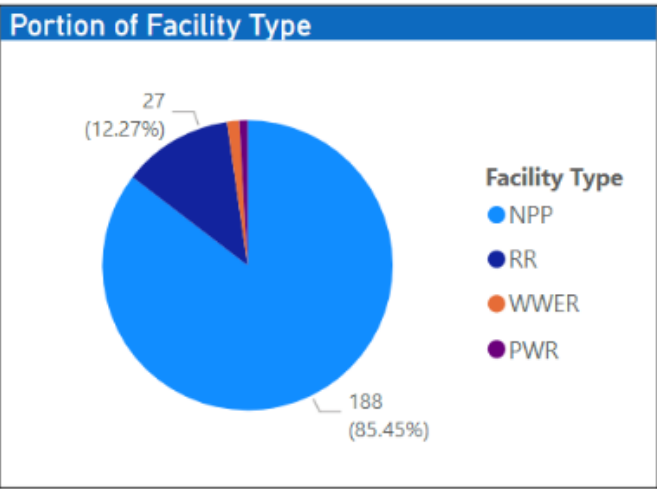
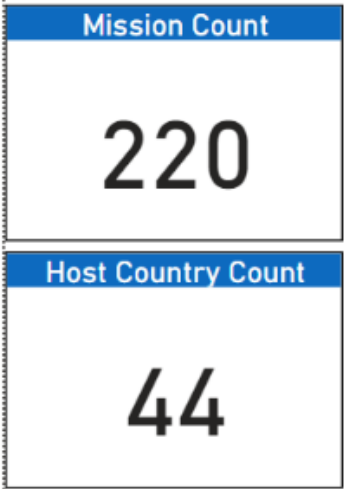
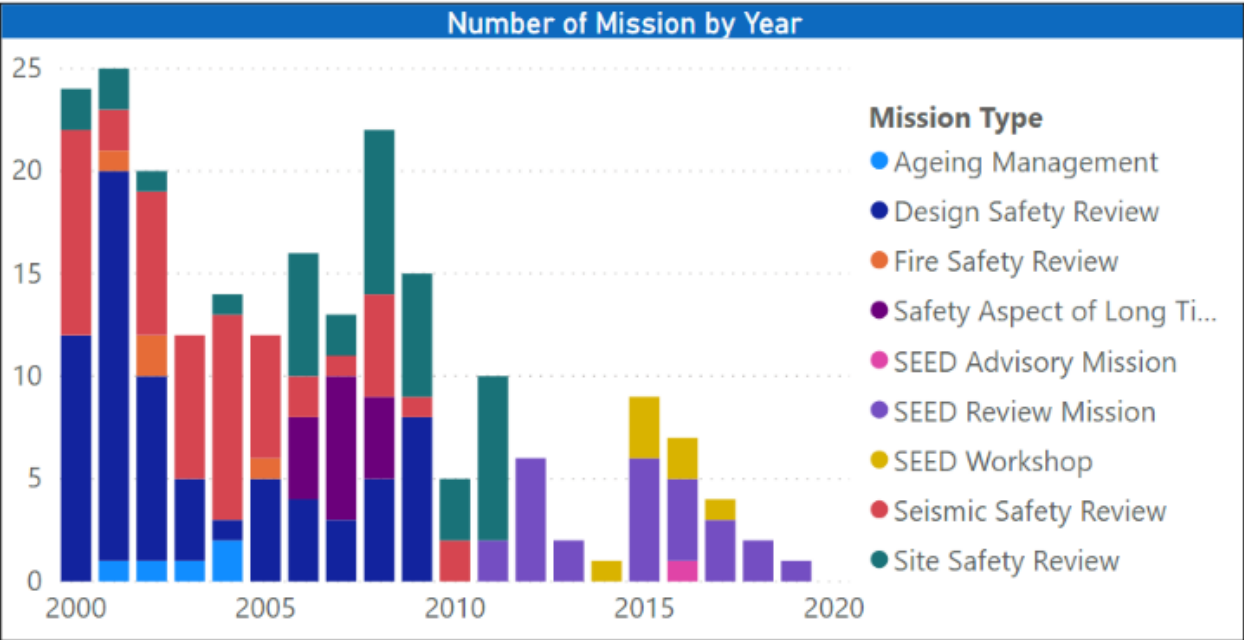
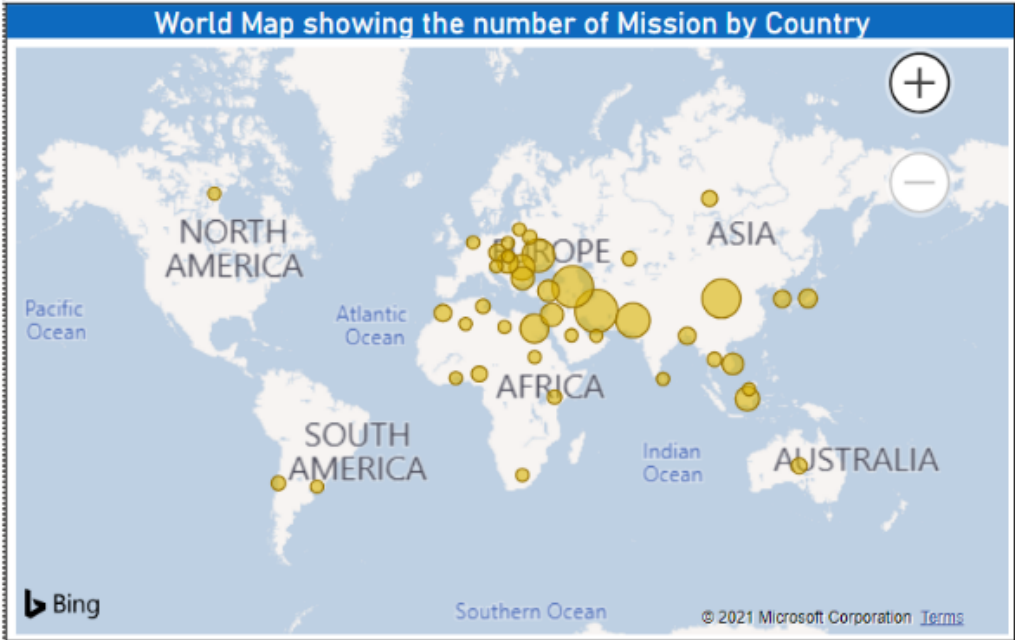
1. External Hazards Assessment
2. Designs Against External Hazards
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4. Seismic Experience Database Project
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Methodologies

1. IAEA SSs and Technical Documentations
2. Research Projects
3. Technical Meetings, CSs and Workshops
4. Advisory Missions and Trainings
5. External Event Monitoring and Alert
6. Knowledge Management



Seed Mission Dashboard



EESS Activities for Capacity Building of Embarking Countries

- To support regulatory bodies and operating organizations to build their capabilities in site and design safety:
- Workshops;
- Training events;
- Webinars.

(1) TECDOC "A Handbook for Education and Training Programme on Nuclear Site Safety for Regulatory Bodies in Embarking Countries"

(2) Safety Reports "SAR Review Guidance on Site Characteristics"

New publications "In Preparation"



The screenshot shows the IAEA website header with the logo and name. Below it, the title "External Events Safety Section: Capacity Building Activities" is displayed. A brief description states: "The External Events Safety Section provides support to Member States in building and sustaining capacity in nuclear safety." The page is divided into two main sections: "Education and training" and "Knowledge management".

Education and training

- As part of the [Site and External Events Design Review Service \(SEED\)](#), the [SEED Guidelines](#) on how to prepare and conduct SEED review missions can be used as training material.
- Collection of training material on site selection and site evaluation for nuclear installations, radiological environmental impact assessment of nuclear installations, design of nuclear installation against external events, safety assessment of existing nuclear installation against external events and for safety standards on site and design safety in relation to external events.

Knowledge management

- The [EESS Portal](#) (login required) contains research outcomes and state of art practice (technical reports, research advancement, presentations) for: external hazards assessments, design against external hazards, safety assessment against external hazards, seismic experience database. It is of added value in particular as knowledge repository for the nuclear safety community on the state of art methods for the assessment of site and design safety in relation to external events.
- The seismic experience database (login required) contains reports on the states of nuclear power plant components after they have been exposed to earthquakes of various intensity
- The external events notification system (login required) contains earthquake notification reports related to the occurrence of external events around the world in the region of nuclear installation sites
- The SEED review mission report database (login required) contains SEED review mission reports conducted in Members States

Related resources

- [Division of Nuclear Installation Safety: Capacity Building Activities \(full list\)](#)
- [List of IAEA training resources \(CLP4NET\)](#)
- [List of global training resources on nuclear safety \(GETR\)](#)
- [List of knowledge networks under GNSSN](#)
- [Search the IAEA Peer Review and Advisory Services Calendar \(including past events\)](#)



The screenshot shows the IAEA GNSSN website header. Below it, the title "E-LEARNING PLATFORM For the Capacity Building on the Site Safety for Nuclear Installations" is displayed. A large group photo of participants is shown. The page is divided into two main sections: "CONTENTS" and "1. INTRODUCTION".

CONTENTS

- [Introduction](#)
- [Self-Assessment](#)
- [Site Survey and Site Selection](#)
- [Environmental Impact Assessment](#)
- [Site Evaluation](#)
- [Hands-On Practice on SAR Review](#)
- [Capacity Building Handbook](#)
- [Feedback](#)
- [Country Specific Trainings](#)

1. INTRODUCTION

1.1 Background

The statute of the IAEA includes the establishment of, and provision for, the application of safety standards for the protection of health, life, and property. Education and training (E&T) play a key role in facilitating the application of Safety Standards in IAEA Member States and for globally strengthening radiation protection. The E&T activities of IAEA follow the resolutions of its General Conference and reflect IAEA Safety Standards and guidance.

In the wake of the accident at TEPCO's Fukushima Daiichi nuclear power plant in 2011, the IAEA developed its Action Plan on Nuclear Safety, which was approved by the General Conference at its 55th session [1]. Capacity building in Member States is one of the twelve main actions identified in the Plan. The IAEA devised an integrated capacity building concept that addresses four main pillars: E&T, human resource development, knowledge management and knowledge networks.

In 2012, the IAEA conducted a review of achievements on E&T in nuclear safety over the

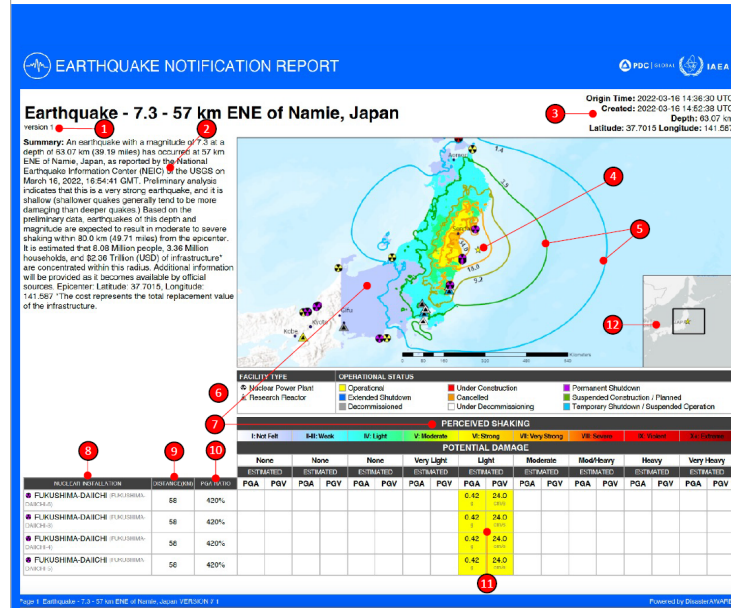
Quick Links

- [EESS Extrabudgetary Programme](#)
- [ShakeCast / External Events Notification System](#)
- [Climate Change](#)
- [Siting of Advanced Reactors](#)

Related Pages

- [IAEA Nuclear Safety Standards](#)
- [IAEA Nuclear Security Series](#)
- [NSS-OUI](#)
- [Siting of Nuclear Facilities](#)
- [Capacity Building Activities](#)
- [Design of Nuclear Power Plants](#)
- [Research Reactor Safety Section](#)
- [Nuclear Power Plant Safety](#)
- [IEC](#)
- [Nuclear Security](#)
- [Nuclear Infrastructure Development Section](#)

Analysis of Lesson Learnt The External Event Notification System



Damage 1



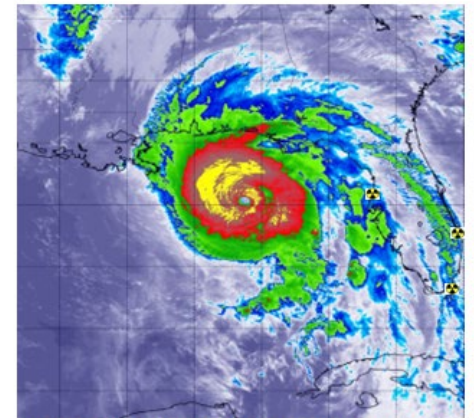
- Damage forecast and assessment to NPPs and population - **Real time alert to the IEC**
- Event Notification Reports – **Statistics on Near Misses**
- Ext. Event Effect Report - **Cooperation with OECD/NEA WGs for information collection**
- All EEs (Winds, Flood, Earthquakes, Tsunami, Fire, Volcanoes)
- **Live since Sept. 2022!!**



EESS Upcoming Events related to SMRs

- Technical Meeting on the Optimization of Protection of Small Modular Reactors in Relation to External Events, 22-25 April, 2025 (EVT2404534)
- 2025 International Conference – Resilience of Nuclear Installations against External Events from a Safety Perspective – Focus on Climate Change, 10/20–10/24/2025

**INTERNATIONAL CONFERENCE
RESILIENCE OF NUCLEAR
INSTALLATIONS AGAINST
EXTERNAL EVENTS: SPECIAL
FOCUS ON CLIMATE CHANGE
VIENNA, 4Q 2025**



*External Events Safety Section (EESS)
Division of Nuclear Installation Safety
(NSNI/IAEA)*



The special issue of the Graded Approach in SMR siting

Application of IAEA Safety Standards to External Hazards Assessment for Advanced NPPs, Including SMRs

What is a “GRADING”

- A ‘graded’ approach is “an application of safety requirements that is commensurate with the characteristics of the facilities and activities or the source and with the magnitude and likelihood of the exposures”, (IAEA Safety and Security Glossary);
- Grading is based on:
 - ✓ **Radiological hazard** and potential impact on health and environment;
 - ✓ Possible **consequences** in case of failure.
- Grading is an open concept; there is no single approach to its application, as long as overarching safety principles are respected.
- Whatever “grading” is used; final **safety requirements** must be met:
 - ✓ Those requirements are eventually expressed in terms of **acceptable doses** to workers and public
- Radiological **risk goals** cannot be graded:
 - ✓ Annual frequencies of exceeding acceptable doses for workers and the public.
- Risk has two components:
 - a) The annual **frequency of failure** of the installation (i.e. reliability)
 - b) The (conditional) **probability** that workers or the public receive **unacceptable doses**
- Component (a) depends on how **site investigation** leading to design basis parameters is carried out.

Application of IAEA Safety Standards to External Hazards Assessment for Advanced NPPs, Including SMRs (Cont'd)

- IAEA Fundamental Safety Principal 5: Optimization of Protection (No. SF-1)

Principle 5: Optimization of protection

Protection must be optimized to provide the highest level of safety that can reasonably be achieved.

3.21. The safety measures that are applied to facilities and activities that give rise to radiation risks are considered optimized if they provide the highest level of safety that can reasonably be achieved throughout the lifetime of the facility or activity, without unduly limiting its utilization.

3.22. To determine whether radiation risks are as low as reasonably achievable, all such risks, whether arising from normal operations or from abnormal or accident conditions, must be assessed (using a graded approach) a priori and periodically reassessed throughout the lifetime of facilities and activities. Where there are interdependences between related actions or between their associated risks (e.g. for different stages of the lifetime of facilities and activities, for risks to different groups or for different steps in radioactive waste management), these must also be considered. Account also has to be taken of uncertainties in knowledge.

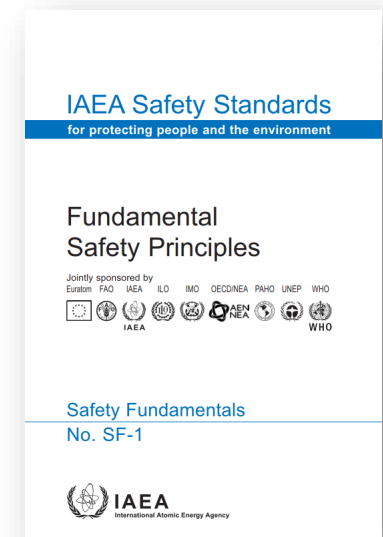
3.23. The optimization of protection requires judgements to be made about the relative significance of various factors, including:

- The number of people (workers and the public) who may be exposed to radiation;
- The likelihood of their incurring exposures;
- The magnitude and distribution of radiation doses received;
- Radiation risks arising from foreseeable events;
- Economic, social and environmental factors.

The optimization of protection also means using good practices and common sense to avoid radiation risks as far as is practical in day to day activities.

3.24. The resources devoted to safety by the licensee, and the scope and stringency of regulations and their application, have to be commensurate with the magnitude of the radiation risks and their amenability to control. Regulatory control may not be needed where this is not warranted by the magnitude of the radiation risks.

Para 3.24 of Principal 5 'Optimization of protection' provided in IAEA SF-1 states that “The **resources devoted to safety** by the licensee, and the **scope and stringency of regulations** and their **application**, have to be **commensurate** with the **magnitude** of the **radiation risks** and their amenability to control. [...]”



Application of IAEA Safety Standards to External Hazards Assessment for Advanced NPPs, Including SMRs (Cont'd)

SSR-1 Requirement 3:

- 4.2. The **application** of the safety **requirements** for site evaluation for nuclear installations shall be **commensurate** with the **potential hazards** associated with the nuclear installation.
- 4.3. The **level** of **detail** needed in the evaluation of a site for a nuclear installation shall be **commensurate** with the **risk** associated with the **nuclear installation** and the **site** and will **differ** depending on the **type** of nuclear **installation**.
- 4.4. The **scope** and **level** of **detail** of the site evaluation process necessary to support the **safety demonstration** for the nuclear installation shall be **determined** in accordance with a **graded approach**.

4. GENERAL REQUIREMENTS FOR SITE EVALUATION

Requirement 3: Scope of the site evaluation for nuclear installations

The scope of the site evaluation shall encompass factors relating to the site and factors relating to the interaction between the site and the installation, for all operational states and accident conditions, including accidents that could warrant emergency response actions.

4.1. The scope of the site evaluation shall cover all external hazards, monitoring activities and site specific parameters relevant for the safety of the nuclear installation. In determining the scope of the site evaluation, a graded approach shall be applied commensurate with the radiation risk posed to people and the environment.

4.2. The application of the safety requirements for site evaluation for nuclear installations shall be commensurate with the potential hazards associated with the nuclear installation.

4.3. The level of detail needed in the evaluation of a site for a nuclear installation shall be commensurate with the risk associated with the nuclear installation and the site and will differ depending on the type of nuclear installation.

4.4. The scope and level of detail of the site evaluation process necessary to support the safety demonstration for the nuclear installation shall be determined in accordance with a graded approach.

4.5. For site evaluation for nuclear installations other than nuclear power plants, the following shall be taken into consideration in the application of a graded approach:

- (a) The amount, type and status of the radioactive inventory at the site (e.g. whether the radioactive material on the site is in solid, liquid and/or gaseous form, and whether the radioactive material is being processed in the nuclear installation or is being stored on the site);
- (b) The intrinsic hazards associated with the physical and chemical processes that take place at the nuclear installation;
- (c) For research reactors, the thermal power;
- (d) The distribution and location of radioactive sources in the nuclear installation;

Seismic Hazards in Site Evaluation for Nuclear Installations

Specific Safety Guide
No. SSG-9 (Rev. 1)

Application of IAEA Safety Standards to External Hazards Assessment for Advanced NPPs, Including SMRs (Cont'd)

SSG-9 Rev. 1:

CATEGORIZATION PROCESS

9.9. Three or more categories may be defined on the basis of national practice and criteria, as well as the information described in para. 9.7. As an example, the following categories may be defined:



- (a) The lowest hazard category, which includes those nuclear installations for which national building codes for conventional installations (e.g. essential facilities such as hospitals) or for hazardous facilities (e.g. petrochemical or chemical plants) should be applied as a minimum;
- (b) The highest hazard category, which includes installations for which standards and codes for nuclear power plants should be applied;
- (c) There is often at least one intermediate category between (a) and (b), corresponding to a hazardous installation for which, at a minimum, codes dedicated to hazardous facilities should be applied.

Seismic Hazards in Site Evaluation for Nuclear Installations

Specific Safety Guide
No. SSG-9 (Rev. 1)

Application of IAEA Safety Standards to External Hazards Assessment for Advanced NPPs, Including SMRs (Cont'd)

SSG-9 Rev. 1:

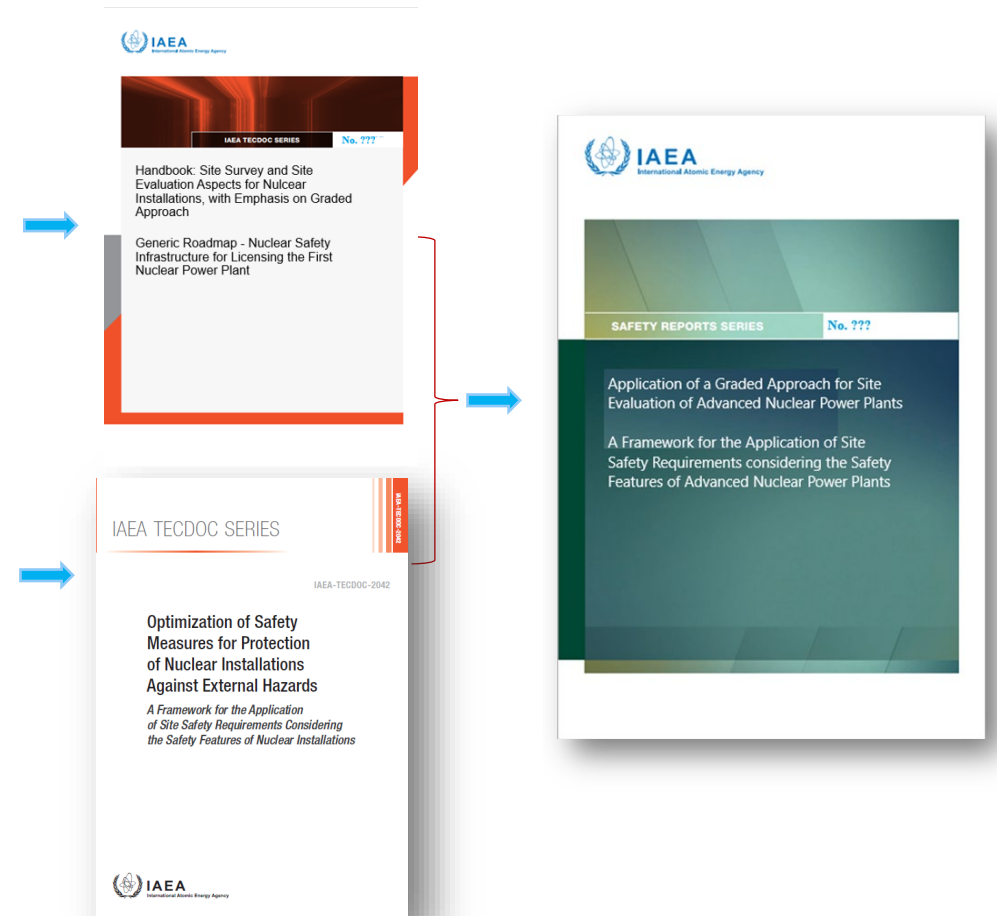
Two options are provided in Para 9.10 of SSG-9 Rev. 1 for grading seismic hazard assessment:

- If methods used similar to Safety Guide, a **lower input** ground motion than that evaluated for **highest** hazard categories may be adopted.
- If the **database** and the **methods** recommended in this Safety Guide are found to be disproportionately **complex, time consuming** and **demanding** for the nuclear installation in question, **simplified methods** for seismic hazard assessment (that are based on a more restricted data set) may be used keeping the **same annual probability of exceedance** for input ground motion.

Possible Approaches for Applying Graded Approach to Site Evaluation of Advanced NPPs

Graded Approach based on:

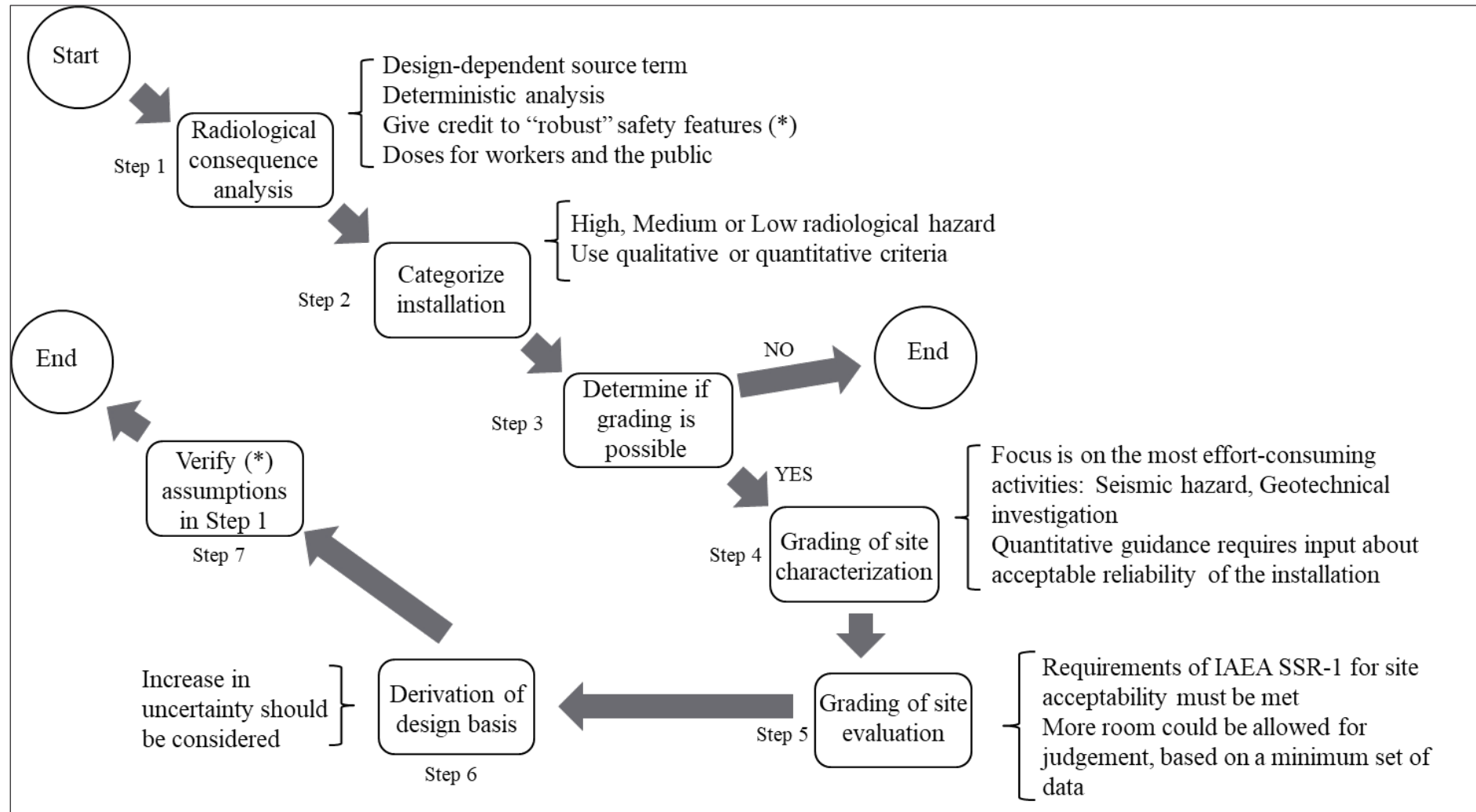
- Consequence Analysis (using information/data from safety analysis report developed by the SMRs vendor for a standard design)
- Probabilistic Safety Assessment (design stage internal/external hazards PSA mostly developed by SMRs vendors for a standard design)



[Optimization of Safety Measures for Protection of Nuclear Installations Against External Hazards | IAEA](#)

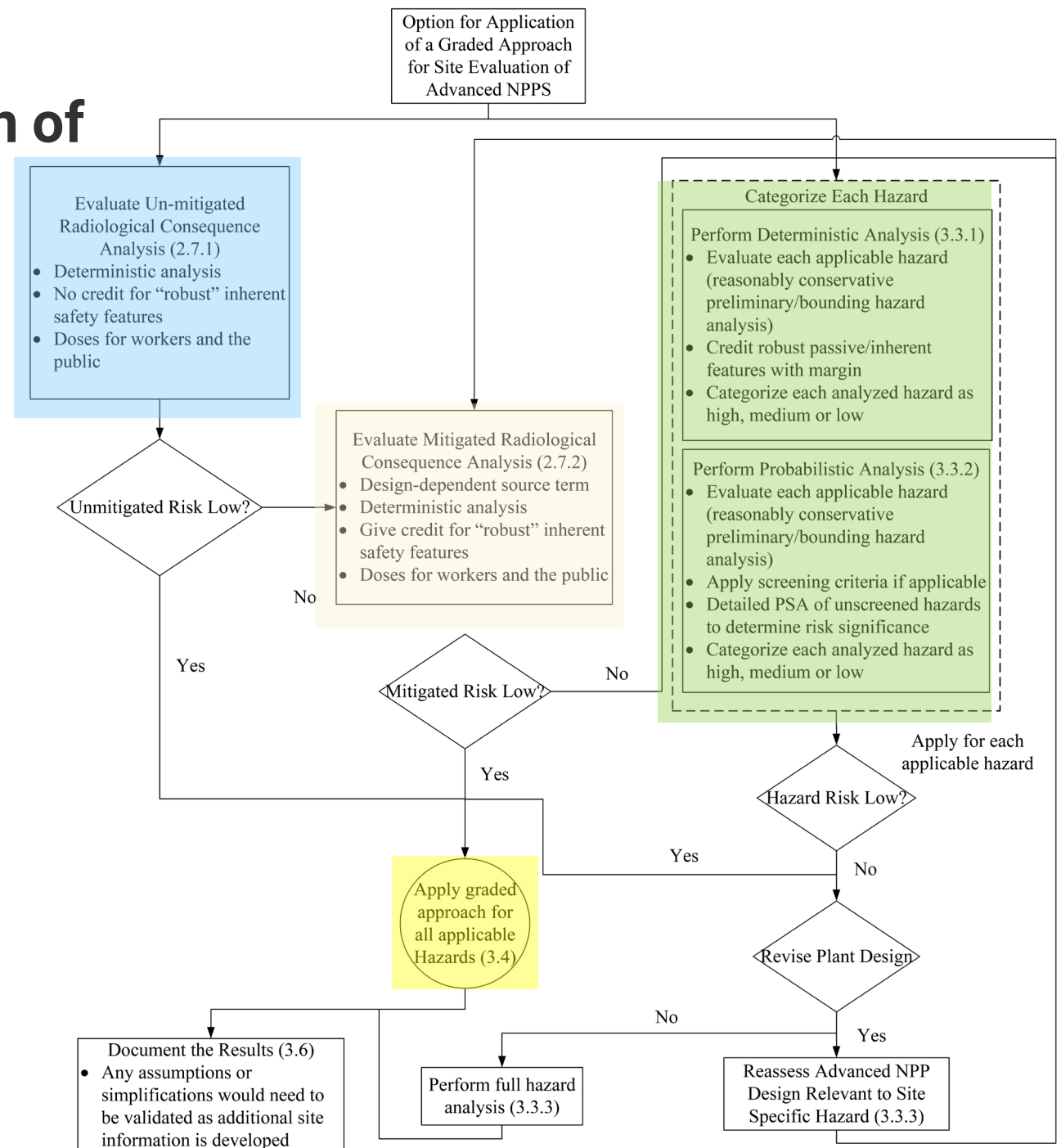
Possible Approaches for Applying Graded Approach to Site Evaluation of Advanced NPPs (Cont'd)

General workflow of a Graded Approach for Site Evaluation:



Possible Approaches for Applying Graded Approach to Site Evaluation of Advanced NPPs (Cont'd)

Overall Process to Apply a Graded Approach for Site Evaluation:



Publications related to Advanced NPPs including SMRs

Working Area 1: External Hazards Assessment



In Preparation

Working Area 2 & 3: Design and safety assessment against external events



Published in 2024

In Preparation

Final Remarks on Applying Graded Approach for Site Evaluation of Advanced NPPs

- Applying a graded approach for advanced NPPs including SMRs is well **covered** in IAEA Safety Standards;
- It is not a new concept, but application to advanced NPPs with **advanced safety features** needs to be **tailored** by developing practical guidance through MSs experience feedback;
- In addition to **new publications** (SR, TECDOC), the **revision** of existing **SSGs** (DS531, DS541) and the development of **new SSGs** (DS552), will include a section on the **graded approach**, specifically addressing **advanced NPPs**;
- Grading is an **open concept**: there may be several ways to grade siting activities;
- A graded approach might be acceptable as far as it respects **final safety requirements**
- Following **consequence analysis** approach grading depends on:
 - ✓ The **radiological hazard category** of nuclear installation;
- A **PSA-based** graded approach provides the idea to reduce efforts in hazards assessment for those **hazards** with **small contribution** to overall **risk** posed by the plant.
- Grading of site characterization increases (epistemic) **uncertainty** for site-based design parameters
 - ✓ The larger uncertainty needs to be introduced somehow when deriving design bases



IAEA

Questions?

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