IAEA
International Atomic Energy Agency
Atoms for Peace and Development

NSNI Activities on Advanced Reactors & Fusion Facilities

Safety Considerations of Advance Reactors

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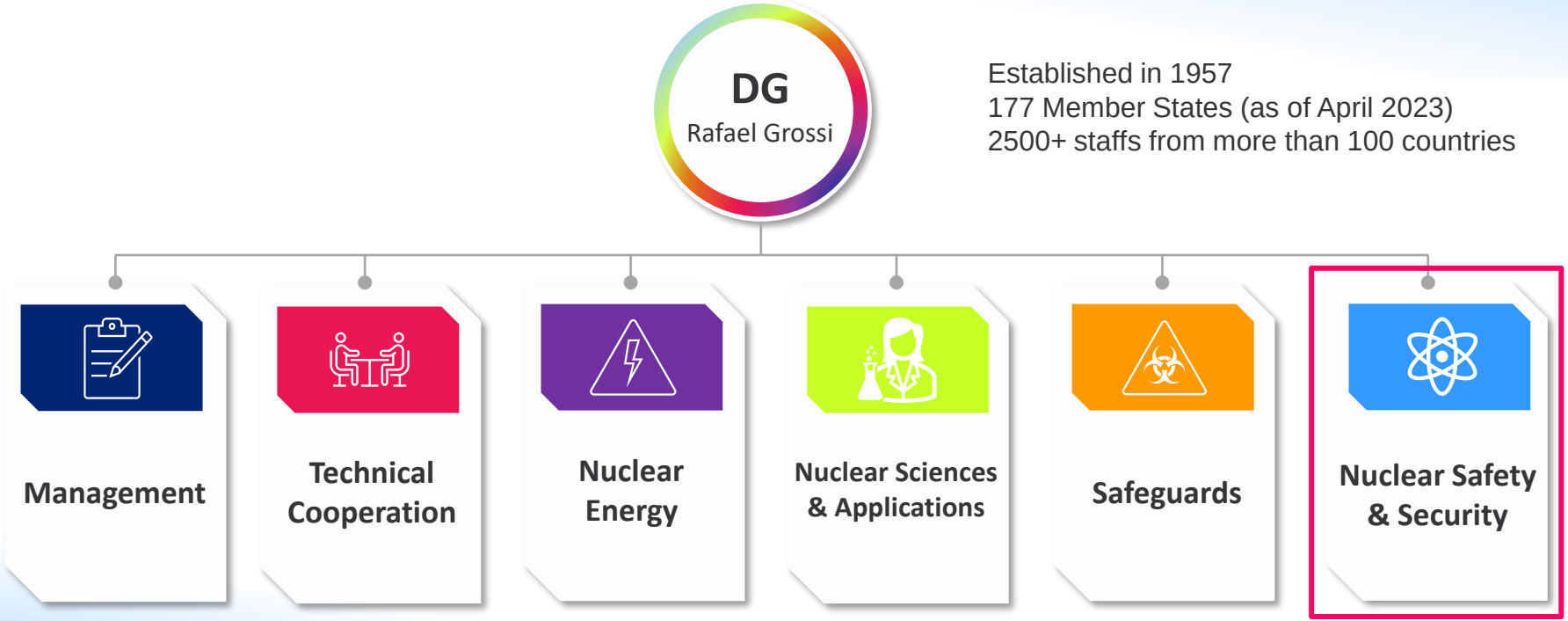
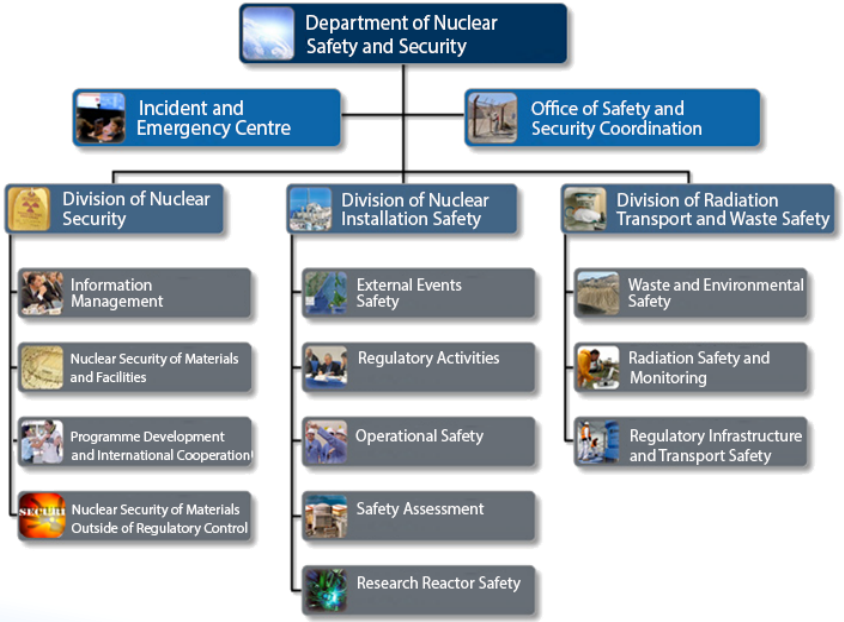
Safety Assessment Section
Division of Nuclear Installation Safety
Department of Nuclear Safety and Security
International Atomic Energy Agency

IAEA Structure

International Atomic Energy Agency (IAEA)



Department of Nuclear Safety and Security (NS)



- Our mission: The protection of people, society and the environment from the harmful effects of ionizing radiation
- NS supports the Member States in their national efforts to further strengthen nuclear safety and nuclear security
- One key role is our contribution to the development or adoption of Safety Standards

Division of Nuclear Installation Safety (NSNI)

- Supports Member States:
  - in establishing the appropriate safety infrastructure
  - in continuously improving the safety of nuclear installations during site evaluation, design, construction and operation
- Contributes to the development of Safety Standards and supporting documents for nuclear installations and provides safety reviews services to support their effective application
- Supports Member States in building and sustaining capacity in nuclear safety

Safety Assessment Section (SAS)

- Contributes to the development of Safety Standards for nuclear installations
- Helps to improve the capability of Member States in carrying out effective safety assessments and enhancing the safety of nuclear installations
- Undertakes Technical Safety Reviews (TSRs) that can be tailored to the needs of requesting parties
- SAS' work covers existing, evolutionary and innovative reactors, including small modular reactors (SMRs), non-water-cooled reactors (NWCRs), and fusion facilities

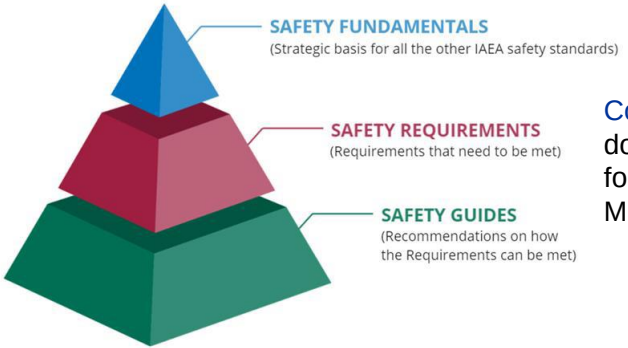
Design Safety

Safety Assessment

SAS's work on Safety Standards

Safety Standards

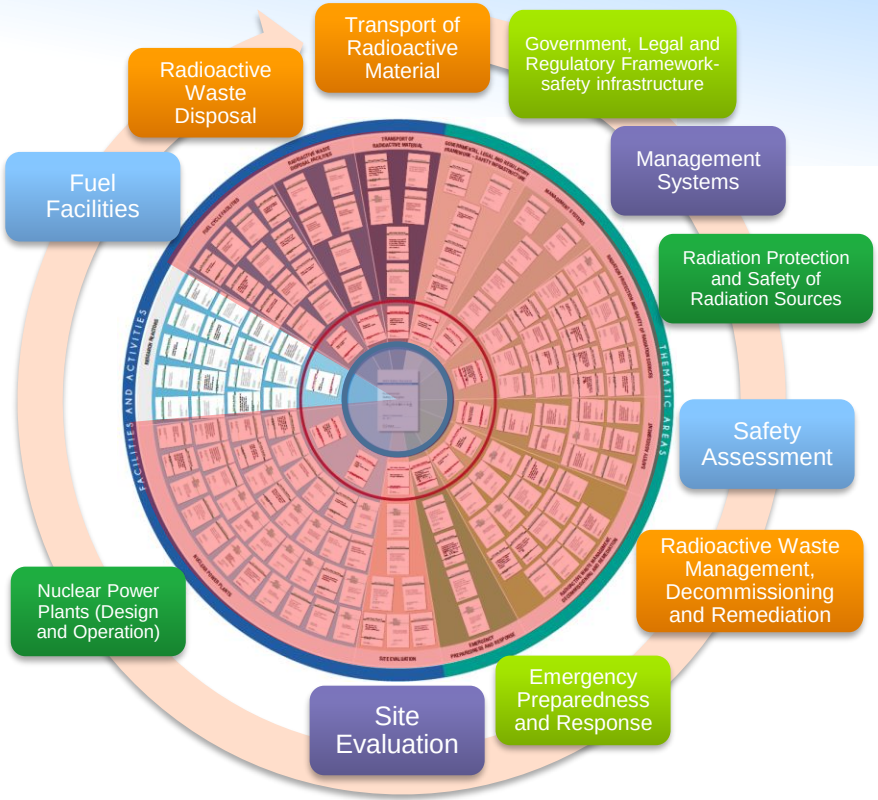
Safety Standards

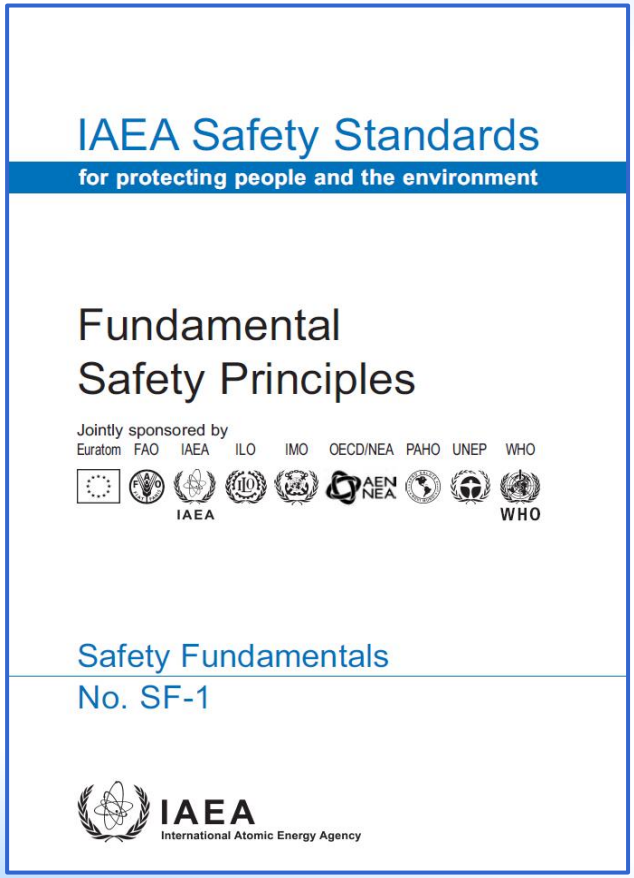


Consensus documents, formal process for MS feedback

TECDOCs & Safety Reports

Describing best practices and MS experience, challenges for specific topic. More detailed, but not consensus documents





SAFETY OBJECTIVE

The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation

SAFETY PRINCIPLES

- **Principle 1:** Responsibility for safety
- **Principle 2:** Role of government
- **Principle 3:** Leadership and management for safety
- **Principle 4:** Justification of facilities and activities
- **Principle 5:** Optimization of protection
- **Principle 6:** Limitation of risks to individuals
- **Principle 7:** Protection of present and future generations
- **Principle 8:** Prevention of accidents
- **Principle 9:** Emergency preparedness and response
- **Principle 10:** Protective actions to reduce existing or unregulated radiation risks

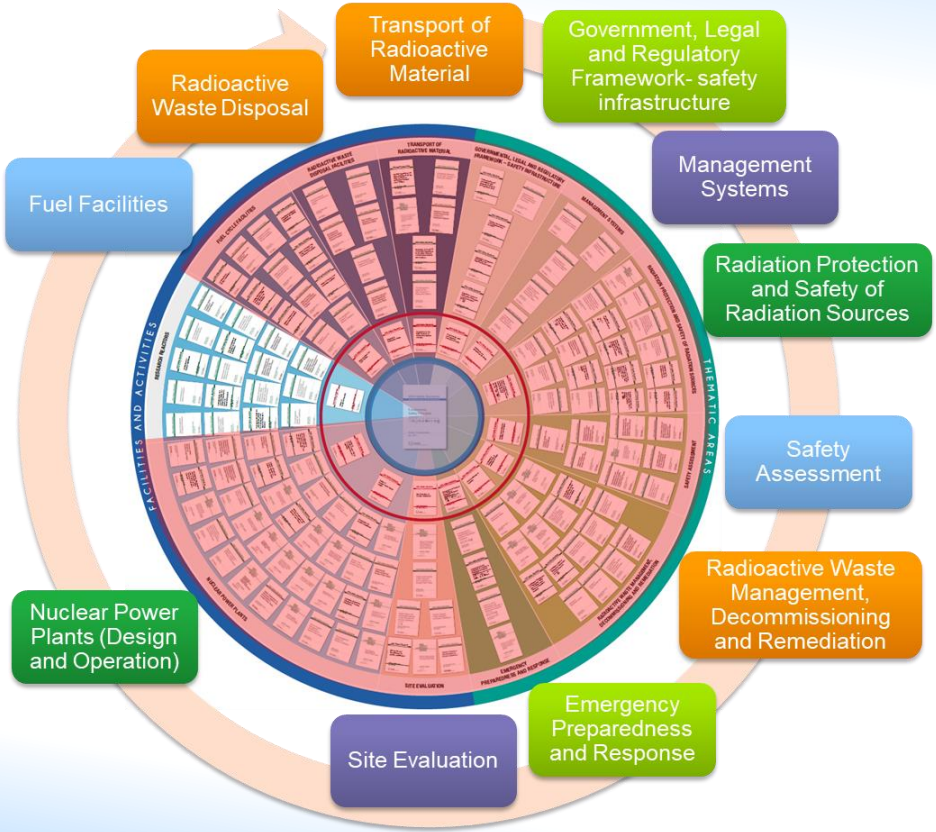
82 REQUIREMENTS

- Management of safety in design **(R1 to R3)**
- Principal technical requirements **(R4 to R12)**

- General plan design:
  - Design basis **(R13 to R28)**
  - Design for safe operation over the lifetime of the plant **(R29 to R31)**
  - Human factors **(R32)**
  - Other design considerations **(R33 to R41)**
  - Safety analysis **(R42)**

- Design of specific systems:
  - Reactor core and associated features **(R43 to R46)**
  - Reactor coolant systems **(R47 to R53)**
  - Containment structure and containment system **(R54 to R58)**
  - I&C systems **(R59 to R67)**
  - Emergency power supply **(R68)**
  - Supporting systems and auxiliary systems **(R69 to R76)**
  - Other power conversion systems **(R77)**
  - Treatment of radioactive effluents and radioactive waste **(R78 - R79)**
  - Fuel handling and storage systems **(R80)**
  - Radiation protection **(R81 – R82)**

Review conducted in 2021-2022



Are **Safety Standards** sufficient and relevant to ensure the safety of SMRs and Non-Water Cooled Reactors?

Safety Standards Covered by the Review

And over 70 supporting Safety Guides!

Review Approach

Identification of **areas of novelty** when compared to operating land-based water-cooled large reactors

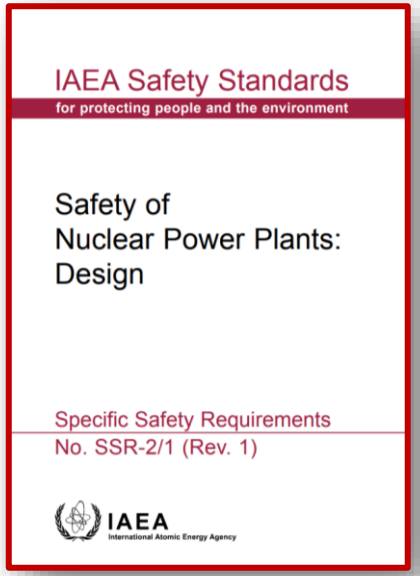
LWR Reference

Identification of **gaps** in the applicability of the safety standards and areas for further consideration, based on the areas of novelty identified

Identification of areas where the safety standards may **not be applicable** or could be adapted for a better application, based on the areas of novelty identified

Siting	Design	Construction	Commissioning and operation	Radiation Protection
Fuel Facilities	Management of waste and spent fuel	Decommissioning	Emergency preparedness and response	Deployment models, Regulation, Transportation

Design Safety



The reactor core (SSG-52)	The containment and associated systems (SSG-53)	The reactor coolant system and associated systems (SSG-56)
The design of electrical power systems (SSG-34)	Instrumentation and control systems (SSG-39)	The design of fuel handling and storage systems for NPPs (SSG-63)
The application of the human factors engineering in the design (SSG-51)	Design of Auxiliary and Supporting Systems (SSG-62)	Internal Hazards (SSG-64)
Radiation Protection aspects of the Design (DS524)	Equipment Qualification (SSG-69)	Safety Classification of SSCs in NPPs (SSG-30)

- Some safety approaches focus on conventional LWRs and do not cover SMR specifics
- Lack of experience on practical application
- Issues of first-of-a-kind
- New modes of failures, equipment failures or phenomena not covered

No applicability considerations (areas of non applicability, gaps, areas for further consideration)	Small number of applicability considerations/ very small impact on safety standard	Some applicability considerations/ small impact on safety standard	Numerous applicability considerations/ more than a third of the safety standard impacted

Summary of Review Outcomes

IAEA

Siting	Design and Const.	Com. and Operation	Fuel Cycle Facilities	Radiation Protection and Safety	Manag. of Waste and Spent Fuel	Decom.	LMfS	Safety Assess.	EPR	Legal and Reg. Transport
SSR-1 SSG-35 SSG-9 SSG-18 SSG-21 NS-G-3.6 NS-G-3.1 NS-G-3.2	SSG-30 SSG-68 SSG-67 SSG-69 DS524 **SSR2/1** SSG-64 SSG-34 SSG-39 SSG-62 SSG-38 SSG-51 SSG-52 SSG-56 SSG-53 SSG-63	SSG-50 SSG-70 SSG-71 SSG-72 SSG-73 SSG-74 SSG-75 SSG-76 SSG-77 SSG-13 SSG-28 SSG-48 **SSR2/2** SSG-54	SSG-27 SSG-43 **SSR4** SSG-5 SSG-6 SSG-7 SSG-42	**GSR- Part3** GSG-8 RS-G-1.7 GSG-7 GSG-9 GSG-10	GSG-16 SSG-45 GSG-3 DS512 SSG-31 SSG-23 **GSR-Part 5** GSG-1 WS-G-6.1 **SSR-5** SSG-14 SSG-40 SSG-29 SSG-41 SSG-15	WS-G-5.1 W-G-5.2 **GSR-Part6** SSG-47	**GSR- Part2** GS-G-3.5	**GSR-Part4** SSG-25 NS-G-2.13 SSG-2 SSG-3 SSG-4	**GSR-Part7** GSG-2 GSG-11 SSG-14 GS-G-2.1 SSG-65	GSG-6 **GSR-Part1** SSG-12 GSG-13 GSG-9 SSG-16 **SSR-6**

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Safety Report No. 123

- Publication expected imminently
- Preprint available on the IAEA website

IAEA Future Programme of Work on SMR Safety

In view of the findings of the review of applicability of the safety standards and the safety issues identified, the IAEA is planning to:

1. Enhance applicability of safety standards to SMRs and non-water cooled reactors as part of planned updates of safety standards

2. Develop publications to capture practical examples of application of safety standards for specific technologies

3. Develop a repository of technology specific knowledge

Other Publications and Activities

Advice on practical application of safety standards documents

Cross-cutting

- 3S for SMRs
- Design for FNPPs
- Chemistry of coolants and materials
- Repository of opex, tests experiments

Siting and External Hazards

- Application of Graded Approach for Site Evaluation
- Siting and Design aspects of SMRs in relation to External Hazards: special issues in the application of Safety Standards

Design

- Design approach for Non-WCRs
- Technical Meetings on HTGRs, MSR, LMFRs Safety
- Internal Hazards for Non-WCRs

Commissioning and and Operation

- Operation and commissioning of SMRs
- Severe accident and accident management for Non-WCRs

Protection and Safety

- Consultancy Meeting to decide way forward on radiation safety challenges

Repository of knowledge

Safety of Fuel Cycle Facilities

- Technical Meeting on Safety of Fuel Manufacturing for Advanced Reactors

Management of waste and spent fuel

- Physico-chemical and radiological characteristics and safe management of novel wastes from SMR and novel waste for non-water-cooled reactors

Safety Assessment

- Safety Analysis for SMRs
- **New Safety Guide**: Safety demonstration of innovative technology in reactor designs

EPR

- Publication on EPR for SMRs

Publications

Design Safety		
SSR-2/1 (Rev.1)	Safety of Nuclear Power Plants: Design	2016
NS-G-1.13 (DS524)	Radiation Protection Aspects of Design for Nuclear Power Plants	2005 (in revision)
SSG-30	Safety Classification of Structures, Systems and Components in Nuclear Power Plants	2014
SSG-34	Design of Electrical Power Systems for Nuclear Power Plants	2016
SSG-39	Design of Instrumentation and Control Systems for Nuclear Power Plants	2016
SSG-51	Human Factors Engineering in the Design of Nuclear Power Plants	2019
SSG-52	Design of the Reactor Core for Nuclear Power Plants	2019
SSG-53	Design of the Reactor Containment and Associated Systems for Nuclear Power Plants	2019
SSG-56	Design of the Reactor Coolant System and Associated Systems for Nuclear Power Plants	2020
SSG-62	Design of Auxiliary Systems and Supporting Systems for Nuclear Power Plants	2020
SSG-63	Design of Fuel Handling and Storage Systems for Nuclear Power Plants	2020
SSG-64	Protection against Internal Hazards in the Design of Nuclear Power Plants	2021
SSG-69	Equipment Qualification for Nuclear Installations	2021

Safety Assessment		
GSR Part 4 (Rev.1)	Safety Assessment for Facilities and Activities	2016
SSG-2 (Rev.1)	Deterministic Safety Analysis for Nuclear Power Plants	2019
SSG-3 (Rev.1)	Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants	2023 (Available in pre-print)
SSG-4 (DS528)	Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants	2010 (In revision)
SSG-25	Periodic Safety Review for Nuclear Power Plants	2013 (In revision)
SSG-54	Accident Management Programmes for Nuclear Power Plants	2019
SSG-61	Format and Content of the Safety Analysis Report	2021
SSG-88 (new)	Assessment of the Safety Approach for Design Extension Conditions and Application of the Practical Elimination Concept in the Design of Nuclear Power Plants	2023 (Available in pre-print)
DS537 (new)	Safety Guide on Safety Demonstration of Innovative Technology in Power Reactor Designs	In development
DSxxx (new)	Development and Application of Level 3 Probabilistic Safety Assessment for Nuclear Power Plants	In planning

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New Safety Guide Under Development

It’s not enough to state that a reactor is safe….

it has to be demonstrated!!!

SAS's work on Fusion Safety

NSNI’s Approach to fusion safety

Step 1	Step 2	Step 3
TECDOCs	**Safety Reports**	**Safety Standards**
Gathering Member States’ experiences	Develop principles for safety and regulation	Framework for fusion design safety, safety assessment and regulation
Drafted and under review	Beginning in Q1 2024	Beyond 2026

Two TECDOC drafts currently in review

TECDOC 1

TECDOC 2

Purpose

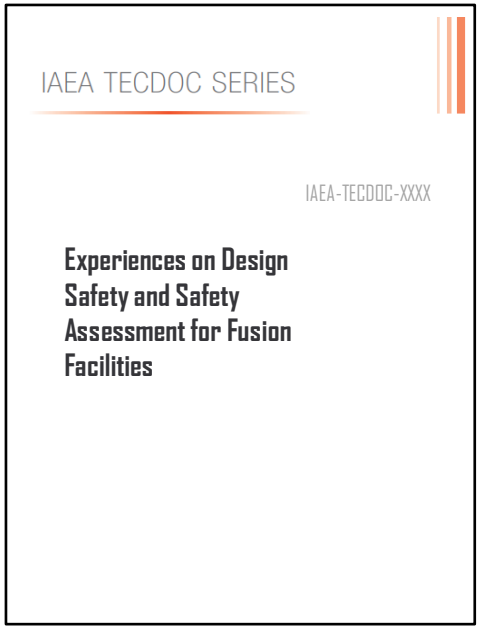
To collect experience and current status of fusion facility regulation and safety design practices

Technology inclusive

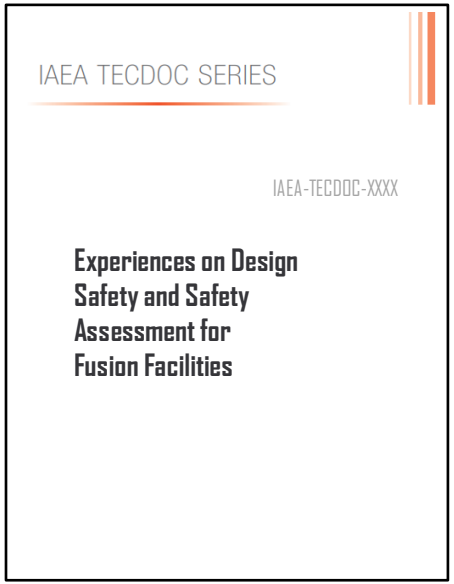
Aim to address broad range of fusion technologies

TECDOC on fusion safety

- Introduction – setting the scene and providing the objective and scope for the TECDOC
- High-level description of different fusion technologies and safety considerations
- The gathered experience from Member States:
  - Fundamental safety objectives, principles and approaches
  - Safety functions and associated systems
  - Internal and external hazards
  - Postulated initiating events
  - Application of design principles and requirements, such as defence in depth, fail-safe design, etc.
  - Radiation protection
- Summary of common issues and approaches
- Additional information forms the Annexes



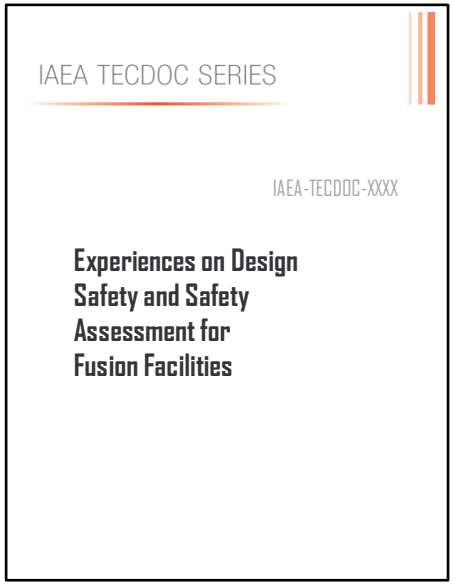
TECDOC on fusion safety



Interim findings (1)

- Hazard potential may be less than for NPPs, but FPPs still have risks that need managing
- Highest-level Safety Standards are applicable to all facilities (e.g., Safety Fundamentals SF-1) and activities using radioactive substances, including FPPs
- Some Safety Standards and guides developed for NPPs have elements that are not applicable to FPP

TECDOC on fusion safety



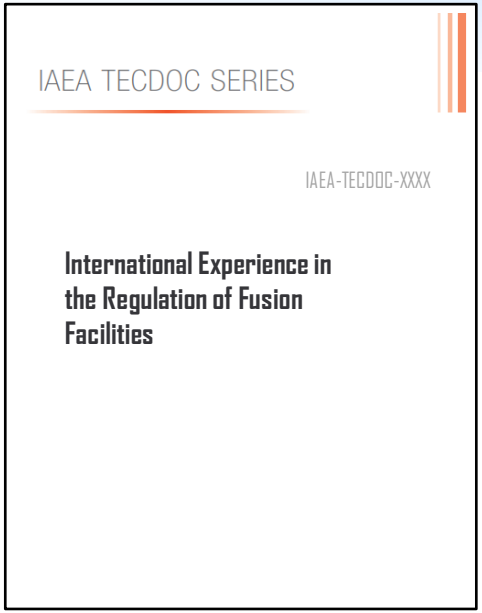
Interim findings (2)

- Key safety concepts like **‘**defence in depth**’** and **‘**practical elimination**’** can be applied to FPPs
  - ✓ By following a ‘graded approach’, level of detail can be adapted to keep requirements and safety assessment **proportionate to risks**
- Among participants, different approaches to safety, e.g., radiological acceptance criteria, safety functions, defence in depth, etc
  - ✓ Some participants using NPP approaches and criteria, others adapting for fusion

TECDOC on fusion regulation

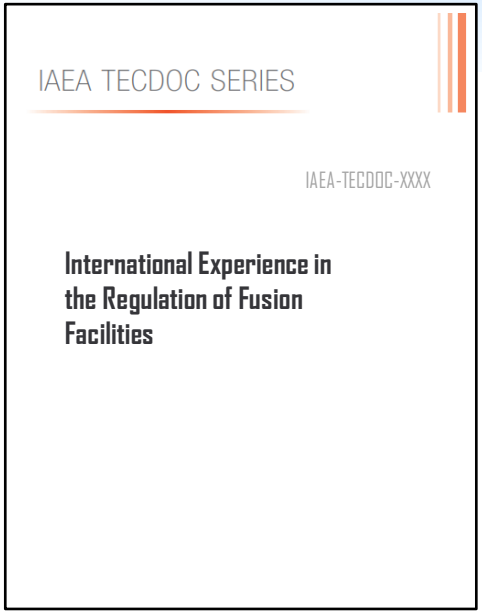
- The gathered experience from Member States:

Country	Examples of recent decisions and on-going activities
USA	NRC Commission decision to create a regulatory framework for near-term fusion energy systems, building on the NRC's existing process for licensing the use of by product materials (April 2023)
UK	UK Government's confirmation that future fusion energy facilities will be regulated under the legal framework already in place and will continue to be regulated by Environment Agency and HSE (June 2022)
Russia	On-going Federal Project Development of controlled fusion technologies and innovative plasma technologies, including the development of the regulatory framework for fusion (2021-2024)

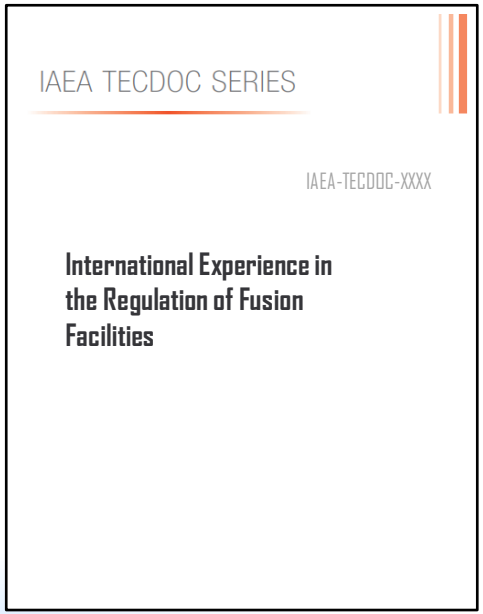


TECDOC on fusion regulation

- Common regulatory issues
  - The implications of new technology, innovation and complexity of operations within their regulatory frameworks compared to existing fusion experimental facilities
  - Fusion presents a quite different level of hazard and associated risk compared to fission processes
  - Either fusion is explicitly out of scope of the existing nuclear regulation, because that is limited to the use of “fissile” materials, or explicitly included
  - Guidance specific to fusion does not currently exist
  - Regulatory engagement (vendor to regulator and regulator to regulator) consistent with national arrangements
  - Public engagement/consultation consistent with national arrangements
- Common regulatory approaches
  - Current use of prescriptive and goal-prientated approaches
  - Current use of and plans for graded approaches



TECDOC on fusion regulation



Interim findings

1. Current states of knowledge and regulation
2. National alignment on fusion regulation
3. International regulatory harmonization
4. Consistent use of terminology
5. Authorization strategies
6. Graded approach
7. Development of implementing guidance
8. Evolving technologies and regulator agility

Technical Meeting on Fusion Design Safety and Regulation (23-25 October, 2023)

102 Participants

- ✓ 23 Member States
- ✓ 3 International Organisations

Technical Meeting Outcome

Fusion Safety

- ✓ General safety approaches, safety cases
- ✓ How to apply technology inclusive safety assessment methodologies
- ✓ How to manage fusion specific hazards such as tritium and decay heat

Fusion Regulation

- ✓ The latest decision on national regulatory frameworks for fusion
- ✓ perspective from the private sectors

Key takeaways

Graded approach, Response to rapid progress of technology, Harmonization to regulatory framework

Future works

Step 1	Step 2	Step 3
TECDOCs	**Safety Reports**	**Safety Standards**
Gathering Member States' experiences	Develop principles for safety and regulation	Framework for fusion design safety, safety assessment and regulation
Drafted and under review	Beginning in Q1 2024	Beyond 2026

Kick-off meeting will take place in December 2023

An exciting programme of work for 2024-2025

Title	Main Planned Outputs
3.2.2.001 Design safety of existing, evolutionary and innovative power reactors	New and revised design safety standards and associated technical documents and reports; reports on Technical Safety Reviews and advisory services for design safety; design safety related training materials and e-learning modules.

Title	Main Planned Outputs
3.2.2.002 Development and application of safety assessment methods	New and revised safety assessment standards and associated technical documents and reports; reports on technical safety assessment peer review and advisory services; NPP safety assessment-related training materials and e-learning modules.

Design safety

Compilation of Information on Design Safety for Advanced Reactors and New Knowledge and Experience in Preparation for Future Update of SSR-2/1

Safety of NWCRs' Fuels and Cores

Advanced Manufacturing and Qualification Programmes for New Materials of SMRs and NWCRs

Chemistry Aspects of NWCRs' Coolants and Materials

Internal Hazards in NWCRs

TNPPs, FNPPs, Fusion

Digital I&C and AI

Safety, Security and Safeguards interfaces

Safety Assessment

Safety Demonstration of Innovative Technology in Power Reactor Designs

Design Safety Approach, Safety Assessment and Safety Analysis for SMRs and NWCRs

Severe Accident Analysis and Management for NWCRs

DSA & PSA: filling the gaps

… and more!

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Thank you!

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