European Commission

Safe, Sustainable Operation of Research Reactor Facilities in the EU

Final Report

Contract ENER/2021/NUCL/SI2.859831

Written by ENCO
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LIST OF ACRONYMS AND ABBREVIATIONS

AMP	Ageing Management Program
ATWS	Anticipated Transient Without Scram
BSS	Basic Safety Standards
CCF	Common Cause Failure
DEC	Design extension conditions
DG ENER	(EC) Directorate-General for Energy
DiD	Defence in Depth
EC	European Commission
ENSREG	European Nuclear Safety Regulators Group
EU	European Union
GSR	General safety requirements (of IAEA)
I&C	Instrumentation and control
IAEA	International Atomic Energy Agency
IMS	Integrated Management Systems
INSARR	Integrated Safety Assessment of Research Reactors
IRRS	Integrated Regulatory Review Service
IRSN	Institut de Radioprotection et de Sûreté Nucléaire (French TSO)
IRSRR	Incident reporting system for research reactors
KOM	Kick-off meeting
KPI	Key Performance Indicator
LOCA	Loss of coolant accident
MS	Member State
NAcP	National Action Plan (within Stress test or TPR)
NSD	Nuclear Safety Directive[1] –
NS-G	Nuclear Safety-Guide (of IAEA)
NPP	Nuclear Power Plant
OAMP	Overall Ageing Management Program
OEF	Operational experience feedback
OLC	Operational limits and conditions
OMARR	Operational and Maintenance Assessment for Research Reactors
OSART	Operational Safety Review Team
PM	Project Manager
PSA	Probabilistic Safety Analysis
PSR	Periodic Safety Review
QA	Quality Assurance
QC	Quality Control
QAP	Quality Assurance Programme
QMS	Quality Management System
RHWG	Reactor Harmonization Working Group
RL	Reference levels
RPV	Reactor Pressure Vessel
RR	Research Reactor
SAR	Safety analysis report
SALTO	Safety Aspects of Long-Term Operation
SRL	Safety Reference Levels
SRS	Safety report Series (of IAEA)
SSC	Structures, Systems and Components
SSG	Specific Safety Guide (of IAEA)

[1] Council Directive 2009/71/Euratom of 25 June 2009 establishing a Community framework for safety of nuclear installations and Council Directive 2014/87/Euratom of 8 July 2014 amending Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations

SSR	Specific Safety Requirement (of IAEA)
SVS	Services series (of IAEA)
TPR	Topical Peer Review
TS	Technical Specifications
WENRA	Western Europe nuclear regulators association
WG	Working Group
WGRR	Working group on Research reactors

EXECUTIVE SUMMARY

Objectives and aims

The aim of this Study was to conduct a review of the alignments of the regulatory requirements for research reactors (RR) in the EU MS specifically with the articles of the Nuclear safety directive, 2014/87/EURATOM (NSD), the requirements of national, EU level and international safety regulations and standards. The review assessed the implementation of the NSD within the Member States that operate research reactors, considering both the regulators and the operators. The Study aimed at improving the understanding of alignment regarding the application of the NSD and international standards for research reactors, across the respective EU Member states (MS) that operate those. The Study assessed and documented the current status (through benchmarking) and establish a set of recommendations that would support sustainable safe operation, including specific emphasis on the conduct of periodic safety assessments (PSR) as well as ageing management for research reactor facilities, reflecting the findings and recommendations of the 1st Topical peer review (TPR).

The NSD requires that all nuclear installations are designed, sited, constructed, commissioned, operated, and decommissioned in a way to prevent accidents, and that in all aspects of the installations' lifecycle, consideration shall be given to accident mitigation as well as avoidance and management of radioactive release. While this requirement applies to all new nuclear installations it must be used as the reference target for existing installations. With that in mind, it is recognised that given the advanced age of the majority of EU's research reactors, together with their diversity in terms of design, operating organizations, ownership, as well as sustainable financing, implementation of some of the NSD's requirements remain a challenge. It should be noted that many of the thirty-six EU research reactors covered by the Study, have been in operation for decades and were/are subject to various safety and operational upgrades, which supported their continued operation. Prior this Study, there was no EU-wide assessment of different approaches the MS are taking to implement the NSD requirements for research reactors. Within this Study and against the above background, the current level of safety requirements for research reactors across the EU has been reviewed, and compliance with the requirements as established by the NSD, Western European Nuclear Regulators Association (WENRA) Reference Levels (RL) as well as applicable International Atomic Energy Agency's (IAEA) standards and guides assessed. A thorough analysis was undertaken and a comprehensive set of recommendations raised, which may be expected to contribute to enhance safety and sustainable operation of research reactors within the EU.

Project Findings

The collection of the information relevant for the Study was undertaken through a questionnaire, that was developed separately for the national regulators and for the operators of research reactors. The questionnaire was structured to address all major safety criteria that are relevant for research reactors, including the requirements set by the NDS, the WENRA RLs for the RRs as well as the IAEA standards and safety guides specific for the RRs. The focus of the regulatory questionnaire was on the regulatory framework in each of the EU MS, while to

focus of the operators’ questionnaire was the implementation, i.e. compliance with the regulatory framework in place.
Based on the evaluation of the questionnaires, it was found that the level of the development of regulations is to a certain extent proportional with the status of MS’ nuclear programmes. Legislative requirements in MS operating nuclear power plants (NPP) are generally more aligned with up-to-date nuclear safety standards than in MS that either have no nuclear energy program, or are phasing out their nuclear program.
Particularly for the EU MS that utilise the same regulatory framework for the NPPs and RRs, proper use of the graded approach regarding for e.g. safety policy, independent safety reviews, competence of staff, OEF, SAR, SSC safety classification, etc., is highly important and relevant. However, in some MS the requirements for the graded approach have yet to be transposed into the national legislative framework. Thus, one of the main issues that stems from this Study is the application of the graded approach, also recognised as very important by the WENRA, in its development of the RL for RRs. Furthermore, WENRA plans to issue additional guidance for the application of graded approach and EU MS are encouraged to follow it and as appropriate include it in their regulatory framework.
A Safety Analysis Report (SAR) is considered a crucial document for ensuring that nuclear safety has been properly evaluated. The format of a SAR may differ between MS and from that defined in the IAEA standard. Different formats are, per se, not an issue as long as all the relevant areas are covered. It is important that every EU MS have a requirement in place that the SAR is regularly updated, in particular following any design change, safety upgrade or change in operational procedures, such that it is maintained as a living document and reflects the up-to-date status. It is therefore surprising that this is not the case for all EU RRs. A harmonisation of regulatory requirements is thus suggested, in line with modern international standards
Some research reactors in the EU appear to have a limited long-term operational strategy. The majority of the RRs are not commercially operated and most are owned by, and thus receive budgetary means from, a state and/or through research institutes or universities. In such a situation, a long-term investment to ensure sustained safe operation cannot always be guaranteed. Such a situation establishes uncertainty, which might be challenging for nuclear safety. This problem with long-term strategy is clearly visible from some of the answers to the questionnaire that were received, and even more from the discussion during the Workshop. There are challenges in the recruitment and retaining the staff, with availability of nuclear fuel, available funding for AMP, modernisation, new experimental facilities, etc., especially in the view of ambiguities regarding remaining lifetime of RRs.
Even though the analysis within this project suggests that in most cases the responsibilities are clear and well set out, there are several cases, particularly amongst smaller research reactors, whereby complicated owner-operator-user relationships appear to exist. For example, the responsible person might be a high-level manager (i.e. removed from the operation of a RR), who may not be a nuclear expert and therefore has limited experience and might not fully understand the importance of nuclear safety. Such arrangement could lead to a loss of responsibility and result in poor levels of nuclear safety in specific areas.
The Study showed that more than half of the EU MS (more precisely, 7 out of 12) still do not require “Design Extension Conditions” (DEC) to be analysed and implemented for research reactors. Nevertheless, the assessment seems to suggest that most operators performed some kind of DEC analysis and implemented additional protective measures (mostly as part of

the Post-Fukushima Stress tests), in particular the larger research reactors. What is particularly noticeable in this review are the differences in the content of DEC analyses.
The results of this Study also show that in most MS a dedicated Ageing Management Programme (AMP) is legally required within the current regulatory framework. Still, there are a few MS with no such requirements. In two of those MS (which also operate some of the largest RRs) it is considered that ageing management is a part of regular maintenance and inspection programmes. Nevertheless, the Study confirmed that noticeable advances were made across the EU population of RRs in relation with the ageing management, with many RR operators implementing the recommendations raised by the 1st TPR.
Complying with NSD, all MS have a legal requirement in place to invite international peer reviews for the regulatory authorities on 10 years' interval. There is no such legal requirement for the operators. Number of research reactors in EU, including some larger facilities, never hosted an international peer review. During the Workshop, regulators expressed their interest in peer reviews. The results of peer reviews are an important additional (and independent) confirmation of the safety level and operational challenges for RRs.
It appears from the answers to the questionnaire that the safety culture might not be considered as an important issue to some of the RRs. This applies mainly, though not exclusively, to MS operating research reactors but not having NPP programme. Also, it seems that some regulators have limited capability (or interest) in independently assessing safety culture at operating RRs. It seems that the regulatory oversight of safety culture is not as thorough as it might be warranted. From answers received it appears that one operator might even not have met the regulatory requirements for safety culture. During the Workshop, the regulators agreed that introducing clear requirements for safety culture at RR is very important, as it is reminding the operators of their role in maintaining the safety culture at their facilities. The workshop recognised that the uncertainty related with future operation of research reactor might have a detrimental effect for safety culture at a facility.

Conclusion

Based on the responses to the questionnaire, supplemented with additional information and clarifications obtained through the review process as well as the discussions held during the Workshop, it can be concluded that the EU MS States operating research reactors generally have a well-established legal and regulatory framework, aligned with the principles set out by the NSD, WENRA RL and IAEA standards. Whilst some discrepancies exist, e.g. many EU MS have not fully transposed the WENRA RL for RR in national regulations, these are not considered to be critical to maintaining nuclear safety. In regard to the compliance with the national regulatory requirements by the RR operators, the conclusion is that the EU research reactors are mostly managed in a manner that ensures nuclear safety at the installation and safety of the public and environment.

Reflecting the analysis undertaken, a set of 8 recommendations and one suggestion has been established. Those have been presented and discussed during the Workshop, with various comments raised, which led to the extension and refinement of some of the recommendations. Also, the activities of WENRA RHWG for RR, which will be providing the guidance on the graded approach and in the mid future undertaking the review of the transposition of the WENRA RRL for RRs into national regulatory framework, is seen as an important activity that to address some of the recommendations of the Study. The consolidated set of the recommendations, reflecting the analysis during the Study implementation as well as the discussions during the Workshop include the following:

Recommendation No. 1: Encourage EU MS regulators to perform an appropriate gap analysis of their national regulations against WENRA RL for RR, other (IAEA) international standards and, as needed, to further develop their regulations, such that they are aligned with the latest standards for research reactors.
Recommendation No. 2: The methodology how to apply the graded approach when regulating nuclear safety of research reactors could be harmonized on an EU level and applied on a consistent manner across the Member States.
Recommendation No. 3: National regulations should require that the SAR for each research reactor facility must be updated following any modifications to the design and or operational practices of the facility and the environment around it (natural, legal and social), such that it reflects the current situation.
Recommendation No. 4: Owners and operators of research reactors should establish and maintain a long-term strategy which is appropriately budgeted, to be reviewed and updated on a 5 to 10-year basis. The strategy should have clear objectives, goals, and financial arrangements, and include the lifetime management plans of the facility.
Suggestion: National regulators are encouraged to regularly remind (and occasionally verify) operators (senior managers) of RRs of their responsibilities for nuclear safety, to ensure that safety is given an overriding priority in all activities and is not compromised by other priorities, as well as to ascertain their understanding of facility's risks and needs for long-term strategy in relation to the operation of RR.
Recommendation No. 5: National regulators should include requirements regarding implementation of DEC analysis and measures for research reactors into their regulation while paying attention to the graded approach, commensurate to the level of risk they may pose.
Recommendation No. 6: National regulators should assure that the regulations covering the requirement to establish dedicated AMP for research reactors are in place.
Recommendation No. 7: Peer review missions might be invited to EU research reactors at regular intervals, especially to research reactors of higher power. IAEA INSARR/OMARR missions, adjusted to the specifics of a RR to be reviewed could be recommended.
Recommendation No. 8: Operators should pay attention to the adoption of best practice in nuclear safety culture, whist Regulators should include a review of nuclear safety culture as a part of their oversight of RR.

ABSTRACT

Recognising that there might be specific safety issues related with Research Reactors (RR) in the EU, the European Commission - DG ENER launched a study to collect information on the status and assess safety requirements as well as actual practice in the safety assurance. Specific emphasis was placed on the systematic re-assessment processes via the Periodic Safety Reviews as well as the ageing management activities, in particular reflecting the conclusions of 1st Topical peer reviews. The Study adds to understanding of the alignments of RRs with the Nuclear safety directive among EU MS.

Both national regulations applicable to RR and their application by operators were benchmarked. The areas where the improvements are possible were identified. The findings of the Study were presented and discussed during the Workshop that was attended by regulators and RR operators. Recommendations, ranging from use of graded approach, safety assessment, Design Extension Conditions, ageing management and long-term strategy, to enhance safe and sustainable operation of RR were proposed. The Study highlighted that although having achieved high safety level, the EU RR are still facing challenges, from ageing facilities over availability of funds for safety improvements to unclear perspective of operation in the long term.

RÉSUMÉ

Reconnaissant qu'il pourrait y avoir des questions de sûreté spécifiques liées aux réacteurs de recherche (RR) dans l'UE, la Commission européenne - DG ENER a lancé une étude pour collecter des informations sur l'état et évaluer les exigences de sûreté ainsi que les pratiques en vigueur en matière d'assurance de sûreté. Un accent particulier a été mis sur les processus de réévaluation systématique ainsi que sur les activités de gestion du vieillissement. L'étude contribue à la compréhension de l'alignement des RR sur la directive sur la sûreté nucléaire parmi les États membres de l'UE.

Les réglementations nationales applicables aux RRs et leur application ont été comparées. Les domaines dans lesquels des améliorations sont possibles ont été identifiés. Des recommandations, allant de l'utilisation d'une approche graduée à l'évaluation de la sûreté, aux DECs, à la gestion du vieillissement et à la stratégie à long terme, pour améliorer l'exploitation sûre et durable des RRs ont été proposées. L'étude a souligné que, bien qu'ayant atteint un niveau de sûreté élevé, les RRs de l'UE sont toujours confrontés à des défis, du vieillissement des installations à la disponibilité de fonds pour l'amélioration de la sûreté en passant par des perspectives d'exploitation parfois floues à long terme.

Disclaimer:

The information and views set out in this report are those of the author(s) and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this study. Neither the Commission nor any person acting on the Commission's behalf may be held responsible for the use which may be made of the information contained therein.

1 INTRODUCTION

Council Directive 2009/71/EURATOM "Establishing a community framework for the nuclear safety of nuclear installations", which was amended following the 2011 Fukushima accident, by Council Directive 2014/87/EURATOM [1] form the basis of the Nuclear Safety Directive (NSD). The NSD is applicable to all European nuclear installations. Article 3a of the NSD defines a nuclear facility as being a nuclear power plant, enrichment plant, nuclear fuel fabrication plant, reprocessing plant, research reactor facility, or storage facility. Thus, the NSD is the governing directive to assure nuclear safety in the lifecycle management of research reactors. Within the European Union, there are currently thirty-six Research Reactors, which are either in operation, temporary shutdown, or under construction. One additional research reactor is planned for construction post-2029.

The aim of this project has been to conduct a review of the alignments of the regulatory requirements for research reactors in the EU MS with the articles of the NSD. The review takes into consideration the implementation of the NSD within the Member States that operate research reactors, how the framework is applied by both regulators and operators. The project was to establish an improved understanding of alignment regarding the application of the NSD across the respective Member States as related with research reactor safety.

It should be noted that many of the thirty-six research reactors mentioned above have been in operation for decades and were/are subject to various safety and operational upgrades, which supported their continued operation. Prior this Study, there was no EU-wide assessment of different approaches the MS are taking to implement the NSD requirements for research reactors.

As can be seen in the Article 3a of the NSD, the types of nuclear installations encompassed vary in their purpose, size, and potential magnitude of radiological risk. However, the NSD requires that all nuclear installations are designed, sited, constructed, commissioned, operated, and decommissioned in a way to prevent accidents, and that in all aspects of the installations' lifecycle, consideration shall be given to accident mitigation as well as avoidance and management of radioactive release. This requirement applies to all new nuclear installations and should therefore be used as the reference target for existing installations. With that in mind, it is recognised that given the advanced age of the majority of Europe's research reactors, together with their diversity in terms of design, operating organizations, ownership, as well as sustainable financing, some of the NSD's requirements remain a considerable challenge.

As discussed later in this report, Chapter 2 of the NSD sets out the obligations placed on the respective Member States' regulatory authorities as well as the license holders (operators). The Recital 25 of the NSD provides for the application of a graded approach, which facilitates the implementation of the provisions of the NSD dependent on the types of nuclear installations on the territory of a Member State. This means that when implementing the NSD provisions in national legislation, Member States should consider the potential magnitude and nature of risks posed by their nuclear installations. Specifically, the graded approach should be applied by Member States that maintain only small inventories of nuclear and radioactive materials. For example, the graded approach can be linked to the operation of smaller research reactor facilities, which in the case of a severe accident would not result in consequences that are in any way comparable to those generated by an NPP. It should be noted that some Member States deploy national regulations that are specific to research reactors, whilst others apply the regulations that cover NPPs also for research reactors. In particular in the latter case it is essential to ensure a differentiation based on the graded approach.

An important aspect of the amendments set out in Council Directive 2014/87/EURATOM, is the introduction of new or refined and detailed obligations. Amongst those are the obligations of the Member States which require the allocation of responsibilities and coordination between relevant state bodies and national nuclear safety requirements, covering all stages of the lifecycle of nuclear installations, as well as a system of regulatory control of nuclear safety to be performed by the competent regulatory authority. Regarding the obligations of a competent regulatory body, these are detailed in Article 5, paragraphs 2 and 3, whilst Articles 6 provides detailed obligations for operators. Articles 7 and 8 required the Member States to ensure several obligations are included in the national framework, which are to be implemented by the operator, with regulatory oversight. Those include but are not limited to the provision of on-site emergency preparedness and the implementation of Periodic Safety Reviews (PSR) and a requirement to participate in the Topical Peer Reviews (TPR) each six-years. Operators are also obliged to maintain an enhanced nuclear safety culture and ensure defence in depth regarding the minimisation of impacts from extreme external natural or man-made hazards. These requirements aim to assure that the highest standards of nuclear safety are met for all installations under the NSD.

Complementary to the requirements of the NSD and in specific regard to research reactors are the IAEA standards in particular the publication SSR-3; “Safety of Research Reactors [2], which is complemented by several guides. The application of the IAEA standards for research reactors is, upon an invitation of an IAEA member state, reviewed by an IAEA team within “Integrated Safety Assessment of Research Reactors” (INSARR). The IAEA also operates the incident reporting system for research reactors (IRSRR) which facilitates the dissemination of information about operational events that occur at research reactors worldwide.

Another important element in assuring safe operation of nuclear installations is the WENRA Reference Levels. Similar to those developed for NPPs, WENRA Reference levels have been developed for research reactors [3]. They are organised into 20 sections, so called Issues:

1. Safety Policy
2. Operating Organisation
3. Leadership and Management for Safety
4. Training and Authorization of Research Reactor Staff (Jobs with Safety Importance)
5. Design Basis Envelope for Existing Research Reactors
6. Design Extension of Existing Research Reactors
7. Safety Classification of Structures, Systems and Components
8. Operational Limits and Conditions (OLCs)
9. Ageing Management
10. System for Investigation of Events and Operational Experience Feedback
11. Maintenance, In-Service Inspection and Functional Testing
12. Emergency Operating Procedures and Severe Accident Management Guidelines
13. Contents and Updating of Safety Analysis Report (SAR)
14. Probabilistic Safety Analysis (PSA)
15. Periodic Safety Review (PSR)

16. Research Reactor Modifications
17. On-site Emergency Preparedness
18. Protection against Internal Fires
19. Natural Hazards
20. Experimental Devices and Experiments

In recent years the DG ENER undertook studies that addressed European research reactor facilities. The study implemented by 'NucAdvisor' [4], in the parts devoted to nuclear safety, determined that the main safety issues for European research reactors are linked to the ageing management (equipment ageing, access to old documentation, ageing of skilled personnel, etc.), safety assessments, human resources, as well as quality assurance. Likewise, the Study concluded that IAEA INSARR missions provide an "essential tool to conduct independent safety evaluations/peer reviews".

During the implementation of this project and against the above background, the current level of safety requirements for research reactors across the EU has been reviewed, and compliance with the requirements as established by the NSD, WENRA RL as well as applicable IAEA standards and guides has been assessed. Information was gathered also from the outcome of the First Topical Peer Review (TPR) on Ageing Management, organised by ENSREG in 2017 [11], as well as from the available reports of several INSARR missions to EU research reactors. A thorough analysis has been performed and a comprehensive set of recommendations has been prepared, which may be expected to enhance safety and sustainable operation of research reactors within the EU.

2 PROJECT OBJECTIVES AND OUTPUTS

The objective of the project was to assess safety of research reactors across the EU, in line with the requirements of the national, EU level and international safety regulations. To achieve the objectives both national regulations applicable for research reactors as well as their application by the licensees were benchmarked. The aim was then to propose improvements and recommendations related to safe operation of research reactors, including the conduct and effectiveness of safety re-assessment as well as ageing management.

2.1 SPECIFIC OBJECTIVES

The specific objectives of the project were defined in three distinctive areas, those being the safety requirements in place for research reactors, the application of safety re-assessments (PSR), and the availability and application of ageing management programmes.

To address these specific objectives, the following was done:

- Collection and assessment of current International, European, and national safety requirements and operating practices of research reactors;
- Assessment of the compliance of research reactors' operation against safety requirements that are in place;
- A review on how research reactor operators are implementing the periodic safety reviews, as well as assess how regulators review the PSR process and their results;
- Identification of the methodology and procedures used to determine necessary safety upgrades on research reactors;
- Assessment of the advances in the development and implementation of Ageing Management Programmes for research reactors, reflecting on the outcome of the 1st TPR.

2.2 PROJECT OUTPUT

The project output was to assess and document the current status (through benchmarking) and establish a set of recommendations that would support sustainable safe operation, improved effectiveness of PSR, and improved ageing management programmes at research reactors in the EU MS.

3 RESEARCH REACTORS IN THE EU

The scope of the study encompasses all research reactors in the EU, which are categorised as nuclear installations as per NSD and therefore a potential source of radiological impact on the public and environment.

Of the total number of research reactors in the EU, the IAEA Database on research reactors identified that:

- 28 are operational
- 3 are in temporary shutdown
- 1 is in extended shutdown
- 2 are under construction
- 2 planned.

The information regarding their status was updated over the course of this project. The information received from operators and regulators corrected the IAEA RR data base as follows:

- 29 are operational
- 1 is in extended shutdown
- 2 are under decommissioning, with no nuclear fuel or radwaste on site (i.e., therefore not being "nuclear facilities" as per NSD
- 3 are under construction with no fuel on site (ditto)
- 1 planned.

The total of thirty-six research reactors are spread across twelve EU Member States and operated by twenty-five different operators. A list of the considered research reactors including their basic specification data is provided in Annex I to this report.

The total number of research reactors currently in operation is twenty-nine[2], which could be defined in the following three categories:

- There are 7 Zero power and 4 subcritical RR, used for training and education;
- There are 6 Low Power Pool and TRIGA II RR and 5 with thermal power up to 10 MW, used for education and scientific research;
- There are 7 RR with thermal power above 10 MW mostly used for production of medical isotopes. This number is set to increase to 10, as an additional two are under construction with a third planned for post-2029.

The NSD and IAEA Standards do not make any categorisation as to the (extent of) applicability of the requirements for different types of RRs. The WENRA Reference Levels for Research Reactors [3] states that those are to be applied to *"all types of research reactors with the exception of critical, sub-critical assemblies, homogeneous zero-power reactors and accelerator driven systems"*. The WENRA RL document is clear that all RLs are to be applied, i.e., waiving is not allowed for the RRs that are within the scope of the application, while graded approach is to be applied to reduce the level of requirements where such is not warranted. The Annex A to the WENRA RL provides information as to how to estimate the risk

[2] Number of operating research reactors not counting reactors under decommissioning or under construction

from a RR facility, which is then to lead to the application of the graded approach. However, there are no detailed instructions as to how the graded approach is to be implemented in practice.

Considering the above, it was decided *not to categorise* the RR for the purposes of data collection and analysis. Instead, the same questionnaire, which encompasses the requirements of the NSD, IAEA and WENRA RL was prepared and sent to all operators, accompanied with a note that the graded approach should be considered (Ref. Chapter 5).

Regarding age, twenty-three of research reactors that are currently operational were constructed between 1956 and 1973, meaning that those were in operation for more than fifty years. This fact alone gives weight to the need for conducting a proper PSRs as well as the introduction of comprehensive ageing management. Only four research reactors in the EU fleet have been constructed after 2000.

4 NUCLEAR SAFETY REQUIREMENTS FOR RESEARCH REACTORS IN THE EU

As mentioned previously, the EU legal framework for ensuring the safety of nuclear installations is Council Directive 2009/71/Euratom and its amendments, defined under Council Directive 2014/87/Euratom, also referred to as the Nuclear Safety Directive (NSD). The objective of this project was to assess elements of safety assurance as implemented by RR operators, to comply with the requirements of national, EU level and international safety requirements. To achieve the objective, both the status of national regulations for RRs and their application by the RR operators-licensees have been benchmarked against the criteria set.

The objective of the NSD is to establish a Community framework to maintain and promote the continuous improvement of nuclear safety and its regulation and to ensure Member States shall provide for appropriate national arrangements for a high level of nuclear safety to protect workers and the public against the dangers arising from ionising radiation from nuclear installations. The NSD aims to meet this objective by setting out in specific Articles the obligations to be met by Member States. Those obligations relate to the establishment of a legislative, regulatory, and organisational framework (national framework), that will facilitate the highest levels of nuclear safety at their nuclear installations. NSD Recital 25 provides for the application of a graded approach, whereby the implementation of the NSD provisions is dependent on the type of nuclear installation. Therefore, when adopting the provisions of the NSD into national legislation, each Member State should/could take into account the potential magnitude and nature of risks posed by the nuclear installations they plan or operate.

It is relevant to note, that the amendments to the 2009 Directive are set out in the recitals and the three Articles of the 2014 Directive. For the purpose of this project, the main focus regarding the amendments to the 2009 Directive is on Recital 25, which introduces the graded approach and Article 2, which sets out the Obligations on Member States, Regulators and the Licensees. Specifically, the NSD requires that the lifecycle of a nuclear installation (i.e., design, siting, construction, commissioning, operation, and decommissioning), is managed in such a way as to prevent accidents and to mitigate the consequences of an accident, should one occur. This objective applies to all new nuclear installations and is to be used as a reference target for existing facilities. Given the age of many research reactors within the EU, some modern safety requirements remain a considerable challenge, in particular, those for which financing might be a challenge.

The NSD further requires enhancements of the nuclear safety culture, which together with the provisions for defence in depth and the mitigation of impacts of extreme external natural or man-made hazards, aims to assure that the high-level safety objectives are met. It also requires the operators to implement a PSR on a 10-year maximum interval, where PSRs would ensure compliance with the current (i.e., at the time of performance of the PSR) design basis and identify safety improvements, which may be necessary, considering technical developments and new safety standards.

The 2014 amendments to NSD also introduce a requirement to assess safety improvements implemented at other nuclear installations in the EU, through “Topical Peer Reviews” (TPR), whereby EU nuclear installations are reviewed against a specific safety topic. The first TPR, which was implemented in 2017-18, was devoted to ageing management. The participation was mandatory for all NPPs and research reactors above 1 MW, and on a voluntary basis for RRs of less than 1 MW. The TPR results showed that the application of aging management programmes at many research reactor facilities is weaker than at NPPs. Whilst the concerns were raised with specific activities, such as ageing of cables, of greater concern is the fact that appropriate Ageing Management Programmes have not been established at all in most EU research reactor facilities. Thus, the recommendation of the 1st TPR regarding research reactors was that *"systematic and comprehensive overall ageing management programmes should be implemented for the research reactors, in accordance with the applicable national requirements, international safety standards and best practices"*.

Like for other nuclear facilities, the IAEA safety standards establish a basic set of safety requirements. Several standards contain requirements that are also applicable to research reactors, including General Safety Requirements GSR Part 1 on Governmental, Legal and Regulatory Framework for Safety [6], GSR Part 2 on Leadership and Management for Safety [7], and GSR Part 7 on Preparedness and Response for a Nuclear or Radiological Emergency [8]. The leading safety requirements for research reactors are given in the SSR-3 Safety of Research Reactors [2], which is complemented by several guides including the SRS No. 99 Periodic Safety Review for Research Reactors [5] that provides technical information and practical examples of conducting a PSR on a research reactor facility, as well as their regulatory reviews. The SSG-10 Ageing Management for Research Reactors [9] documents the application of methods and activities on identification of ageing management processes specially designed for RRs. In addition, the SSG-50 Operating Experience Feedback for Nuclear Installations [10] is used for determining guidance on how to perform analysis, trending, recording, and reporting of internal and external operational events. Furthermore, the IAEA offers safety reviews of research reactors through their INSARR missions, the outcome of which provides useful guidance on the level of compliance with the IAEA standards.

An important element of assuring safety of research reactors is the adoption of the 2020 WENRA Reference Levels dedicated to research reactors [4], which, in agreement with ENSREG, all EU MS have committed to introduce in their national arrangements.

All the above-mentioned documents were used in the process of establishing the benchmarking EU MS regulatory requirements and operator's activities in relation to their research reactors.

5 THE PROCESS AND METHODOLOGY OF THE BENCHMARK

5.1 THE PROCESS

The objective of the project was to assess various elements of safety assurance of research reactors in the EU against the requirements of the NSD, as transposed in national regulations. The objective was to benchmark both the applicable regulations of the relevant Member States and their application by the licensees/operators, including the identification of safety upgrades, PSR and ageing management.

In order to undertake the benchmark and associated analyses, the information on the status of the legislation and regulations applicable to research reactors as well as the information from the operators was collected. In order to systemise the data collection, and later-on the analysis, it was decided that the development of a questionnaire that systematically covered all areas of interest was the most effective way. The questionnaire was developed and sent to regulatory authorities and operators in Member States. The questions were prepared in a way to:

1. Obtain the required information related to the national framework and regulation specific to research reactors, regulatory practice, and implementation of regulatory requirements and their alignment with the NSD;
2. Obtain the required information from the licensees required to perform an adequate benchmarking of operational practices and their alignment with the NSD

The concept of the questionnaire was to establish a parallel questioning method, i.e., the questionnaires for the operators and regulators covered the same areas but the wording of questions was adjusted appropriately. There were a handful of questions that were focused on operators or regulators only. Those were marked as such. Upon receiving answers, where needed, the information was extended and/or corroborated in direct contact with the respondents.

5.2 PREPARATION OF QUESTIONNAIRES

The main articles of the NSD represent the skeleton of requirements that should ensure the nuclear safety of nuclear installations in the EU. Thus, these NSD requirements represent the main issues that need to be assessed in relation with the RRs in the EU MS oversight of the operation of research reactors nationally. To develop questions that would facilitate findings needed, more details need to be provided for each of the areas.

After the requirements of the NSD were aggregated into core questions of the questionnaire, the WENRA Safety Reference Levels for Existing Research Reactors were reviewed. This included detailed requirements on Safety Policy, Operating Organisation, Leadership and Management for Safety, Design Basis Envelope, Design Extension Conditions, etc. All these requirements were assessed to elaborate on the main areas as structured by the NSD. As the WENRA reference levels include around 400 detailed requirements, a careful grading was performed to select those that are substantially relevant for the safety of research reactors, in line with the objectives of the project.

Furthermore, to ensure that the gathered information would be comprehensive and above all complete, the IAEA standards and guidelines were reviewed to assess whether there are (project-relevant) safety requirements that are beyond WENRA RLs. The IAEA standards assessed included the following:

1. SF1, Fundamental Safety Principles, 2006
2. GSR Part 1, Governmental, Legal and Regulatory Framework for Safety, 2016
3. GSR Part 2, Leadership and Management for Safety, IAEA, 2016
4. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, 2014
5. GSR Part 4, Safety Assessment for Facilities and Activities, 2016
6. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA, 2015
7. SSR-1, Site Evaluation for Nuclear Installations, 2019
8. SSR-3, Safety of Research Reactors, 2016
9. SSG-10, Ageing Management for Research Reactors, 2010
10. SRS No. 99, Periodic Safety Review for Research Reactors, 2020
11. SVS-35, Guidelines for Self-assessment of Research Reactor Safety, 2018
12. SSG-20, Safety Assessment for Research Reactors and Preparation of the Safety Analysis Report, 2012
13. SRS No. 55, Safety Analysis for Research Reactors, 2008
14. SVS-25, Guidelines for the Review of Research Reactor Safety: Revised Edition, 2013
15. SSG-22, Use of a Graded Approach in the Application of the Safety Requirements for Research Reactors, 2012
16. SSG-24, Safety in the Utilization and Modification of Research Reactors, 2012
17. SSG-37, Instrumentation and Control Systems and Software Important to Safety for Research Reactors, 2015
18. SRS No. 41, Safety of New and Existing Research Reactor Facilities in Relation to External Events, 2005
19. SRS No. 53, Derivation of the Source Term and Analysis of the Radiological Consequences of Research Reactor Accidents, 2008
20. IAEA, NS-G-4.1, Commissioning of Research Reactors, 2006
21. IAEA, NS-G-4.2, Maintenance, Periodic Testing and Inspection of Research Reactors, 2006
22. IAEA, NS-G-4.3, Core Management and Fuel Handling for Research Reactors, 2008
23. IAEA, NS-G-4.4, Operational Limits and Conditions and Operating Procedures for Research Reactors, 2008

24. IAEA, NS-G-4.5, The Operating Organization and the Recruitment, Training and Qualification of Personnel for Research Reactors, 2008
25. SRS No. 75, Implementation of a Management System for Operating Organizations of Research Reactors, 2013
26. IAEA, NS-G-4.6, Radiation Protection and Radioactive Waste Management in the Design and Operation of Research Reactors, 2009
27. SRS No. 80, Safety Reassessment for Research Reactors in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plan, 2014
28. SRS No. 94, Approaches to Safety Evaluation of New and Existing Research Reactor Facilities in Relation to External Events, 2019
29. SSG-35, Site Survey and Site Selection for Nuclear Installations, 2015
30. SSG-67, Seismic Design for Nuclear Installations, 2021
31. SSG-68, Design of Nuclear Installations Against External Events Excluding Earthquakes, 2021
32. SSG-9, Seismic Hazards in Site Evaluation for Nuclear Installations, 2022
33. SSG-18, Meteorological and Hydrological Hazards in Site Evaluation for Nuclear Installations, 2011
34. SSG-27, Criticality Safety in the Handling of Fissile Material, 2014
35. SSG-40, Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors, 2016
36. SSG-47, Decommissioning of Nuclear Power Plants, Research Reactors and Other Nuclear Fuel Cycle Facilities, 2018
37. SSG-50, Operating Experience Feedback for Nuclear Installations, 2018
38. SSG-69, Equipment Qualification for Nuclear Installations, 2021
39. GS-G-3.5, The Management System for Nuclear Installations, 2009
40. SRS No. 103, Methodologies for Seismic Safety Evaluation of Existing Nuclear Installations, 2020

Many of those standards and guidelines were found to be overlapping. At the end, the main references that provide the requirements that were used to establish the questionaries for regulators and operators included the following:

1. Nuclear Safety Directive
2. WENRA Safety Reference Levels for Existing Research Reactors
3. GSR Part 1, Governmental, Legal and Regulatory Framework for Safety, IAEA, 2016
4. GSR Part 2, Leadership and Management for Safety, IAEA, 2016
5. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA, 2015
6. SSR-3, Safety of Research Reactors, IAEA, 2016
7. SSG-50, Operating Experience Feedback for Nuclear Installations, IAEA, 2018
8. SRS-99, Periodic Safety Review for Research Reactors, IAEA, and
9. SSG-10, Ageing Management for Research Reactors, IAEA, 2010.

Some questions are not universal, i.e., applicable for both regulator and operators, but rather targeted for one of the two. The reason for this is that even the same requirement would see a different application by each. Therefore, for some of the requirements, different questions were prepared, one for the regulators, the other one for the operators. Additionally, some requirements are specific to regulators and some specific to operators, therefore, questions related to those requirements were developed respective to the respondent.

The questions were grouped into six chapters:

1. Legal and Regulatory Framework
2. Responsibilities and Conditions for Nuclear Safety
3. Safety Analyses
4. Periodic Safety Review and Other Reviews
5. Ageing Management
6. Emergency Preparedness

The final questionnaire included 15 main question categories, with an additional 52 sub-questions. Each question was supported with a reference to the appropriate NSD, WENRA or IAEA requirement, to enhance the responders' understanding of the background of a question and to facilitate the preparation of adequate answers.

Once completed, the set of questions was independently evaluated by a regulatory expert and a RR operation expert of the project team. The considerations for the availability of data, comprehensiveness (regarding the project objectives) as well as the resources needed by operators and regulators to answer the questionnaire, were all assessed. The final set of questions are detailed in Chapter 6 of this report.

To reduce/minimise the time and effort needed by the responders, the project team performed a "prefill" of the questionnaires, with publicly available information. Sources of data included primarily the national reports prepared for the 2019/2022 Review meeting of Convention on Nuclear Safety, the national reports for the 1st Topical Peer Review (TPR), the IRRS mission reports (those having the Module 5, Research Reactors) as well as the INSARR mission reports, where available.

Another important element of the prefill was to obtain insights of the status of regulations for research reactors, operational compliance, as well as the safety issues faced by EU research reactors. This information was not only used in the pre-fill of the Questionnaire, but also as the background information for the analysis of the answers.

Each of the prefilled questionnaires was independently reviewed by the project team, to make sure that the information is both accurate and focused, so that proper answers were found to the questions raised.

The prefilled questionnaires were finally sent to the 12 regulators, and the operators of research reactor facilities that are considered "nuclear facilities" per NSD. Examples of questionnaires are given in Annex III and Annex IV.

5.3 ANALYSIS OF ANSWERS

The answers were received from all 12 regulators (12 out of 12), and from 21 out of 25[3] operators of research reactors. Despite multiple request and contacts, no response was received from 4 operators. Three of those are zero power and one is a low power research reactor (100 kWt).

Most responses received from the EU regulators were of high quality, with very good, comprehensive answers. This greatly facilitated the analysis of the state of legislative requirements in the Member States under consideration.

The responses received from the operators were in general satisfactory, with a variation of level of details and depth of information provided by different operators. Some of the responses were very well prepared with comprehensive answers, especially from the operators of research reactors with higher thermal power. Other responses, especially of operators of smaller research reactors, contained less details. This was, however, consistent with the accompanying instructions, which assumed that the graded approach would be used, as not all requirements are applicable to all research reactors considered (i.e., many of the requirements are not applicable to zero power reactors or subcritical assemblies).

The analyses were performed in two distinctive patterns:

1. The "horizontal analysis" in which all received answers (i.e., from all regulators and operators) to a specific question were analysed. This analysis provides a general overview of how a certain area is considered or certain issue addressed in all of the MS, how legislative/regulatory requirements are established and implemented, and what are the practices of the RR operators in a certain area (e.g., requirements on the implementation of periodic safety reviews (PSR), what safety factors are used, what kind of improvements stem from PSRs and how often PSRs are performed, etc.). Horizontal analysis offers a great opportunity for comparison of national approaches, and the identification of best practices that could serve as a good example for other countries.
2. The "vertical analysis", in which the individual MS was scrutinised, i.e., consistency of legislative/regulatory requirements with the NSD and international standards in individual areas, how do individual facilities meet those requirements, the utilisation of the graded approach considered, etc.

In some cases during the analysis discrepancies were identified in relation with answers received, which required further explanations or clarification from the respondents. To shorten and streamline the process, only some direct inquiries were undertaken, while the corrections, clarifications and verifications of the results of the assessment (and in that the answers) were accomplished through the MS' review of "vertical analysis" reports.

For this purpose, the vertical analysis reports for each Member State were prepared. Each vertical report included an integrated assessment of the status related to each main topic (e.g., summary of answers on what are the requirements of the implementation of research reactor modifications in the considered MS, and how each research reactor performs the

[3] Although there are 36 RRs in the EU, there are only 25 operators, as 7 operators operate more than one RR.

licensing and implementation of modifications), as assessed by the project team from the provided answers to the questionnaire.

The review process generated additional information, including comments and corrections but also clarifications or supplements to the original answers. The outcome of this process was also used to supplement the horizontal analysis.

The aim of the project **was not** to assess safety of the individual research reactors in a particular MS. The purpose of the project was to benchmark the legislative/regulatory requirements for research reactors in MS (as compared with the NSD and other international requirements) as well as compliance to those by the RR operators. The purpose was to assess and identify the areas where safety enhancements could be made from the perspective of the entire fleet of EU RRs, and provide general recommendations and suggestions in that regard.

The main output of the project are the results of the horizontal analysis, which are summarised in Chapter 6, as well as recommendations and suggestions, which are provided in Chapter 7 of this report.

6 ANALYSIS OF THE SAFETY OF RR IN THE EU

On the basis of a detailed analysis of all of the answers received, a summary of the status of each of the issues of interest has been prepared. This establishes general conclusions at EU level, across the fleet of RRs. It has to be noted that the fleet of RRs in the EU is all except homogeneous, there are many very different types of research reactors operating in the EU. Additionally, the approach to answering questions as well as level of details provided differed between regulators and operators, sometimes significantly. After the first version of vertical reports were prepared, those were distributed to regulators and operators of individual countries with the request for additional information and clarifications. In several cases, when even such additional information did not clarify certain issue, direct contact was made for clarification. The answers provided allowed the identification of (some) common issues, which support the final conclusions made as well as the recommendations drawn.

The following is a question by question summary of the status in relation with each question raised in the questionnaire, across the EU. As stated previously, the way the questions were raised was to be specifically focused for regulators and operators. The questions are reproduced here, along with the "legal basis" for raising a specific question. On one hand the summary provides for a synthetical view of approaches across the EU MS to better identify recommendations applicable at EU level. On the other hand, detailed analysis was also performed through the vertical analysis and the full responses to questionnaires. Following are conclusions relevant for the whole EU, while through the vertical reports each country got also more detailed and focused reminders about their specific issues.

6.1 LEGAL AND REGULATORY FRAMEWORK

1. **Regulators:** What are the requirements regarding licensing, inspection, and enforcement in all stages of lifecycle of Research Reactors?
   Operator: Which legally binding safety requirements you have to follow in different stages of lifecycle of your Research Reactor (RR)? Please provide the reference to existing laws/regulation.

   Basis: NSD Article 4, GSR Part 1 § Req. 2

   In all MS appropriate legal basis is in place for licensing research reactors, though the specifics of the regulations differ.
   In all countries a license is required during the preoperational stages, construction, and operation.
   All the operators are aware of legal requirements and have the same understanding as the regulators.

1.1. **Regulator:** Who is responsible for the regulatory oversight (licensing, inspection, and enforcement) of Research Reactors (RRs)?
Operator: n/a

Basis: NSD Article 5, GSR Part 1 § Req. 3 & 18 SSR-3 § 3.10

In all the MS it is very clear who is the licensing authority. In some MS those are the ministries, in others independent administrative bodies. In a few MS this responsibility is shared (e.g., issuing licences and safety assessment/inspection are not performed by the same organisation).

1.2. **Regulator:** What type of authorization/licence is required for the operation of a RR and for the conduct of activities, and on which basis (submittals) is such being issued?
Operator: What kind of licenses did your facility needed to operate, and how often it needs to be renewed?

Basis: NSD Article 4, GSR Part 1 § Req. 4, SSR-3 § 3.1 – 3.5

In all MS research reactors must obtain the operating license based on the legal framework that is described in Question #1. In most MS, additional licences are necessary, such as water right licences, which can be issued by other authorities.

In some countries operating licenses are without time limit, while in some their validity is conditioned by the performance of periodic safety reviews.

1.3. **Regulator**: Is the regulatory body functionally separate from license holders or any other body or organization concerned with the utilization of RRs?
Operator: /

Basis: NSD Article 5, GSR Part 1 § Req. 4

There is no MS where the position of the regulatory body would indicate a functional connection with a license holder.

1.4. **Regulator:** Is there a process in place at regulatory authority to perform assessments and inspections at RRs to verify the compliance with safety requirements?
Operator: Does the regulatory authority perform inspections at your RR to verify the compliance with safety requirements?

Basis: NSD Article 4, GSR Part 1 § Req. 2 & 27, SSR-3 § 3.13 – 3.16

All the regulators have a process in place to perform assessments and inspections of research reactors. In some countries they are supported by personnel of technical support organisations.

1.5. **Regulator:** In normal conditions, how many inspection visits do you organize at RRs per year?
Operator: How many inspections do you receive per year by the regulatory authority and/or other authorized authorities?

Basis: NSD Article 4, GSR Part 1 § Req. 2 & 27, SSR-3 § 3.13 – 3.16

Answers were very different between different MS and for RR with different power levels. It is understandable that for research reactors with low power, fewer inspections are performed and those are less frequent than for more complex facilities or higher power RRs.
There are various specifics of inspection practices, where in some MS a very high number of inspections is reported, while the order of inspections varies depending on the location and/or uses of a RR. There were some inconsistencies in the number of yearly inspections as reported by the operators and regulators, possibly indicating a different understanding what an "inspection" consists of.

In spite of the differences identified, it does not appear that there is a problem with the implementation of the regulatory inspections in the EU MS. The differences might be a consequence of cultural and historical background. There are no indications they could jeopardise the fulfilment of requirements set in the NSD, IAEA and other standards, or WENRA RLs.

1.6. **Regulator:** Have you ever performed any regulatory enforcement actions at RRs, such as suspending the license, issuing a fine or warning?
Operator: n/a

Basis: NSD Article 4, GSR Part 1 § Req. 2 & 27, SSR-3 § 3.13 – 3.16

From the answers it could be concluded that suspension of license or issuance of fines is not a frequent method of enforcement. Most regulators have responded that just the oral or written warnings by inspectors are mostly used and followed on by licensees in a reasonable time. However, there were also several cases of financial fines.

6.2 RESPONSIBILITIES AND CONDITIONS FOR NUCLEAR SAFETY

2. **Regulator:** Does the prime responsibility for safety rest with the license holder of the Research Reactor and could not be delegated to any other body?
Operator: Is your organization (i.e., the manager as responsible individual) the only one responsible for safety of your RR (even in the case, that you rely on subcontractors for certain activities)?

Basis: NSD Article 6, GSR Part 1 § Req. 5&6, SSR-3 § Req. 2 & 67 (with subordinate req's)

In all EU MS nuclear safety legislation is requiring the prime responsibility for nuclear safety to rest with the license holder. All the operators of research reactors have confirmed their responsibility for nuclear safety.
However, it could be recognised from the answers that for some zero or low power reactors at universities the relationships between the responsibilities of the owner (often an organisation of a State), operating organisation (a University or a Faculty) and the reactor manager could be made clearer.

2.1. **Regulator:** Is a safety policy, which gives safety an overriding priority in all RR activities and requires regular reviews and continuous improvement of nuclear safety, required for the RR license holders?
Operator: Does your organization have safety policy in place, which gives safety an overriding priority in all RR activities and requires continuous improvement of nuclear safety? If yes, please attach a copy of it to the questionnaire.

Basis: WENRA Issue A, SSR-3 § 4.1, Req. 3 (with subordinate req's)

In several MS there is no explicit legal requirement demanding a written safety policy from the operator of the nuclear facilities. In some MS a legal requirement for such policy is more general, not requiring a special written document. In other countries clear legal requirements are in place.
Most operators have it, but in different forms. In some cases, the operators do have such policy although it is not legally required in their country. There are also 9 operators that do not have such a policy in place or did not give a clear answer about its existence.

2.2. **Regulator:** Are the modifications, activities that could impact safety subject to an independent safety review? Who is performing those safety reviews?
Operator: What is the process of independent review of issues relevant to safety (e.g., modifications) at your RR, i.e., by your staff, that were not involved at original review and/or decision making or by external staff/bodies? If latter, how do you select those?

Basis: WENRA Issue B2, SSR-3 § Req. 5 & 6 + 4.27

In most MS the legal requirements for an independent safety review are clear, but there are exceptions. In most cases such safety reviews are done by the independent safety officer, an independent department or a safety committee consisting of experts from other departments of the host organisation or of external experts.
It seems that the term »external expert« is understood differently in different countries. In some cases, these are the RR staff members, who are not involved in the given modification, while elsewhere these are experts from other organisations. In a few cases, mainly for zero/low power reactors, operators seem to rely on the review and assessment by the regulator during the licensing process. Such practice is not fully in line with the requirements of relevant standards, but might be accepted with the consideration of the graded approach. Certainly, in such cases the regulator has to be fully aware of that situation and should during the review look himself for confirmation of eventual delicate

solutions by some competent independent third-party expert. This is an issue that should be a matter of discussions and the establishment of a common EU approach in the scope of the Recommendation No. 2 on graded approach (see Chapter 7).

2.3. **Regulator:** Is it required to establish a safety committee (or an advisory group) that is independent from the RR manager to advise on safety aspects of operation/ modification/ maintenance, etc.?
Operator: Does your organisation have an independent safety advisory committee encompassing external experts?

Basis: SSR-3 § Req. 6

It seems that the role and importance of such a safety committee is understood quite differently in different MS. In many cases it was reported how such a body (the committee, the officer, the department) is performing the review and assessment. Such a function is, of course, very much required and needed. However, the main intention of the quoted requirement is the **advisory** role of an independent (group of) expert(s). This seems to be missing in a number of MS.

Establishment of a safety advisory committee or group is legally required in six MS. In five countries there is no legal requirement, but their operators have established their safety advisory committees. In one country such advisory safety committees are not required and also the operators do not have them. In their case the operators and regulators rely on the review undertaken by a Technical Support Organization.

3. **Regulator:** Are the RR license holders required to have Integrated Management Systems (IMS) implemented with the main aim to achieve and enhance nuclear safety?
Operator: Does your organisation have an Integrated Management System (IMS) in place?

Basis: WENRA C3.1, SSR-3 Req. 4 (with subordinate req's)

In all MS there is a legal requirement in place for operators to have an Integrated Management System.

Not all operators have it however. Those are mainly zero or low power reactors. Some RRs in their answers referred to an operating and testing manual instead.

3.1. **Regulator:** What are the requirements on IMS, the processes, documentation, etc.?
Operator: Does your organisation have any certification of your IMS? If yes, against which standard?

Basis: SSR-3 Req. 4 (with subordinate req's)

All the countries have proper requirements for IMS, which are mainly following the IAEA SSR-3. Some operators with IMSs have their IMSs certified against ISO-9001 or against national standards.

3.2. **Regulator:** What are the requirements on the control of documentation?
Operator: What is your IMS based on (which standard)? What are the processes your IMS covers?

Basis: WENRA C, SSR-3 Req. 4 (with subordinate req's)

This question was probably too broad and was understood by responders in different ways. Nevertheless, it could be concluded that the care for documentation is reasonably legally prescribed in all the MS. This is valid also for most of the operators, although nine answered negatively or did not answer.

3.3. **Regulator:** n/a
Operator: Does your organization have a procedure describing how to manage documentation, including records?

Basis: WENRA C 3.12, GSR Part 2 Req. 8 (with subordinate req's)

The answers to this question vary significantly. No obvious conclusion could be made.
It must be considered together with question 3.1 and is a supplement to question 3.2 for operators. No obvious negative conclusion could be drawn from answers.

4. **Regulator:** Are there any legal requirements in place for RR license holders to make arrangements for recruitment, training and retraining for their staff having responsibilities related to the nuclear safety?
Operator: How does your organization recruit, train and retrain your personnel?

Basis: NSD Article 8b.2, SSR-3 § Req. 69 & 70 (with subordinate req's)

In all MS there is a legal requirement in place about recruitment, training and retraining for RR operators.
The operators are reporting on their arrangements, where the graded approach is very obvious and utilised. The larger RRs with strong commercial activities have strong human resource management systems in place, while low or zero power university reactors reported about just a few older staff members with no foreseeable replacements.

4.1. **Regulator:** What are the requirements regarding qualifications and authorization of personnel carrying out tasks important to safety?
Operator: What kind of qualifications and authorizations your staff members that carry out tasks important to safety are required to possess (knowledge, skills, safety attitude, etc.)?

Basis: WENRA Issue D2.1, D4.1, 7.14, 7.15, 7.16, 7.21, 7.23, Req. 70, 7.28 – 7.31

Most of the regulators and operators have answered extensively, but some have provided just brief summaries. Reasonable legal requirements are in place in all MS (except one, but there a RR is already defueled).

In some MS, the key personnel of the operators must be licensed by a state commission, while in others the operators have their internal authorization systems.

4.2. **Regulator:** What are the requirements regarding systematic analysis of number and competence of staff for safe operation, as well as on regular verification and documentation of staff sufficiency?
Operator: Does your organisation systematically, regularly analyse the number of staff needed for safe operation, and their competence?

Basis: WENRA B3.1&3.2, SSR-3 § 7.14, 7.30 & 7.31

Most of the MS have requirements regarding systematic competence analysis in their regulations, except three MS (which are those having RRs but no NPPs).
Operators also answered mostly positively, although some have problems. This issue might be related with non-existence of long-term operational plans for some of the RR. It is very difficult to attract young, skilled personnel into facilities without clear long-term perspectives.

5. **Regulator:** What are the regulatory requirements for the license holders to assure that adequate financial and human resources for nuclear safety of RR are available?
Operator: Does your organisation have sufficient financial and human resources for fulfilment of your nuclear safety obligations?

Basis: NSD Article 6, GSR Part 1 § 4.3(f), SSR-3 § 4.15NSD Article 8b.2, SSR-3 § Req. 69 & 70 (with subordinate req's)

All the MS have legal provisions in place requesting proper financial and human resources of operators.
All the operators indicated that they do not have financial problems, except one. In this case problems with aging staff and lack of finances were reported.

6. **Regulator:** What are the regulatory requirements for a RR operator to maintain the operating experience feedback?
Operator: Does your organization collect, screen, analyse, trend, document operating experience also at similar facilities in a systematic way?

Basis: NSD Article 8b.2

In most MS operators are obliged to report to the regulator about safety related events, but the requirement to register, evaluate and document internal and external safety significant operating experience is not always explicitly stated in national legislations.
Most of the operators indicate that they do have an OEF system in place. Some rely on annual or biannual meetings with operators of similar reactors as the main tool for exchange of experiences.

6.1. **Regulator:** n/a
Operator: How many such events were recorded during last 12, 48 months?

Basis: SSR-3 § Req. 88 (with subordinate req's), SSG-50

There was some ambiguity in the answers, likely because the question might not have been clear as to what kind of events are being asked for. The positive and to some extent even surprising fact is that in all MS the operators have an obligation to report to the regulator regarding unusual events. But it seems that there are differences about the definition of such events. In some cases, there have been no such events for a decade, while some operators report several times per year, obviously suggesting a very different understanding (or maybe MS' definition) as to what an "unusual event" is. Some common effort on the EU level to establish similar definitions of such events could reduce such differences. However, as there do not seem to be too few, but even too many such reports, there is no urgent need for such harmonisation.

6.2. **Regulator:** Is license holder reporting about operating events to you?
Operator: Is your organization reporting about safety significant events to your regulatory body?

Basis: NSD Article 8b.2, SSR-3 § 7.126

In all MS it is required to report to the regulatory body and all the operators do so.

6.3. **Regulator:** n/a
Operator: How frequently you have done so in last 10 years?

Basis: NSD Article 8b.2, SSR-3 § 7.126

In line with answers to the Question 6.1, the answers vary significantly, possibly/likely due to the differences in the definition of reportable events.

6.4. **Regulator:** n/a
Operator: What were the most significant events reported and what were lessons learned from them?

Basis: NSD Article 8b.2, SSR-3 § 7.126, 7.127, 7.128

Several operators answered with a short description of reported events.
One operator refused to describe the event claiming it being "restricted data", while another referred only to the home page of the regulatory body. These might indicate a bit of openness and/or transparency problems among the operators.

6.3 SAFETY ANALYSIS

7. **Regulator:** Does the operator of a RR have to justify nuclear safety when applying for the license? Is the license holder obliged to verify the safety level and further improve it in a regular fashion for the period of validity of the operating license?
Operator: Did your organization perform thorough safety analyses of your RR when you applied for different licenses, and periodically, especially in a case of major modifications or other changes from previously licensed status?

Basis: NSD Article 6, GSR Part 1 § Req. 24 (with subordinate req's), SSR-3 § Req. 5

As expected, this is the case in all legal systems and has to be done by all the operators of research reactors in EU. Four RRs, even some of higher power, reported that their licenses have not been changed since several decades ago, when they were issued. According to those operators, no modifications have been performed to the installation that would require a change of the license, therefore there was no need for safety assessments. Modifications are obviously performed following some other verification process and procedures, as the same operators answered positively to the question no. 2.2. about independent safety reviews of modifications.

7.1. **Regulator:** Is a license holder required by national regulation to provide a Safety Analysis Report (SAR) to demonstrate that the RR fulfils relevant safety requirements? Does the national regulation define the content of the SAR, and does it require periodic or regular updates?
Operator: Does your RR have an up-to-date Safety Analysis Report (SAR)? If yes, to which standard/requirements is it developed? How often is it updated/reviewed? When was it last time updated? What were the main reasons for the update?

Basis: WENRA N1.1, SSR-3, Req. 1 (with subordinate req's)

The Safety Analysis Report is a required document in all nuclear safety legislations in EU. In most cases its content is prescribed, while in some it is referring to IAEA standards.
In some cases, however, there is no requirement for updating the SAR and therefore also the operators are not updating them. One operator reported an extreme case: their SAR is from the year 1974 and was never updated.

7.2. **Regulator:** Are lists of Postulated initiating events (PIE) established and Design Basis Accidents (DBA) for RRs defined in the national regulation?
Operator: Is the SAR for your RR developed to address a list of Postulated Initiating Events (PIE) that covers all events that could affect the safety of your reactor?

Basis: WENRA E4.1 and E4.2, SSR-3 § Req. 18 (with subordinate req's)

Questions to the regulators were somewhat stricter than the WENRA and SSR-3 requirements. There is no requirement to have the list of PIEs established in the national legislation. Therefore, also the negative answers of regulators should not be considered wrong. In all MS except in one, the list of PIEs is required to be established and analysed.

7.3. **Regulator:** Does your national regulation specify minimum seismic requirements (i.e., peak ground acceleration) that a RR needs to fulfil?
Operator: Has the seismic impact been analysed as a part of the safety justification of your RR?

Basis: WENRA T4.2, SSR-3 § Req. 19 + para 6.52 – 6.57

In most MS there are legal requirements about minimum seismic requirements of RRs. In most cases there is no explicit request for the resistance to at least 0,1 g peak ground acceleration, but rather a requirement for the seismic analysis and determination of the appropriate seismic resistance.
Operators are almost all reporting about such analysis being performed for their facilities with the exception of three zero power reactors. Several research reactors have reanalysed their seismic resistance in the scope of post-Fukushima stress tests. This included, for example, primary circuit integrity assessments (preventing major LOCA) and building integrity assessments (preventing damage to support systems). Such reassessments also contributed to improvements in some of the reactors.

7.4. **Regulator:** Are the requirements to ensure that all modifications, including experimental devices and experiments meet relevant safety requirements defined in your legislation/regulations?
Operator: Does your organization have a process in place ensuring all modifications, including experimental devices and experiments meet relevant safety requirements?

Basis: WENRA Q & X, SSR-3 § Req. 83 (with subordinate req's)

As expected almost all MS regulators and operators responded positively. In some cases, however, there are no provisions explicitly requiring safety review of every modification or an experiment, but only those with higher safety risk.
Operators in most cases rely on the review by their safety committees/safety officers.

7.5. **Regulator:** Are there regulatory requirements in place to keep the temporary modifications including experimental set-ups in RRs at a minimum?
Operator: How many temporary modifications including specific experimental set-ups, are typically in place at your RR and for how long?

Basis: WENRA Q5.3, SSR-3 § 7.104

In several MS there is no legal requirement for keeping temporary modifications at a minimum, while other MSs have such regulation. Some operators consider experimental setups at their reactors as a temporary modification.
The operators answered as having zero to several such temporary modifications active at the moment.

7.6. **Regulator:** Are there requirements in your regulations to ensure that decisions on safety matters are timely and preceded by appropriate assessment and consultation so that all relevant safety aspects are considered?
Operator: What kind of investigations and assessments your organization performs before making decisions on safety matters?

Basis: WENRA B2, GSR Part 2 § 4.9(d), 4.14

As this question is in line with questions 2.2, 7. and 7.4, the answers should be seen jointly. In all the MS the legal system requires that the decisions on safety matters are timely and preceded by assessments and safety consultations.
All the operators answered that they are performing such assessments and consultations on all decisions related to safety matters.

7.7. **Regulator:** What are the requirements related to fire hazard analysis and fire protection of RRs?
Operator: Did you perform the fire safety or hazard analysis for your RR? What measures are in place to prevent and limit the consequences of fires that may challenge safety at your RR?

Basis: WENRA S1.1., SSR-3 § 6.48 – 6.51, Req. 79 (with subordinate req's)

National legislations related to research reactors typically rely on standard fire protection arrangements as they are applicable for industrial facilities.
All the research reactor operators indicated that they follow applicable rules. In most cases fire protection is regulated by separate national authorities. In most cases, nuclear regulators did not identify a need to introduce some additional requirements, though some MS have a separate regulation on fire safety applicable to all nuclear installations, including RRs. Fire hazards and the measures related to management of fire hazards are described in the Safety analysis reports.

8. **Regulator:** Are there legal requirements in place for license holders to perform nuclear safety self-assessment and invite international peer review at least every 10 years?
Operator: When was the last time your organization has performed the safety self-assessment of your RR? When (and which) was the last international peer review mission you hosted?

Basis: NSD Article 8e, GSR Part 1 § Req. 14 & para 3.2

All the MSs have the legal requirements in place to invite international missions to peer review their regulatory bodies.
However, there are no such legal requirements for the operators to invite international missions, and the NSD does not explicitly require that either. There are more than a dozen RRs in EU that have never hosted any international peer review.

8.1. **Regulator:** n/a

Operator: What were the main improvements as a result of the last review mission (e.g., INSARR)?

Basis: NSD Article 8e, GSR Part 1 § Req. 14 & para 3.2

The answers were provided by the operators that have hosted international peer reviews in the past. In these cases, the answers mentioned valuable suggestions for safety improvements that were the outcome of such missions.

9. **Regulator:** Is the application of "graded approach" when assessing safety of RR required or recommended in your national legislation/regulation? What requirements apply to RRs (different kinds of RRs), e.g.:

Operator: As per international recommendations, "Graded approach" reflecting possible risks should apply to RRs. How are the following requirements implemented in your RR:

Basis: NSD Articles 6, 8b, WENRA Issues E, G, K, IAEA SSR-3

This question was mainly addressed to the regulators. For the operators it was relevant in view of the following sub-questions. In general, graded approach is recognised in national legislations and regulators do apply it in their work. In some countries the legislation is the same for NPPs and for research reactors, therefore graded approach is a logical and understandable principle to be applied.

9.1. **Regulator:** Safety analysis of Design Basis Accidents (DBA)

Operator: What are design basis accidents (DBA) for your RR? Were all of those analysed in your safety assessments?

Basis: SSR-3 § Req. 20 & 41 (with subordinate req's)

All the reactors have defined design basis accidents and all the national legal systems do require it. In some countries the DBA list is in the regulations, while in others the operator must prepare it and it is thoroughly reviewed, assessed and finally approved by the regulator.
Graded approach is most obvious in countries, where the same regulations apply for NPPs and for RRs. In such cases it is logical that the demands for research reactors are graded compared to their power as well compared to nuclear power plants.

9.2. **Regulator:** Design Extension Conditions (DEC)?

Operator: What are design extension conditions that apply to your RR? Were all of those analysed in your safety assessments?

Basis: SSR-3 § Req. 22 (with subordinate req's)

This is an area that deserves more attention. As underlining of importance of Design Extension Conditions has emerged only after the accident in Fukushima and primarily for

nuclear power plants, it is not surprising that improvements in the research reactor area are lagging. The reasonable use of graded approach in that respect is important, as consequences of beyond design accidents in reactors of lower power would be of limited magnitude.
In a majority of MS there are no explicit legal requirements regarding design extension conditions for research reactors, while in a few of them they have such requirements or requirements for nuclear power plants are applicable also for research reactors.
Most operators of reactors of smaller power do not have design extension conditions analysed and defined. On the other hand, several higher power reactors did prepare appropriate analyses and measures.

9.3. **Regulator:** External hazards (natural, man-made) analysis?
Operator: Which external hazards (natural, man-made) are analysed for your RR and what are the provisions in place to protect against these?

Basis: SSR-3 § 5.6, 5.9, Req. 18 (with subordinate req's)

External hazards are not a new concept, they were foreseen to be considered in safety analyses of nuclear facilities from the beginning of their use. So, all the national legislations require such analysis also for research reactors and it was done for all of them.

9.4. **Regulator:** Classification of structures, systems and components (SSCs) important for safety?
Operator: Are structures, systems and components (SSCs) important for safety in your RR classified into safety classes?

Basis: SSR-3 § Req. 16 (with subordinate req's)

In most MS such classification is legally required also for research reactors.
However, not all operators have their SSCs classified.

9.5. **Regulator:** Provisions to prevent, detect and control abnormal operation and failures, design basis accidents and DEC?
Operator: Which features are in place at your RR to prevent, detect and control abnormal operation and failures, design basis accidents and severe accidents?

Basis: SSR-3 § Req. 23, 45, 46, 48, 49 & 50 (with subordinate req's)

As this was a broad question, answers varied from extensive to quite specific, often different in the explanations provided. Certainly, all the regulations in the EU require such and all the operators aim towards prevention, detection and control of all kinds of abnormal operations, failures and accidents. One of the operators provided the following comment, which is a very good explanation for the variance of the answers received:
"Answering this question would mean providing the entire safety analysis. This is a question that cannot be comprehensively answered. It would include a combination of safety systems, monitoring systems, procedures, emergency response organisation etc."

9.6. **Regulator:** Use of single failure criterion and consideration of common cause failure (CCF)?
Operator: Is the single failure criterion used in the safety analysis of your RR and are common cause failures (CCF) considered as well?

Basis: SSR-3 § Req. 25&26 (with subordinate req's)

Although the single failure criterion is one of the basic principles of nuclear facilities design since the very beginning, it seems it is not explicitly required in national legal systems for RRs. There is no such explicit requirement for research reactors in six countries. Similar applies for common cause failures (CCF).
Additional issue regarding CCF is the fact that not all the research reactors have performed a Probabilistic Safety Analysis.

9.7. **Regulator:** Redundancy, diversity, and independence of SSCs, use of multiple barriers?
Operator: Are SSCs of your RR important to safety designed to take into account redundancy, diversity, and independence and for defence in depth?

Basis: SSR-3 § Req. 17, 27 & 43 (with subordinate req's)

Those are other issues present as design principles since the beginning of the existence of nuclear facilities. Also, in this case there seems to be no explicit legal requirements in just one MS.
All operators confirmed that the redundancy and diversity requirements were considered for all safety relevant SSCs.

9.8. **Regulator:** Operational limits and conditions (OLCs)?
Operator: Compliance with operational limits and conditions (OLCs)?

Basis: WENRA H2.2, H2.3, SSR-3 § 7.20, Req. 71 (with subordinate req's)

Operating limits and conditions are required by legal systems in all MS.
All research reactor operators do have the OLCs and follow them in operation.

9.9. **Regulator:** Are OLCs required to be updated regularly to incorporate any RR changes and operating experience?
Operator: Are OLCs updated regularly to incorporate any RR changes and operating experience?

Basis: WENRA H2.2, H2.3, SSR-3 § 7.20, Req. 71 (with subordinate req's)

All the regulators and operators have answered positively. A few operators of low power facilities claim there were no changes in the facility and therefore no updates needed.

9.10. **Regulator:** Are modifications of OLCs required to be adequately justified by safety analysis and independent safety review?
Operator: Are modifications of OLCs adequately justified by safety analysis and independent safety review?

Basis: WENRA H2.2, H2.3, SSR-3 § 7.20, Req. 71 (with subordinate req's)

In almost all MS this is explicitly required by the national regulations.
The operators largely confirmed that the modification of OLC would require safety analysis except those who indicated that they did not have changes in the OLC in the past.

9.11. **Regulator:** Programmes of maintenance, testing, surveillance, and inspection of SSCs important to safety (including in-service inspection) to ensure that their availability, reliability, and functionality remain in accordance with the design?
Operator: Does your organization have programmes in place, which establish the requirements for maintenance, testing, surveillance, and inspection of SSCs important to safety (including in-service inspection) to ensure that their availability, reliability, and functionality remain in accordance with the design?

Basis: WENRA K1.1, K2.2, K2.4, K3.2, SSR-3 § Req's 31, 74 & 77 (with subordinate req's) + 7.38, 7.39

All the legal systems, with one exception, require such a programme.
All the operators have such programmes in place. However, the depth of these programmes appears to vary, which is obvious given the variation of the types and sizes of the RR fleet across the EU.

9.12. **Regulator:** Are procedures for conducting these activities required to be established, reviewed, and validated?
Operator: Are procedures for conducting these activities established, reviewed, and validated?

Basis: WENRA K1.1, K2.2, K2.4, K3.2, SSR-3 § Req's 31, 74 & 77 (with subordinate req's) + 7.38, 7.39

Most of the legal systems require that procedures are reviewed and validated.
Most the operators have such procedures in place, with the exception of some low or zero power reactors.

6.4 PERIODIC SAFETY REVIEW

10. **Regulator:** Are there legal requirements in place for license holders to perform Periodic Safety Review (PSR) at least every 10 years?

Operator: When were the last and previous Periodic Safety Reviews (PSR) of your RR performed?

Basis: NSD Article 8c, SSR-3 § 4.25, 7.121, 7.122

In all MS that operate NPPs, there is a legal requirement in place for license holders to perform a Periodic Safety Review at least every 10 years.
Most of the operators have already performed at least one PSR, while in a few facilities they are ongoing or planned in the near future.

10.1. **Regulator:** What was the process of the last PSR based on (national regulations, guides, IAEA standards...)?
Operator: How did you define the scope and the methodology for your last PSR?

Basis: IAEA Safety Reports Series No. 99

Most of MS legislations prescribe the methodology of PSR for research reactors or refer to the appropriate IAEA Safety Standards.
In some countries the selection of the methodology is a first step in the review process, where the regulator has to agree with the proposal by the operator.

10.2. **Regulator:** Are the national requirements in place (regulations) on safety factors to be addressed in a PSR?
Operator: Which safety factors did you address during the last PSR?

Basis: IAEA Safety Reports Series No. 99

The MS that have national regulations requiring the PSR for research reactors also define the list of safety factors. One country referred to national legislation from 2005, which could be considered a bit outdated, while another one does not have explicit relevant requirements.
Some operators have answered with detailed lists of safety factors, while the others only indicated that such a list exist.

10.3. **Regulator:** Is it required that during the PSR the basic justification principle is checked, i.e. that the further operation of the reactor outweighs the associated risks?
Operator: Did you check the basic justification principle during the last PSR, i.e. that the further operation of the reactor outweighs the associated risks?

Basis: IAEA Safety Reports Series No. 99, 3.6(g)

There were quite different answers ranging from "no" to "yes" with different kinds of explanations in between. One of the regulators explained that the *"Justification itself is not explicitly checked but the PSR summary report shall include an overall assessment of nuclear safety which enables a decision to be taken on the continuation of operation and* *on the acceptability of the remaining deviations from the safety standard after implementation of the corrective and improvement actions."*

Similarly, a spectrum of answers was provided by operators, from "yes" to "no" with justifications by some.

In reality, the legal system is to establish the criteria and their acceptance. The regulator is there to control their fulfilment of those. It is on the operator (and the owner of the facility) to determine whether the benefits obtained would justify the investment into everything what is needed to fulfil modern standards, the alternative being closing down the RR facility. Such a decision could be done already before the PSR or soon after its conclusion when it becomes obvious whether it is worth investing into the RR facility's improvements.

11. **Regulator:** Were there any other safety reviews (stress tests, topical peer reviews, INSARRs etc.) required and/or performed at your RRs?
    Operator: Were there any other safety reviews (stress tests, topical peer reviews, INSARRs etc.) required and/or performed at your RRs?

    Basis: NSD 8e

    A Majority of research reactors in EU had some kind of external safety reviews. However, the number of reactors that have never been exposed to such reviews, is not negligible.

12. **Regulator:** What were the key improvements (those with highest impact on safety of the RR) of the last PSR and other safety reviews?
    Operator: What were the key improvements (improvements that had the most benefit for the safety of the RR) that were decided on the basis of the outcome of the last PSR or other safety reviews?

    Basis: IAEA Safety Reports Series No. 99, SSR-3 § 7.121, 7.122

    The answers were provided to different levels of details. It could be concluded that there was a (significant) impact from performance of PSRs. In most answers technical improvements and modifications have been mentioned, in other cases documentation, procedures, internal standards etc. have been mentioned as well.

6.5 AGEING MANAGEMENT

13. **Regulator:** What are the requirements for RR license holders on the implementation of Ageing Management Programme (AMP) defined by your national legislation?
    Operator: Does your organization have an Ageing management Programme (AMP) in place, to ensure safety functions through the entire lifetime of the RR, as well as address technological obsolescence?

    Basis: WENRA I1, SSR-3 § Req. 86, 7.120, SSG-10 § 1.2

In most MS there is a legal requirement in place for the preparation of an AMP and the operators are saying that they follow those requirements. In one MS there are no such requirements nor has the operator prepared the Ageing Management Programme.
In some MS there is no explicit Ageing Management programme of research reactors, rather it is considered to be a part of regular maintenance.
In one MS regulations just recommend preparation of an AMP rather than require it.

13.1. **Regulator:** Is the AMP subject to the regulatory review? Are there requirements in place for regular/periodic updates of the AMP?
Operator: How often is your AMP reviewed, updated and is AMP independently reviewed?

Basis: WENRA I1, SSG-10 § 2.18 & 4.20

In some countries the regulatory review of the AMP is being undertaken.
In the countries where there is no requirement for the AMP, it is not being reviewed or updated. There are countries that consider ageing management to be part of regular maintenance. Those operators responded that the AMP is regularly reviewed, although formally they don't have an ageing programme. Most zero or very low power reactors don't have an AMP.

13.2. **Regulator:** What are the requirements for the inputs for the AMP updates – e.g., new information, new issues, modifications, assessment of the effectiveness of the AMP?
Operator: What are origins of inputs for AMP updates?
- 13.2.1. Independent assessment of AMP by the safety committee (Y/N)
- 13.2.2. Non-conformances and implementation of corrective actions (Y/N)
- 13.2.3. Audits to determine the adequacy and effectiveness of AMP (Y/N)
- 13.2.4. Other (please describe)

Basis: WENRA I1, SSG-10 § 2.18 & 4.20

The answers by the operators reflect the situation with AMP in their country (see previous answers). When they have AMPs in place, the answers were mostly "yes".
With no AMP in place, answers are negative.
In addition to the first three positive answers, the operators have mentioned as other sources also the information from other facilities or exchange with staff on international workshops for RR operation.

13.3. **Regulator:** Does your national regulation define the SSCs important to safety to be included in the AMP?
Operator: Which type of SSCs important to safety are included in the AMP for the RR, and which (and with which justification) are not? If possible, provide some examples of SSCs in each category.

13.3.1. concrete structures (Y/N)
13.3.2. mechanical components and equipment (Y/N)
13.3.3. electrical equipment (Y/N)
13.3.4. instrumentation equipment (Y/N)
13.3.5. control equipment (Y/N)
13.3.6. cables (Y/N)
13.3.7. Others: (please describe)

Basis: SSG-10 § 2.2

The answers by the operators reflect the situation with AMP in their country (see previous answers). When there was an AMP in place, it was so confirmed.

All the research reactors of higher power, which have the AMP in place, indicated that all of the relevant SSCs (listed in the question), were covered by the AMP. Some additional issues mentioned by operators included coolant system, coolant pumps, fire sensors, neutron sensors, secondary (buried) pipelines, high voltage transformers, battery system elements, power circuit breaker, underground pipelines, etc. For example, at one reactor the neutron measurement chains were renewed, all important cables are now contained in a database and no cables were found to be in an aggressive environment.

The first EU Topical Peer Review in 2017 on aging management was a strong push towards improvements of AMP at research reactors, as it was recognised how big the gap in this area is as compared with the EU NPPs. The review of implementation of the Action plans (NAcP) in 2021 showed that a majority of them were either already implemented or were being implemented. Unfortunately, the Covid-19 pandemic did slow down some of the implementation though at the time of preparation of this report things are back to normal.

Most of the operators of lower or zero power reactors do not have a complete AMP in place, though some elements of AMPs are being implemented.

13.4. **Regulator:** Does national regulation establish specific requirements for addressing extended shutdown in the AMP?

Operator: In a case your RR would be in an extended shutdown, how does the AMP address eventual degradations and/or stressors during that period?

Basis: SSG-10 § 4.1

Legal frameworks of MS seem not to address the issue of extended shutdowns for RRs.

The operators do not consider it specifically. A typical answer was that also during the extended shutdowns all the processes, including AMP, would have to be run in a similar way as during operation.

13.5. **Regulator:** n/a

Operator: How long do you intend to operate your RR? Please inform us about the foreseen shut-down date.

Basis: n/a

The lifetime of a research reactor in the EU is in most cases not firmly established. Most of the operators answered that the shutdown date has not been decided yet, while some have offered approximate periods: e.g., in one MS “until 2045”, in another “for 20 years”,

in a third “until 2027”, for some training reactors in a 4th MS “until 2035”, in another “until 2030”, in another for “5 years”, as well as in one “beyond 2055”.
In many cases, actual end of lifetime depends on governmental decisions and/or availability of (financial) resources, possibility to obtain fuel, etc., thus making long-term operation planning complicated.
The lack of long-term planning in relation as to how long a reactor is likely to remain in operation could potentially be a challenge for nuclear safety related issues including the human resources availability and development, safety management including safety upgrades as well as periodic maintenance activities.

13.6. **Regulator:** n/a
Operator: What is your usual regime of operation, i.e. what percentage of time your reactor operates at power? How does the operation regime influence safety factor, for example how does it influence the embrittlement of structures?

Basis: n/a

Reactors are in use very differently from just a few hours per year to 260 days per year.
Concerning the influence of operating regime on safety/ageing, operator answers stated that for very low neutron flux RRs, embrittlement is not an important factor. For some other reactors, special programs are implemented for evaluation of embrittlement.
Other ageing processes were not mentioned.

13.7. **Regulator:** n/a
Operator: Do you experience problems related to the obsolescence of design, material replacement like-for-like or challenges with upgrades?

Basis: n/a

Almost all the operators did experience such problems or at least recognised them soon enough and avoided the issue to become a real problem.
Typical area affected is instrumentation and control system.

13.8. **Regulator:** Are there requirements in place for operators to adjust operation in case when old reactor designs cannot fulfil modern safety requirements?
Operator: Did you ever have to adjust operation of your reactor because its old design could not fulfil modern safety requirements?

Basis: n/a

The answers of regulators could be summarized as: *“The license holder shall comply with requirements stipulated by the legal framework. There are no relaxations for “old reactors” in it.”*
No regulator reported about any legal possibility for relaxations of such kind. Nevertheless, as reported during the Workshop, there are instances that e.g., due to obsolesce, some of the equipment or parts of systems might not be operational any more, and cannot be

replaced because similar or replacement components or systems are not available. In one instance it was reported that on a RR a function of one train of a redundant system was lost (it relates to the in-core measurements), but an alternative system would be providing similar information, effectively assuring the redundancy of the function. In case the second train would be lost, it will become a problem of compliance with the regulation, and may lead to a loss of the operating license.
Operators did not report about any conditions where the "old design" could be an obstacle to fulfilling the modern safety requirements, although there are reports of components or systems being replaced with more modern versions, with extended functionality etc., which at least to some extent may indicate a need to comply with more stringent requirements.

Ultimately, all RRs need to fulfil the requirements set by the national regulator in terms of safety of the design and operation, and those are being more demanding than the regulation that was in place 50 years ago. As it was confirmed by the regulators, a case of non-compliance that could not be compensated by other means may ultimately lead to various restrictions on the operation or even a withdrawal of the license. At least one MS regulator is contemplating on a withdrawal of a license for a RR that did not implement the improvements that were deemed necessary.

6.6 EMERGENCY PREPAREDNESS

14. **Regulator:** Are there legal requirements in place for license holders to make on-site or even off-site emergency?
Operator: Does your organisation have on-site and off-site emergency arrangements in place properly co-ordinated with competent authorities?

Basis: WENRA I1, SSR-3 § Req. 86, 7.120, SSG-10 § 1.2

Answers are straightforward in all cases: Yes, there are legal requirements, and the operators are prepared to follow them.
For most of reactors only on-site emergency preparedness is developed due to the (almost) absence of the possible off-site consequences.

14.1. **Regulator:** What are the national requirements on the emergency preparedness for RRs (e.g., organization, staff, procedures, facilities and equipment, trainings and drills, etc.)?
Operator: Do your emergency arrangements include provisions for organization, staff, procedures, facilities and equipment, trainings and drills, etc.?

Basis: SSR-3 § Req's. 55 & 81 (with subordinate req's)

In their answers the regulators have shortly summarised their national requirements, while operators generally confirmed that they have suitable arrangements in place.

14.2. **Regulator:** Are emergency response procedures required to be in place, and are these required validated during training and drills?
Operator: Does your organization perform periodic emergency drills based on these procedures? How often?

Basis: SSR-3 § Req's. 81 (with subordinate req's)

In all MS such procedures are required, and all the operators do perform drills based on these procedures. Such drills are performed at least annually. The depth/extent of such drills (from table-top exercises to full scale emergency drills) varies, and it is not clearly established by all MS.

14.3. **Regulator:** does the regulatory authority participate in the nuclear emergency drills?
Operator: n/a

Basis: SSR-3 § Req's. 81 (with subordinate req's)

In all the cases the regulatory body is informed about drills. In some MS, the regulator observes a drill in others (who?) also participate in it, according to the national emergency arrangements. The regulator could send inspectors to observe drills.

14.4. **Regulator:** Which other external organizations and local authorities participate in these drills?
Operator: Are you inviting external organizations/ local authorities to participate or observe your emergency drills?

Basis: n/a

In all cases at least the local fire brigade is involved, but also other relevant authorities (typically local/regional emergency response organizations and TSOs). Depending on the extent of the exercise and the size of the reactor.

14.5. **Regulator:** Are there national requirements in place for RR on preventing accidents with early radioactive releases that could not be handled by off-site emergency measures in due time or in limited area?
Operator: Is your RR designed to prevent accidents with radioactive releases, which would require off-site emergency measures? Have you been introducing safety improvements to prevent such radioactive releases?

Basis: NSD Article 8a, SSR-3 § 2.2, 2.6, 6.1, 6.13

All the regulators and all the operators responded positively. Low power RRs can exclude off-site effects as a result of low core inventory. For larger power RRs additional safety barriers (such as containment systems) and safety systems/measures are implemented.

14.6. **Regulator:** Are requirements from previous question applicable to old and new RRs in your country?
Operator: n/a

Basis: NSD Article 8a

As expected, there are no such distinctions in nuclear legislation of EU countries.

7 ANALYSIS AND RECOMMENDATIONS

7.1 REGULATORY FRAMEWORK

All of the EU MS established regulatory infrastructures that meet the obligations of the NSD, as determined by the assessment of the transposition that was conducted by the EC. Furthermore, the regulators would have had transposed all of the WENRA reference levels (for the NPPs; the RL for RR are planned to be transposed within the activities of the WENRA's RHWG) in the national regulations. The IAEA standards and guidance may have been transposed, or in some Ms those are deemed applicable in general, as per main Atomic law or another legal act. The Regulatory inspections and other means of regulatory oversight are in place to verify that the operators comply with established regulatory requirements.

Following are some examples where requirements from WENRA Reference Levels or from IAEA standards have not been fully transposed:

- Requirement for the operator to have a written safety policy. However, in many cases the operators have safety policy written either as a separate document or as part of the other general policy documents.
- Requirement for establishment of an independent safety advisory committee. Most operators would have some kind of advisory committee, although the role and composition vary. In some MS they are even used not only for advising, but also for reviewing and approving modifications.
- Requirements for the operator to maintain the operating experience feedback system. Such a requirement is missing mainly in the few countries without nuclear power plants. Nevertheless, RR operators confirmed that they are in general collecting and using operating experience for safety improvements.
- Explicit requirements regarding seismic safety. In all MS the research reactors have to follow general building codes. In most countries with nuclear power plants there are specific seismic safety requirements, only in a few countries without NPPs there are no specific requirements for research reactors. However, all the operators confirmed they have considered seismic safety in their re-evaluation of safety, e.g., during the Stress test.
- Explicit requirement for application of single failure criteria for safety systems. Such a principle is indeed applicable in all nuclear facilities, but surprisingly in a few countries it is not formally legally prescribed and required.
- Requirement to limit the number of temporary modifications. In a few countries there is no such explicit requirement, but operators seem to be aware of this and are, trying to minimise such situations.
- Requirements related to Design Extension Conditions. As this is still a relatively new concept it is understandable that it is not everywhere already fully included in legislation (There are additional findings and recommendations regarding DEC below).

Again, the MS not operating NPPs are generally in a worse position than those with NPPs.

- In a few MS who are not operating NPPs ageing management might not be strictly defined in the regulations. Likewise, in countries operating larger research reactors (>10 MW) the ageing management is not explicitly required, but is considered part of regular maintenance, or part of PSR.
- In some countries there are no requirements on independent safety review of modifications and other activities that could impact the safety. Still, operators report that modifications relevant to safety are examined by e.g., the radiation protection officer, but for major modifications an independent safety advisory committee is involved.
- In several countries there are no requirements to limit the number of temporary modifications to a minimum.
- In most/all MS there are requirement to regularly update the Safety Analysis Report (though sometimes implicit rather than explicit). In most countries a SAR has to be up-to-date. Nevertheless, it was revealed that a research reactor has a SAR that was not changed since the beginning of operation in 1974. The explanation was that there is no requirement for a regular update of SAR.
- Requirements for programmes of maintenance, testing, surveillance, and inspection of SSCs are important to safety. In a few MS there is no explicit requirement in regulations, but the operators do have the programmes in place.

Based on the evaluation of the questionnaires, it is obvious that the level of the development of regulations is commensurate with the status of a MS' nuclear programmes. Legislative requirements in MS operating NPPs are generally aligned with up-to-date nuclear safety standards and thus are generally more advanced than in MS that either have no nuclear energy program, or are phasing out their nuclear program. This is also reflected in safety requirements for research reactors.

Particularly in MS that utilise the same regulatory requirements applied to NPPs, use of the graded approach regarding for example safety policy, independent safety reviews, competence of staff, OEF, SAR and its update, SSC safety classification, OLC modification, maintenance procedures, and AMP, etc., is highly important and relevant. However, in some MS some requirements have yet to be transposed into the national legislative framework.

The WENRA's WGRR is currently undertaking a self-assessment of the implementation of the WGRR RLs in national regulatory frameworks. The outcome of the self-assessment is expected to be peer reviewed by the WGRR. Like it was the case with WENRA RL for NPP, verifying the implementation in practice would be useful in that context.

Recommendation No. 1: Encourage regulators to perform an appropriate gap analysis of their national regulations against WENRA RL for RR, other (IAEA) international standards and as needed to further develop their regulations, such that they are aligned with the latest standards for research reactors.

7.2 USE OF THE GRADED APPROACH

This project established the evidence that the EU RR operators strive to maintain adequate (high) levels of nuclear safety, commensurate with the risk the operations of their facilities pose. Larger reactors, in which a severe accident with damage of nuclear fuel and radioactive releases would be possible, are generally designed and operated with a high safety margin. The features to support such include safety classified and redundant systems (based on DiD principles), DEC consideration, comprehensive surveillance and maintenance programmes, ageing management activities and programmes, fire protection, on- and off-site emergency preparedness, as well as well-developed IMSs, independent safety committees, regular peer reviews, etc.

Smaller reactors, where the probability of a severe accident with off-site consequences is low to negligible, pose less of a threat to the public and environment. In this respect, those might be considered intrinsically “safe” from the perspective of their impact to the population and environment, even though they may not apply all requirements defined by modern safety standards.

Thus, one of the main issues that stems from this Study is the application of the graded approach, which is provided for under Recital 25 of the NSD, as well as recognised as very important by WENRA RL for RRs. WENRA RL for RRs generally allow grading and efforts are on-going to further clarify this via guidance. It is obvious that a graded approach has been adopted and is being used in some MS, though not necessarily in others.

Graded approach is mostly used in the MS where there are unified regulations for NPPs and RRs, as the regulations are designed primarily for nuclear power plants. In such a case it is understandable that some of the requirements could be appropriately lowered when applied to research reactors. Another example where graded approach is required, is using the same safety requirements for research reactors of different power (e.g., 20 MW research reactor vs. “zero power” reactor).

The study shows some good examples of the use of graded approach, such as:

- grading of the requirements for scope of the management system depending on power of reactors (e.g., less detailed requirements for lower power or zero power reactors);
- grading of the requirements regarding recruitment, training and retraining of staff for safe operation, as well as on systematic analysis of number and competence of staff - against more relaxed requirements for lower (and zero) power reactors;
- grading of the seismic analysis requirements - higher power reactors have to perform detailed seismic analysis, while low power reactors are allowed to perform simplified, bounding analysis showing that no seismic event could cause radioactive releases;
- analysis of DEC-B scenarios not required for subcritical assemblies;
- (some) low power research reactors are not required to nominate a nuclear safety officer;
- scope of PSRs - less safety factors for smaller RRs;
- simplified procedure for obtaining licenses for lower power RRs.

On the downside, it is evident that the approach to grading very much differs MS to MS. One such example are the seismic design basis requirements. In some countries, for the seismic design of RRs (even low or zero power) a minimum seismic loading of 0.1g PGA shall apply as a design basis. In one country, with no minimum seismic loading required, the exceedance frequencies of design basis earthquake are graded based on RR power (where annual exceedance frequency is ranging between 10^{-1} and 10^{-3}). Other MS have no specific seismic requirements, including some countries with larger (>10 MW) reactors. So it may happen that in one country a zero power reactor will be designed to the applicable seismic requirements for nuclear facilities while in another a large reactor will be constructed on the general building code requirements.

Another example of different graded approach is visible with requirements regarding the implementation of DEC analysis, where inconsistent or even contrasting approaches are observed in different EU MS:

- all reactors need to perform a complete DEC analysis
- lower (zero) power and subcritical assemblies can do only DEC A analysis
- lower (zero) power and subcritical assemblies do not need to do a DEC analysis
- DEC analyses are not required at all.

Also interesting is the example of the graded requirements concerning implementation of PSRs. Most EU MS require that PSRs are performed every 10 years (though this varies down to 4 years for one MS), regardless of the reactor's power. Likewise, most MS require the IAEA standard 14 safety factors to be addressed, regardless of reactor power. There are some regulators who would apply the graded approach, to determine the scope of the PSRs for each facility. Thus, it may happen that in one country a PSR with all 14 factors is performed on a 250 kW TRIGA, while in another country 3 safety factors are reviewed for a 1 MW or even higher power reactor.

An example of maybe not the best use of graded approach is a MS that requires that PSRs are performed (every 5 years) on all research reactors. So it happens that a subcritical assembly in that country performs a PSR every 5 years, while in another MS PSRs are not required at all for critical assemblies.

Different approaches are visible in the identification of grading thresholds, i.e., where certain requirements would change from looser to more demanding ones. Here, the MS also have a different concept of a reactor power that represent a lower or higher risk, ranging from 5 kW in one country, through 50 kW in another, to 100 kW in the third one.

It is nevertheless obvious and concluded to be so, not just within this project (e.g. strongly supported by the Workshop), but also by WENRA and the IAEA, that the use of the graded approach for RRs is appropriate and suitable, not only to allow for a modification of the requirements that were originally established for NPPs, but also to allow for different requirements to be applied to RRs of different power level (or design). Presently, each MS uses (or does not use) its own approach to grading, leading to obvious differences and inconsistencies. This alone might be (or is) leading to potentially (very) different levels of safety requirements for RRs across MS, possibly leaving some facilities underregulated while unnecessary overburdening other facilities.

The point of the graded approach is that it must consider the risk of a facility, to allow for a simplification where those are warranted from the risk perspective. The graded approach to safety of RRs is not harmonised on the EU level, so every MS approves it as it sees fit. It would obviously be of benefit for MS who operate research reactor facilities to harmonise and possibly align their methodology of applying the graded approach, reflecting the level of risk posed by the respective facilities. With the WENRA RL for RS transposed into MS regulations, it might be expected that the approaches to grading would converge.

Recommendation No. 2: **The methodology of how to apply the graded approach when regulating nuclear safety of research reactors could be harmonised on an EU level and applied on a consistent manner across the Member States**.

Implementation of this Recommendation No. 2, might apply to obligations such as design requirements of different research reactors, regulatory inspections, development of IMS, emergency preparedness, etc. Considering that WENRA developed the RL for RRs that stipulate the utilisation of graded approach, it might be prudent for WENRA to support the preparation of a standard methodology on how to apply it in practice.

7.3 SAFETY ANALYSIS REPORT

National regulations in MS recognise the need for safety analysis to be a systematic evaluation of potential hazards associated with the conduct of a proposed activity and/or operation of a nuclear installation, which gives due consideration to the effectiveness of preventative and mitigating measures in reducing the effects of the potential hazards. Therefore, a Safety Analysis Report (SAR) is considered as a crucial document for ensuring issues related to nuclear safety have been properly evaluated and incorporated in the design and operation of a nuclear installation.

The format of a SAR may differ between MS and from that defined in the IAEA standard. Different formats are, per se, not an issue as long as all the relevant areas are covered. It is important that there is a requirement for the operator that the SAR is regularly updated, in particular following any design change, safety upgrade or change in operational procedures, such that it is maintained as a live document and reflects the up-to-date status. It is therefore surprising that this is not the case in several MS. One operator responded that their SAR had not been updated "since 1974, when the facility was first put into operation".

Within this project a number of operators have reported about upgrades of their facilities in the past and corresponding updates of SARs. For example, one reactor reported about their stress tests after Fukushima, which included re-analyses of the damage to the reactor building, immediate complete loss of cooling water, loss of integrity of all fuel elements, etc. which was introduced into the SAR for the facility.

In most EU MS, there is a regulatory requirement for the SAR to be up-to-date, taking into account modifications in the installation, operational experience and new requirements. Nevertheless, in some MS with operating RRs (even one larger >10 MW reactor) regular updates are not required. In one MS (also operating larger RRs) update is required in 10 year intervals (as PSR). A harmonisation of regulatory requirements is thus suggested, in line with modern international standards, e.g., the IAEA says: "*The safety analysis report shall be periodically updated over the research reactor's operating lifetime to reflect modifications made to the facility and on the basis of experience and in accordance with regulatory requirements*."

Recommendation No. 3: **National regulations should require that the SAR of a research reactor facility must be updated following any modifications to the design and or operational practices of the facility and the environment around it (natural, legal and social), such that it reflects the current situation.**

7.4 LONG-TERM STRATEGY

Most research reactors in the EU appear to have limited (if any), long-term operational strategy. A Majority of the RRs are not commercially operated (thus dependent on a State or an organisation's budgets) and most are owned by the state and operated by research institutes or universities. In such a situation, a long-term investment to ensure sustained safe operation cannot always be guaranteed. In several cases, budgetary decisions are made at the last moment and could also be reversed, as higher priority financing is required elsewhere. Such an approach establishes a high degree of uncertainty, which negates the ability for an appropriate long-term strategy and planning and may have a negative effect on nuclear safety. One of the main areas of concern is with research reactors that have been in operation since the 1970's and are ageing. In such cases, the operator may not have resources (nor interest) to pay appropriate attention to ageing management and long-term operation. This may lead to significant safety challenges.

This problem with long-term strategy is clearly visible from some of the answers to the questionnaire that were received, and even more from the discussion during the Workshop. There are challenges in the recruitment and retraining of the staff, with availability of nuclear fuel, available funding for AMP, modernisation, new experimental facilities, etc., especially in the view of ambiguities regarding remaining lifetime of RRs. Uncertainty is high, some RRs seem to be rather doubtful or lack clear perspective for continued operation, in particular in respect of changing conditions (e.g. no interest or possibilities to continue isotope production, when new dedicated reactors come on line).

The problem with staffing might be most acute for university reactors, though several large RRs, especially in countries with expanding nuclear programmes, have been reporting noticeable lack of interest and/or non-attractive employment opportunities, leading to unfulfilled job opening at RRs. In one zero power reactor there are only two staff employed with no possibility for recruitment. It is not surprising that there was no clarity as to who is responsible for safety on that facility, that there is no safety policy or IMS, no systematic ageing management (despite noticed problems with ageing of I&C), etc. The operators have no idea as to how long the reactor will continue to operate, waiting for the decision from the owner in regards to their "fate". Another zero power RR was, at the time of this Study, under regulatory investigations due to lack of human resources, with the regulator considering withdrawing the operating licence (that RR did not provide answers to the questionnaire, possibly due to lack of staff).

Such uncertainty may lead to other issues, a typical case being reluctance to invest in safety, operations or experimental facility upgrades when the expected remaining operating life time is short or uncertain. This may cascade into other areas, such as safety culture, development and maintenance of IMS and OEF, and procurement of sufficient quantities of new fuel.

Recommendation No. 4: Owners and operators of research reactors should establish and maintain a long-term strategy which is appropriately budgeted, to be reviewed and updated on a 5 to 10-year basis. The strategy should have clear objectives, goals, and financial arrangements, and include the lifetime management plans of the facility.

The long-term strategies should be reviewed and updated based on the results of the PSR as well as good international practice, e.g., from the TPR on ageing or the forthcoming one on fire safety. They should also include the most important issues influencing the medium-term outlook of a RR facility, such as required and available financial resources, fuel supply, human resource issues, required safety upgrades, etc. Prior to embarking on significant modifications and/or immediately post-PSR, a long-term strategy should be reviewed and revised in accordance with needs analysis, which would further enhance informed decision making on the long-term financial viability of operation.

7.5 CLEAR RESPONSIBILITIES

Even though the analysis within this project suggests that in most cases the responsibilities are clear and well set out, there are several cases, particularly amongst smaller research reactors, whereby complicated owner-operator-user relationships appear to exist. For example, the responsible person might be a high-level manager (i.e., removed from the operation of a RR), who may not be a nuclear expert and therefore has limited experience and might not fully understand the importance of nuclear safety. Such an arrangement could lead to a loss of responsibility and result in poor levels of nuclear safety in specific areas.

Likewise, there are examples where the owners are government bodies, with university departments being the operators. There may or may not be a person specifically appointed to assume responsibility for safety. The challenge was visible from some replies to the questionnaire, where the replies to the question *"Is your organisation the only one responsible for safety of your RR?"* seems to indicate that "somebody else" (i.e., the owner) shares the responsibility for safety.

Although the NSD as well as all international standards clearly stipulate the operator's full responsibility for safety (i.e., it cannot be delegated or divided with another entity), this might be an issue that might be present mainly at smaller (zero power) reactors. Nevertheless, since this is one of the fundamental principles of nuclear safety, it seems that at least a suggestion to MS regulators to pay more attention to this issue is (fully) warranted. The notion that this might be a problem and that it is relevant that the regulators raise the issue with the operators was supported by the majority of participants at the Workshop.

Suggestion: National regulators are encouraged to regularly remind (and occasionally verify) operators (senior managers) of RRs of their responsibilities for nuclear safety, to ensure that safety is given an overriding priority in all activities and is not compromised by other priorities, as well as to ascertain their understanding of a facility's risks and needs for long-term strategy in relation to the operation of a RR.

7.6 DESIGN EXTENSION CONDITIONS

The study shows that more than half of the EU MS (more precisely, 7 out of 12) still do not require "Design Extension Conditions" (DEC) to be analysed and implemented for research reactors. Two of those countries are in the process of implementing them following the publication of the WENRA RL for RR.

Nevertheless, the outcome of the questionnaire sems to suggest that most operators performed some kind of DEC analysis and implemented additional protective measures (mostly as part of the Post-Fukushima stress tests), in particular the larger research reactors. Some smaller reactors have not performed DEC analysis, as they are not required to (e.g., subcritical assemblies).

What is particularly noticeable in this review are the differences in the content of DEC analyses. Most of EU RRs' "DEC analyses" were done during the post-Fukushima stress tests, which, as the main scenarios, considered beyond design external hazards (earthquake, flood, weather conditions), loss of power and loss of cooling. Many of those "DEC analyses" stayed on that level and did not consider analysing additional possible scenarios. However, some of the reactors did go further in their DEC analyses, and incorporated additional accident scenarios, such as:

- ATWS,
- insertion of reactivity (sometimes combined with ATWS),
- aircraft crash (sometimes with consequential fuel fire),
- specific human errors,
- damage of capsules of irradiation samples,
- failure of a fuel bundle in air due to the failure of the crane, and even
- core melt (DEC B).

Nevertheless, the difference between MS' requirements for DEC analysis was noted. In some MS, for example, all RRs must perform DEC analyses, even zero power reactors and subcritical assemblies. In other MS, DEC type analyses are not required even for low or mid power level reactors (e.g., 250 kW or even 1 MW) and as a result those RRs did not perform such analyses. Such differences are due to diverse approaches of MS, e.g., application of the graded approach. Another obvious reason is that some MS seem not to notice that the DEC analyses are relevant/applicable to RRs. To overcome this, WENRA WGRR is currently drafting the guidance for DEC application for RRs.

Recommendation No. 5: **National regulators should include requirements regarding implementation of DEC analysis and measures for research reactors into their regulation while paying attention to the graded approach, commensurate to the level of risk they may pose**.

To facilitate better understanding and harmonise the approach in implementing DEC requirements it is likewise recommended **that the EU level coordination (e.g. through**

ENSREG or WENRA) is organised to clarify and, as needed, harmonise understanding and implementation of the DEC concept for research reactors.

7.7 AGEING MANAGEMENT PROGRAMME

Experience shows that having an established AMP, in compliance with current standards, represents a level-up in ensuring long-term reliability and nuclear safety of an installation, in particular its safety related SSCs (including passive components and structures), and thus facilitates assuring the appropriate/required level of nuclear safety in long term. Furthermore, the application of an appropriate AMP will support the establishment of a long-term operational strategy.

Higher power research reactors took part in the 1st TPR on ageing management in 2017 and were evaluated along with the EU NPPs, which generally have much more extensive ageing management programmes in place. Consequently, the TPR concluded that improvements are necessary at RRs. The main conclusion was that *"overall ageing management programmes need to be established for research reactors, in accordance with applicable national requirements, international safety standards and best practices"*.

The status of implementation of the 1st TPR national action plans were reported by all MSs in 2021. The review of the implementation of such action plans showed that a majority of corrective actions at RRs were either already implemented or the implementation was underway.

This study shows similar results. Out of 7 bigger RRs (in operation), with thermal power above 10 MW, 4 have implemented dedicated AMPs, while two reactors are in different stages of developing them. Only for one bigger reactor a dedicated AMP is not required, as ageing management is based on maintenance and inspection programmes.

Out of 6 RRs with thermal power between 500 kW and 10 MW, all of them have established a dedicated AMP, which is indeed commendable.

Dedicated AMPs have also been implemented at 3 low power reactors (thermal power between 1 - 500 kW). For two lower power RR a dedicated AMP is not required as per regulation of the MS, as ageing management is based on maintenance and inspection programmes.

Zero power reactors and subcritical assemblies are mostly not required to develop a dedicated AMP, although 3 of them have it, usually with a limited scope (electrical components, I&C).

The results of this study also show that in most MS a dedicated AMP is legally required. Still, there are a few MS with no such requirements. In two of those MS (which also operate some of the largest RRs) it is considered that ageing management is a part of regular maintenance and inspection programmes, and PSR.

Recommendation No. 6: National regulators should assure that the regulations contain clear requirement to establish dedicated AMP for research reactors.

It is important to implement these requirements with a well-defined graded approach, as for smaller reactors the development and the implementation of a full-scope AMP would be very difficult to achieve, and it is likely that it might not be needed. Nevertheless, a detailed study identifying SSCs critical for safety and effect of ageing on those needs to be implemented on all RRs.

7.8 PEER REVIEWS

Complying with NSD, all MS have a legal requirement in place to invite international peer reviews for the regulatory authorities on a 10 years' interval. There is no such legal requirement for the operators. A number of research reactors in EU, including some larger facilities, never hosted an international peer review.

While the answers in the questionnaire were provided to different levels of details, those are sufficient to conclude, that there has been a positive impact from such reviews (including post-Fukushima stress test as well as 1st TPR) where those took place. These review missions resulted in some major improvements, such as:

- increase of seismic robustness,
- improvements of emergency power supplies,
- improvements of flood protection,
- improvements of post-accident instrumentation,
- upgrade of firefighting capabilities,
- installation of bunkered emergency operations control centre,
- installation of additional means for reactor and spent fuel pool cooling,
- expanding the scope of aging management,
- expanding safety analysis with DEC scenarios, etc.

Most operators mentioned only technical improvements and modifications, although it is likely that in many cases documentation, procedures, internal standards etc., must have been improved as well.

The order to perform the stress tests came from the ENSREG, as a result of the Fukushima accident, with a purpose to verify the robustness of European research reactors against specific scenarios (i.e., extreme external hazards, loss of power and cooling). Based on those self-assessments, followed by peer reviews, several improvements were incorporated to the research facilities.

In contrast, the purpose of peer review missions (such as IAEA's INSARR or OMARR missions) is to review a nuclear installation against the most up to date standards and best practices in all areas (e.g., design, operation, ageing management, IMS, emergency preparedness, processes and procedures, etc.) and provide recommendations and suggestions that always lead to safety enhancements, whether these are design reinforcements, or upgrades of the operational practices. These missions make possible the exchange of experiences between the host operator and the review team. Such an exchange of information and comparison with foreign colleagues is one of the best drivers for nuclear safety improvement, and if performed regularly, as in some EU reactors, it represents another form of continuous improvement (which is one of the basic NSD principles).

In the EU, such missions took place mainly on larger RRs (10 MW and above), even though INSARR missions are conducted in some smaller RRs as well (e.g., 5 MW, 2.3 MW, and even two 250 kW TRIGA reactors). One country includes a requirement to perform regular INSARR missions on its largest reactors, which is considered as a good practice. There are some MS, which operate large RRs, that never hosted such missions.

However useful, such international peer review missions require significant efforts by the RR operator hosting one. For small RRs with few staff members, hosting a mission would be very challenging given the amount of work needed to prepare for and interact during the mission. The peer reviews like INSARR and OMARR should therefore be adjusted to focus on relevant aspects of a RR facility that is being reviewed, also considering the size of a RR, its utilisation, experimental facilities as well as operations, ownership, etc. A smaller, focused, peer review specially for zero power RRs might be a more adequate way to go.

During the Workshop, regulators expressed their interest in peer reviews. The results of peer reviews are an important additional (and independent) confirmation of the safety level and operational challenges for RRs. INSARR recommendations are of high interest to regulators and normally an action plan would be developed by a RR operator to address the recommendations. At least one MS took a commitment in inviting an INSARR every five years. In other MS, a large-scale change or a modification might trigger an INSARR invite.

Recommendation No. 7: Peer review missions should be invited to EU research reactors at regular intervals, especially to research reactors of higher power. **IAEA INSARR/OMARR missions, adjusted to the specifics of a RR to be reviewed could be recommended.**

7.9 SAFETY CULTURE

Although Safety Culture is specifically mentioned along with defence-in-depth under Recital 18 of the NSD, and it is a requirement of Article 8b, it was not directly covered by the questionnaire due to an inherent difficulty in objectively assessing safety culture on the basis of a questionnaire. However, when considering experience, findings of the Final Report EC-01-08-D-30/07/2018 [4]. Section 2 above), together with several responses to the questionnaire, it appears that the position of operators in relation to safety culture is not consistent across the EU RRs.

It appears from the answers to the questionnaire that the safety culture might not be considered as an important issue to some of the RR. This assumption is reflecting mainly, but not exclusively, the MS operating research reactors but not having a NPP programme. Also, it seems that some regulators have limited capability (or interest) in independently assessing safety culture at operating RRs. It seems that the regulatory oversight of safety culture is not as thorough as it might be warranted. From answers received (and as verified through the vertical analysis) it seems that one operator might not have met even the regulatory requirements for safety culture.

During the Workshop, the regulators agreed that introducing clear requirements for safety culture at RRs is very important, as it is reminding the operators of their role in maintaining the safety culture at their facilities. The workshop recognised that the uncertainty related with future operation of research reactors might have a detrimental effect on the safety culture at a facility.

It has been confirmed by peer reviews, national and international assessments that having a well-established and strong nuclear safety culture at a nuclear installation, facilitates overall strengthening of nuclear safety. This is as true for a research reactor as it is for a NPP or other nuclear facility. Even when considering graded approach, core safety culture is still essential for RR facilities. Establishment of an aligned approach to nuclear safety culture across all RRs in the EU might be considered an important element of assuring RR safety.

Recommendation No. 8: Operators should pay attention to the adoption of best practice in nuclear safety culture, whist Regulators should include a review of nuclear safety culture as a part of their oversight of RRs.

Whilst this recommendation might be seen as a “burden” on both human and financial resources of RRs, considering the experience of nuclear installations internationally it is clear that establishing a programme of nuclear safety culture, facilitates an overall improvement in nuclear safety.

8 THE REGULATORY CONCLUSIONS AND RECOMMENDATIONS

The objective of the project was to assess safety of research reactors across the EU, in line with the requirements of the national, EU level and international safety regulations. The approach utilised was to benchmark the regulatory framework and the application of requirements by the operators against the NSD, WENRA RL for RRs and IAEA standards and guides.

To implement this project, the key task was to collect relevant information about the regulatory frameworks and the operational practices of the research reactors in the EU MS. For this purpose, a questionnaire was developed and sent to the 12 EU regulators and 25 RR operators.

The aim of the project was to assess the regulatory requirements and operational practices at EU research reactors, with the conditions as defined by NSD. The basic structure of the questionnaire that was used for assessment was based on 9 main NSD elements, which were the expanded with relevant conditions from the WENRA RL for RRs as well as RR focused IAEA standards and guides, to provide supplementary questions. In such a way detailed questions related to licensing, design, operation, (periodic) safety assessments, ageing, etc., were established. The questionaries contained 15 main questions, having a total of 52 sub-questions. These were formulated into two separate questionnaires, one for regulators and one for operators.

Whilst all 12 regulators responded, 21 out of 25 operators provided a response. The 4 operators that did not respond to the questionnaires operate smaller (mostly) zero power research reactors. Based on the responses two approaches to the analyses were performed, horizontal and vertical.

The “horizontal analysis” assessed how the MS meet their obligations within the NSD as well as the compliance with WENRA RL for RR and the IAEA standards related to the establishment of a regulatory framework and how the operators comply to the regulatory requirements in their respective MS.

The “vertical analysis” was a situational assessment on the key elements of interest, i.e., the regulatory framework in each MS and the operator’s compliance with the requirements. The intention of the vertical analyses was additionally to assure both the completeness and correctness of the analysis, as these were sent back for review and approval. During their review, each Member State provided additional information in the form of clarifications, comments, and corrections (where necessary). These final inputs were used to finalise the analyses on the EU level.

Following the analysis, a Workshop was organised bringing together both the regulators and operators of RRs from the EU MS, to discuss the findings and critically asses and then contribute to the conclusions and recommendations from the Study. The outcome of the Workshop is reflected in this Final report.

The main conclusion of the study

Based on the responses to the questionnaire, supplemented with additional information and clarifications obtained through the review process as well as the discussions held during the Workshop, it can be concluded that the EU Member States operating research reactors generally have a well-established legal and regulatory framework, aligned with the principles set out by the NSD, as well as with WENRA RL and IAEA standards. Whilst some discrepancies exist, these are not considered to be critical to maintaining nuclear safety of installations. In regards to the application of regulations and compliance with the NSD, WENRA RL and IAEA standards by the operators, the conclusion is that the EU research reactors are mostly managed in a manner that ensures nuclear safety at the installation and safety of the public and environment.

The level of safety is further assured by regulatory oversight of research reactors, to ensure that different aspects of design and operational safety activity are properly assessed, verified by independent experts and authorized by the regulatory authorities. The research reactors are operated by trained, competent and licensed staff, while safety policies and management systems are (mostly) in place to ensure the highest priority is given to nuclear safety. Furthermore, operating experience is being collected and analysed to enhance safety and peer reviews are performed occasionally. Additionally, emergency preparedness and response procedures are in place and regularly tested through arranged emergency exercises.

PSRs are required to be performed in most MS, although some MS introduced such a requirement only recently. Most MS use IAEA safety guides as their main reference for implementing PSR, which might be expected to ensure that all 14 safety factors are addressed during PSRs. The implementation of PSRs has already resulted in positive impact, through enhancements of design safety, development of SSC safety classification, as well as updates of safety analysis reports.

Another important area of the analysis was the existence and application of the ageing management programmes. The 1st TPR found that, in contrast to the regulatory requirements and the development of AMPs at NPPs, the AMPs for Research Reactors was not on the same level and in general somewhat deficient. This study determined that the situation improved significantly in the meantime. Many of MS have regulatory requirements in place requiring some kind of AMP. Furthermore, and more importantly, most research reactors (with exception of some lower/zero power RRs) have in the meantime implemented (or are in the process of implementing) an AMP, not always of the same extent and level of depth. This is particularly true for large RRs, where practically all have a comprehensive AMP covering safety relevant elements in place. Some exemptions still exist, with MS that do not have formal regulatory requirements for a dedicated AMP in place, so ageing management is performed through regular maintenance and inspection programmes. It is recommended for those countries to amend their regulations accordingly, taking into account a reasonable graded approach for zero power reactors and subcritical assemblies.

It is important to stress that, unlike for NPPs, the safety requirements and approaches are not equally applicable to all research reactors, as risks posed by those are by no means equal. The solution for having appropriate safety requirements for a varied fleet of RRs is the application of a graded approach. The values of the graded approach are recognised internationally, detailed in the IAEA standards as well as in the WENRA RL for RR. WENRA also provides some suggestions on the implementation of a graded approach, with more to come in the future from WENRA RHWG. A graded approach is considered/applied in many of the MS, though the application varies across the MS. Nevertheless, the consideration of the graded approach allows for more stringent requirements and greater regulatory oversight being applied to larger RRs, while smaller ones, with very low risk to the public and environment, could have certain relaxation to the rules and regulations.

The Study identified areas where improvements are possible, but also areas where EU level harmonisation would support consistency in the application, to lead to a more coherent safety level across the EU RR fleet. A total of 8 recommendations and one suggestion have been established, as detailed in the previous section.

9 REFERENCES

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ANNEX I: SUMMARY OF THE STATUS PER EU MS

The project team prepared a detailed assessment of the situation in each MS. The document was sent to the regulator and operator(s) of each MS for review. After getting their replies the documents were adjusted accordingly.
A short summary of the status on the most important themes in each MS is provided below.

AUSTRIA

Austria is a country which is not operating a nuclear power plant, but there is one operating research reactor, TRIGA at the Technical University of Vienna, with a nominal power of 250 kW. Austria's legal system is harmonised with the requirements of the Nuclear Safety Directive, although there are some areas where some gaps might exist.
Only in recent years a functional separation of the regulatory body responsible for the RR from the body that is responsible for funding of the RR operation has been achieved. The regulatory body is now part of the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, while the Federal Ministry of Education, Science and Research provides the funds for the operation. The regulatory body is relatively small. Inspections of the reactor are performed by external experts typically once per year.
National regulations have some requirements for the management system of a nuclear facility, also the requirements about competence of staff are not very explicit. Safety analysis of modifications are mandatory as well as the safety analysis report. The reactor did perform a Periodic Safety Review in 2014, where major components of the reactor have been renewed, but there is no requirement for an Ageing Management Programme nor has the operator prepared it. Instead, continuous periodic tests are implemented to verify the condition of the research reactor.
Vienna TRIGA has never invited any international peer review mission.

BELGIUM

Belgium has three operating research reactors and one in the pre-construction licensing phase. Belgium is also a nuclear power country therefore their legal framework is well established. The regulatory body is functionally independent. The regulatory body is supported by a strong Technical Support Organisation, who is performing a majority of nuclear safety related inspections. Legal requirements for safety analyses, independent verifications, management systems, human resources management, operating experience feedback and reporting are all in place and implemented at research reactors. Reactors are regularly performing Periodic Safety Reviews. Surprisingly, the operators have responded that there were almost no applications for the change of their licenses (with one exception) as they never did any modification requiring such a process.
The Design Extension Conditions for research reactors are not yet legally required but are being added. Some DEC analyses have already been performed during the EU Stress Tests, that were performed also for all three Belgian research reactors.
Two Belgian reactors have already hosted INSARR missions.

CZECH REPUBLIC

The Czech Republic is a country with operating nuclear power plants and has a well-established legal and regulatory framework in the area of nuclear safety. It is well harmonised with the EU Nuclear Safety Directive. The regulatory body is functionally separate from the operator or other bodies concerned with promotion or the utilisation of the research reactor. There are three operating research reactors in the country, the biggest one with a thermal power of 10 MW. They are regularly inspected. Modifications and other activities, that could impact the safety, have to be and are independently safety reviewed. Operators have management systems in place, safety analysis reports are regularly updated, the regulation even requires research reactors to perform Design Extension Conditions analysis. Periodic Safety Reviews are mandatory as well as Ageing Management Programmes.

There was an INSARR missions on one of the reactors.

The improvements are possible in requiring establishment of independent safety advisory committees at research reactors, implementation of operating experience feedback systems and explicitly formulating clear written safety policy at each facility emphasising the nuclear safety.

FRANCE

France as the country with the largest number of operating nuclear power plants has also several research reactors in different lifecycle stages, e.g., under construction (Jules Horowitz Reactor) or under temporary or extended shutdown. However, only the two operating RRs (HFR, Cabri) have been included in this survey, as those are the only ones having nuclear fuel or radioactive waste on the site.

There is a large number of laws, orders and decrees applicable to nuclear facilities. Research reactors are regulated similarly as NPPs. The regulatory body is functionally separate from operating organisations. Their decisions rely heavily on support of the national Technical Support Organisation IRSN. Inspections of research reactors are regularly done.

Any application for change of the license must be supplemented by a justification of the nuclear safety. The safety level should be justified and further improved also in a regular fashion in application of the mandatory periodic safety reviews.

There are no legal requirements in place regarding the Design Extension Conditions for Research Reactors. However, both RRs did such analysis in the scope of the post-Fukushima stress tests. Both reactors also took part in the EU Topical Peer Review, however they have never hosted an INSARR mission.

In France they consider that the ageing management is part of Periodic Safety Reviews and regular maintenance programmes. The PSR is considered as a self-standing document in regards to ageing management. There is, however, a non-binding guide in place stipulating that licensees must develop and implement an AMP as part of their integrated management system.

GERMANY

In Germany the regulatory functions are generally performed by the competent authorities of the Länder (states) on behalf of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection. Regulators rely very much on Technical Support Organisations for review and assessment as well as for inspections of research reactors. The national legal system is harmonised with EU directives. There were four research reactors included in this survey.

All the modifications at facilities have to be reviewed and assessed before the licenses are changed.

The national regulation requires that research reactors have a Safety Analysis Report (SAR). However, there is no requirement for regular updates of SAR, therefore operators do not update them.

There are no specific requirements in place regarding the Design Extension Conditions for research reactors. The requirements for NPPs are applied using a graded approach. Similar is the situation regarding the safety classifications of structures, systems and components.

All German research reactors were subject to a safety review after the events in Fukushima. Some of them were included in EU Topical Peer Review exercises.

No INSARR mission took place in any German research reactors so far.

In Germany they consider that the ageing management is part of regular maintenance programmes. Therefore, the operators (with one exception) do not prepare and implement the self-standing Ageing Management Programmes.

GREECE

Greece is without nuclear power plants. There are two sub-critical assemblies in the country, which were not included in this survey, and only one research reactor. But even that one is shut down forever and defueled. The national legislation is to a large extent harmonised with EU directives. The regulator is functionally separate from the operator and the reactor is regularly inspected.

Considering the state of reactors and plans for the future, it is understandable that some requirements of EU directives, WENRA Reference levels and IAEA standards might not have been implemented. For example, there are no explicit requirements for the operator to perform independent safety assessment before any changes (although that was done in the past), operators do not have to establish an operating experience feedback system, no requirements for maintenance programmes or ageing management, even design basis accidents and design extension conditions are not mentioned in the legislation. All of this would be reasonable to improve if the use of research reactors in the country is changed.

During its active time (before 2010) the research reactor did host international peer review missions.

HUNGARY

Hungary has four operating nuclear power reactors and has therefore a well-established legal framework harmonised with EU directives. A 10 MW BRR research reactor participated in this

study. The regulatory body is functionally separate from the operator or other bodies concerned with promotion or the utilization of the research reactor.
Any modification, that could have safety implications, has to be justified and independently reviewed before the license is changed. The operator of a research reactor has the management system in place, operating experience feedback system and ageing management programme are implemented, safety analysis report is regularly updated, the periodic safety review is performed every 10 years and they took part in EU Topical Peer Review exercises.
There was no INSARR mission at that reactor yet. The BRR has an advisory safety committee consisting of external experts although national legislation does not require it.
There are no legal requirements in place regarding the Design Extension Conditions, and the operator of BRR has not done it yet, however there are safety analyses for severe accidents and beyond design basis accidents in the SAR of the BRR.

ITALY

Italy is a country without operating nuclear power plants, but with five research reactors. The regulator is functionally separate from the operator or other bodies concerned with promotion or the utilization of the research reactor. Research reactors in the country are regularly inspected. National legislation is to a large extent harmonised with the EU Directives. Operators have established systems for independent safety reviews by the safety committees and by external experts and approvals by the regulator. Establishment of safety committees is required by the regulations. Also, the management systems are required to be established by the operators, but some of them reported that they do not have them. Similarly, not all operators have the operating experience feedback systems in place, although they all report to the regulator in case of safety significant events.
It is not clear if the national regulation requires analysis of the Design Extension Conditions for research reactors. However, from the answers of the operators it could be concluded they have made some considerations in that respect.
National regulations recommend (but not require) to the operator to prepare Ageing Management Programs. Only one research reactor has it at present. Ageing Management Programs are not a subject of the regulatory review, and regular updates are not required.
Only one research reactor in Italy has hosted an international peer review mission.

THE NETHERLANDS

The Netherlands has many different nuclear facilities, from fuel fabrication through an operating nuclear power plant to long term radioactive waste storage facilities. Among the others there are also three research reactors, one of them high power (45 MW). The regulatory body has been reorganised a few years ago into an organisation independent from any other bodies concerned with promotion of the use of research reactors. Research reactors are regularly inspected.
National legislation is harmonised with EU Directives. Any modifications of the licenses have to be independently safety reviewed. All reactors have independent advisory bodies and management systems in place. The biggest reactor has operating experience feedback system implemented, while the other reactor of higher power is implementing it now. Reactors have

safety analysis reports and they are working on their improvements to have them more aligned to the format recommended by the IAEA standard.
In The Netherlands the regulations do not prescribe requirements into every detail, but they prefer to concentrate such conditions into individual licences of a particular facility. Such an example is a very brief requirement for ageing management in regulation, but extensive mentioning of it in the individual licenses. Ageing management programmes have to be reviewed during the periodic safety reviews.
Research reactors have performed periodic safety reviews. They did host international peer reviews.

POLAND

Poland has only one research reactor and no nuclear power plants. The regulatory body is functionally independent. The reactor is regularly inspected. National legislation is to a large extent harmonised with EU Directives.
The operator has management system in place together with the clear safety policy. There is no requirement to establish the independent safety advisory committee, but the operator has it. The operating experience feedback system is in place and the operator is reporting to the regulator in case of safety related events. Any modifications have to be properly justified and reviewed by independent reviewer before the change of the licence is approved.
The research reactor has a safety analysis report which is regularly updated. The national regulation requires analysis of design extended conditions and the operator has performed it. The national regulation requires that the Periodic Safety Review (PSR) is performed regularly. The last PSR of the only research reactor has been performed in 2019. The research reactor operator performed a post-Fukushima stress test, took part in the Topical Peer Review, and hosted an INSARR mission.
National regulations require management of ageing processes in nuclear facilities and the one for the research reactor is being updated.

ROMANIA

In Romania there are two operating nuclear power plants and one research reactor. The regulatory framework is harmonised with the EU Nuclear Safety Directives. The regulator is functionally separate from the operator or other bodies concerned with promotion or the utilization of the research reactor. The Research Reactor is regularly inspected.
The national regulation requires that modifications and other activities, that could impact the safety, must be independently safety reviewed. There is no requirement for an independent safety committee to be established, but the operator has it. The national regulation requires establishment of Management System, and the operator has it.
There are legal requirements in place for the license holders to assure that adequate financial and human resources for nuclear safety of the research reactor are available. However, the operator reported on issues of ageing staff and challenges with finances.
The operator maintains the operating experience feedback system and is reporting to the regulator on operating events. Any application for change of the license must be supplemented by a justification of the nuclear safety. A Safety analysis report is in place and

is regularly updated. The national regulation requires analysis of design extension conditions, and the operator has reported on them.

The first periodic safety review (PSR) is ongoing and is scheduled to be completed in 2024. The national regulation prescribes specific safety factors for the PSR. However, the actual legal act is from 2006 and therefore might not be up-to-date with current international standards.

The research reactor operator participated in the Topical Peer Review and has hosted an INSARR mission. They have ageing management programme in place.

SLOVENIA

Slovenia has one operating nuclear power plant and one research reactor. The regulator is functionally separate from the operator or other bodies concerned with promotion or the utilisation of the research reactor. Research reactor is regularly inspected.

The national regulation requires that modifications and other activities, that could impact the safety, must be independently safety reviewed and approved by the regulator before implementation.

The national regulation does require the establishment of an independent safety group for monitoring the safety. The operator has such a group, which fulfils the requirements for a "safety committee". The regulation requires a management system in place, and the operator has it.

The operator has established the safety performance indicators system and system for analysis of its own operating events as well as foreign operating experience. The safety analysis report is regularly updated.

There is no legal requirement for the operator to invite international peer review missions, but the research reactor has hosted such missions. Nevertheless, national regulations require that international mission are carried out to fulfil the county's obligations within international treaties.

The national regulation does not require analysis of design extended conditions yet for the research reactor as it is required for a nuclear power plant. The regulation is currently being updated to include this requirement also for Research Reactors. The operator considered design extended conditions in the scope of its periodic safety review.

The last PSR of the research reactor has been performed in 2014. The second PSR is in progress. National regulations require Ageing Management Programme to be established for each nuclear facility. The operator of the research reactor developed such.

ANNEX II: RESEARCH REACTORS IN EU

Country	Reactor name	Operator	Type of reactor	Thermal Power (kW)	Start of operation	Status
Austria	TRIGA II, Vienna	TU Wien, TRIGA Center Atominstitut	TRIGA II	250	1962	operational
Belgium	BR-2	SCK CEN	TANK IN POOL	125.000	1963	operational
	BR-1	SCK CEN	GRAPHITE	1.000	1956	operational
	VENUS-F	SCK CEN	ZERO POWER	0,5	1964	operational
	MYRRHA	SCK CEN	SUBCRITICAL REACTOR DRIVEN BY HIGH POWER LINEAR ACCELERATOR	100.000		Planned for 2036
Czech Republic	LVR-15	Research Centre Rez	TANK VVR	10.000	1957	operational
	LR-0	Research Centre Rez	ZERO POWER	5	1982	operational
	VR-1	Czech Technical University	ZERO POWER	0,1	1990	operational
	VR-2	Czech Technical University	SUBCRITICAL ASSEMBLY	0		under construction; Q4 2023
France	ILL HFR	Institut Laue Langevin	POOL	58.300	1971	operational
	Cabri	CEA	POOL	25.000	1964	operational
	Isis	CEA	POOL	700	1967	under decommissioning no nuclear fuel or radwaste on site
	Masurca	CEA	ZERO POWER	5	1966	under decommissioning no nuclear fuel or radwaste on site
	RJH	CEA	POOL	100.000		under construction nuclear fuel expected on site in 2030's

Country	Reactor name	Operator	Type of reactor	Thermal Power (kW)	Start of operation	Status
Germany	FRM II	Technical University of Munich	POOL	20.000	2004	operational
	FRMZ	Johannes Gutenberg-Universität Mainz	TRIGA II	100	1965	operational
	AKR-2	Technische Universität Dresden	ZERO POWER	0	2005	operational
	SUR Stuttgart	University of Stuttgart	ZERO POWER	0	1966	operational
	SUR Ulm	Technische Hochschule Ulm	ZERO POWER	0	1967	operational
	SUR Furtwangen	Furtwangen University	ZERO POWER	0	1973	operational
Greece	GRR-1	National Centre for Scientific Research "Demokritos"	POOL	5.000	1961	extended shutdown
	GR-B	Atomic and nuclear physics laboratory, University of Thessaloniki	SUBCRITICAL ASSEMBLY	0	1971	operational
Hungary	BRR	Centre for Energy Research of the Hungarian Academy of Sciences	TANK VVR	10.000	1959	operational
	Training reactor	Institute of Nuclear Techniques of the Budapest University of Technology and Economics	POOL	100	1971	operational
Italy	TRIGA RC-1	ENEA - Casaccia, Rome	TRGA II	1.000	1970	operational
	LENA, TRIGA II, PAVIA	University of Pavia	TRIGA II	250	1965	operational
	RSV TAPIRO	ENEA - Casaccia, Rome	FAST SOURCE	5	1971	operational

Country	Reactor name	Operator	Type of reactor	Thermal Power (kW)	Start of operation	Status
	SM-1	University of Pavia	SUBCRITICAL ASSEMBLY	0	1961	operational
	AGN-201 Constanza	University of Palermo	ZERO POWER	0	1960	operational
Netherlands	HFR	Nuclear Research and consultancy Group	TANK IN POOL	45.000	1961	operational
	HOR	Delft University of Technology, Reactor Institute Delft	POOL	2.300	1963	operational
	Delphi	Delft University of Technology, Reactor Institute Delft	SUBCRITICAL ASSEMBLY	0	2004	operational
	PALLAS	NRG|PALLAS	TANK IN POOL	55.000		under construction
Poland	MARIA	National Centre for Nuclear Research	POOL	30.000	1974	operational
Romania	TRIGA II Pitesti	Institute for Nuclear Research	TRIGA II Pool type, Dual core	14.000	1979	operational
Slovenia	TRIGA II, LJUBLJANA	Jožef Stefan Institute (JSI)	TRIGA II	250	1966	operational

ANNEX III: THE QUESTIONNAIRE FOR THE REGULATORS

Safe, sustainable operation of research reactor facilities in the EU

Questionnaire to Member States for regulators about Research Reactors safety

Country:

1. Legal and Regulatory Framework

Questions for regulators	Basis
1. What are the requirements regarding licensing, inspection and enforcement in all stages of lifecycle of Research Reactors?	NSD Article 4 GSR Part 1 § Req. 2
1.1. Who is responsible for the regulatory oversight (licensing, inspection and enforcement) of Research Reactors (RRs)?	NSD Article 5 GSR Part 1 § Req. 3 & 18 SSR-3 § 3.10
1.2. What type of authorization/licence is required for the operation of a RR and for the conduct of activities, and on which basis (submittals) is such being issued?	NSD Article 4 GSR Part 1 § Req. 4 SSR-3 § 3.1 – 3.5
1.3. Is the regulatory body functionally separate from license holders or any other body or organisation concerned with the utilisation of RRs?	NSD Article 5 GSR Part 1 § Req. 4
1.4. Is there a process in place at regulatory authority to perform assessments and inspections at RRs to verify the compliance with safety requirements?	NSD Article 4 GSR Part 1 § Req. 2 & 27 SSR-3 § 3.13 – 3.16
1.5. How many inspection visits do you organise at RRs per year?	NSD Article 4 GSR Part 1 § Req. 2 & 27 SSR-3 § 3.13 – 3.16
1.6. Have you ever performed any regulatory enforcement actions at RRs, such as suspending the licence, issuing a fine or warning?	NSD Article 4 GSR Part 1 § Req. 2 & 27 SSR-3 § 3.13 – 3.16

2. Responsibilities and Conditions for Nuclear Safety

Questions for regulators	Basis
2. Does the prime responsibility for safety rest with the license holder of the Research Reactor and could not be delegated to any other body?	NSD Article 6 GSR Part 1 § Req. 5&6 SSR-3 § Req. 2 & 67 (with subordinate req's)
2.1. Is a safety policy, which gives safety an overriding priority in all RR activities and requires regular reviews and continuous improvement of nuclear safety for the RR required in your country?	WENRA Issue A SSR-3 § 4.1, Req.3 (with subordinate req's)
2.2. Are the modifications, activities that could impact safety subject to an independent safety review? Who is performing those safety reviews?	WENRA Issue B2 SSR-3 § Req. 5 & 6 + 4.27
2.3. Is it required to establish a safety committee (or an advisory group) that is independent from the RR manager to advise on safety aspects of operation/modification/maintenance, etc.?	SSR-3 Req. 6
3. Are the RR license holders required to have Integrated Management Systems (IMS) implemented with the main aim to achieve and enhance nuclear safety?	WENRA C3.1 SSR-3 Req. 4 (with subordinate req's)
3.1. What are the requirements on IMS, the processes, documentation, etc.?	SSR-3 Req. 4 (with subordinate req's)
3.2. What are the requirements on the control of documentation?	WENRA C SSR-3 Req. 4 (with subordinate req's)
4. Are there legal requirements in place for RR license holders to make arrangements for recruitment, training and retraining for their staff having responsibilities related to the nuclear safety?	NSD Article 8b.2 SSR-3 § Req. 69 & 70 (with subordinate req's)
4.1. What are the requirements regarding qualifications and authorization of personnel carrying out tasks important to safety?	WENRA Issue D2.1, D4.1 7.14, 7.15, 7.16, 7.21, 7.23, Req. 70, 7.28 – 7.31
4.2. What are the requirements regarding systematic analysis of number and competence of staff for safe operation, as well as on regular verification and documentation of staff sufficiency?	WENRA B3.1&3.2 SSR-3 § 7.14, 7.30 & 7.31

Questions for regulators	Basis
5. What are the regulatory requirements for the license holders to assure that adequate financial and human resources for nuclear safety of RR are available?	NSD Article 6 GSR Part 1 § 4.3(f) SSR-3 § 4.15
6. What are the regulatory requirements for a RR operator to maintain the operating experience feedback?	NSD Article 8b.2
6.1. Intentionally blank – This question is for operators only	SSR-3 § Req. 88 (with subordinate req's) SSG-50
6.2. Is license holder reporting about operating events to you?	NSD Article 8b.2 SSR-3 § 7.126
6.3. Intentionally blank – This question is for operators only	SSG-50 § 3.11 – 3.14
6.4. What were the most significant events reported and what were the lessons learned from them?	NSD Article 8b.2 SSR-3 § 7.126, 7.127, 7.128

3. Safety Analyses

Questions for regulators	Basis
7. Does the operator of a RR have to justify nuclear safety when applying for the license? Is the licence holder obliged to verify the safety level and further improve it in a regular fashion for the period of validity of the operating licence?	NSD Article 6 GSR Part 1 § Req. 24 (with subordinate req's) SSR-3 § Req. 5
7.1. Is a license holder required by national regulation to provide a Safety Analysis Report (SAR) to demonstrate that the RR fulfils relevant safety requirements? Does the national regulation define the content of the SAR, and does it require periodic or regular updates?	WENRA N1.1 SSR-3, Req. 1 (with subordinate req's)
7.2. Are lists of Postulated initiating events (PIE) established and Design Basis Accidents (DBA) for RRs defined in the national regulation?	WENRA E4.1 and E4.2 SSR-3 § Req. 18 (with subordinate req's)
7.3. Does your national regulation specify minimum seismic requirements (i.e., peak ground acceleration) that a RR needs to fulfil??	WENRA T4.2 SSR-3 § Req. 19 + para 6.52 – 6.57

Questions for regulators	Basis
7.4. Are the requirements to ensure that all modifications, including experimental devices and experiments meet relevant safety requirements defined in your legislation/regulations?	WENRA Q & X SSR-3 § Req. 83 (with subordinate req's)
7.5. Are there regulatory requirements in place to keep the temporary modifications including experimental set-ups in RRs at a minimum?	WENRA Q5.3 SSR-3 § 7.104
7.6. Are there requirements in your regulations to ensure that decisions on safety matters are timely and preceded by appropriate assessment and consultation so that all relevant safety aspects are considered?	WENRA B2 GSR Part 2 § 4.9(d), 4.14
7.7. What are the requirements related to fire hazard analysis and fire protection of RRs?	WENRA S1.1. SSR-3 § 6.48 – 6.51, Req. 79 (with subordinate req's)
8. Are there legal requirements in place for license holders to perform nuclear safety self-assessment and invite international peer review at least every 10 years?	NSD Article 8e GSR Part 1 § Req. 14 & para 3.2
9. Is the application of "graded approach" when assessing safety of RR required or recommended in your national legislation/regulation? What requirements apply to RRs (different kinds of RRs), e.g.:	NSD Articles 6, 8b WENRA Issues E, G, K IAEA SSR-3
9.1. Safety analysis of Design Basis Accidents (DBA)	SSR-3 § Req. 20 & 41 (with subordinate req's)
9.2. Design Extension Conditions (DEC)?	SSR-3 § Req. 22 (with subordinate req's)
9.3. External hazards (natural, man-made) analysis?	SSR-3 § 5.6, 5.9, Req. 18 (with subordinate req's)
9.4. Classification of structures, systems and components (SSCs) important for safety?	SSR-3 § Req. 16 (with subordinate req's)
9.5. Provisions to prevent, detect and control abnormal operation and failures, design basis accidents and DEC?	SSR-3 § Req. 23, 45, 46, 48, 49 & 50 (with subordinate req's)

Questions for regulators	Basis
9.6. Use of single failure criterion and consideration of common cause failure (CCF)?	SSR-3 § Req. 25&26 (with subordinate req's)
9.7. Redundancy, diversity, and independence of SSCs, use of multiple barriers?	SSR-3 § Req. 17, 27 & 43 (with subordinate req's)
9.8. Operational limits and conditions (OLCs)?	WENRA H2.2, H2.3 SSR-3 § 7.20, Req. 71 (with subordinate req's)
9.9. Are OLCs required to be updated regularly to incorporate any RR changes and operating experience?	WENRA H2.2, H2.3 SSR-3 § 7.20, Req. 71 (with subordinate req's)
9.10. Are modifications of OLCs required to be adequately justified by safety analysis and independent safety review?	WENRA H2.2, H2.3 SSR-3 § 7.20, Req. 71 (with subordinate req's)
9.11. Programmes of maintenance, testing, surveillance, and inspection of SSCs important to safety (including in-service inspection) to ensure that their availability, reliability, and functionality remain in accordance with the design?	WENRA K1.1, K2.2, K2.4, K3.2 SSR-3 § Req's 31, 74 & 77 (with subordinate req's) + 7.38, 7.39
9.12. Are procedures for conducting these activities required to be established, reviewed, and validated?	WENRA K1.1, K2.2, K2.4, K3.2 SSR-3 § Req's 31, 74 & 77 (with subordinate req's) + 7.38, 7.39

4. Periodic Safety Review and Other Reviews

Questions for regulators	Basis
10. Are there legal requirements in place for license holders to perform Periodic Safety Review (PSR) at least every 10 years??	NSD Article 8c SSR-3 § 4.25, 7.121, 7.122

Questions for regulators	Basis
10.1. What was the process of the last PSR based on (national regulations, guides, IAEA standards...)?	IAEA Safety Reports Series No. 99
10.2. Are the national requirements in place (regulations) on safety factors to be addressed in a PSR?	IAEA Safety Reports Series No. 99
10.3. Is it required that during the PSR the basic justification principle is checked, ie. that the further operation of the reactor outweighs the associated risks?	IAEA Safety Reports Series No. 99, 3.6(g)
11. Were there any other safety reviews (stress tests, topical peer reviews, INSARRs etc.) required and/or performed at your RRs?	NSD 8e
12. What were the key improvements (those with highest impact on safety of the RR) of the last PSR and other safety reviews?	IAEA Safety Reports Series No. 99 SSR-3 § 7.121, 7.122

5. Ageing Management

Questions for regulators	Basis
13. What are the requirements for RR license holders on the implementation of Ageing Management Programme (AMP) defined by your national legislation?	WENRA I1 SSR-3 § Req. 86, 7.120 SSG-10 § 1.2
13.1. Is the AMP subject to the regulatory review? Are there requirements in place for regular/periodic updates of the AMP?	WENRA I1 SSG-10 § 2.18 & 4.20
13.2. What are the requirements for the inputs for the AMP updates – e.g., new information, new issues, modifications, assessment of the effectiveness of the AMP?	WENRA I1 SSG-10 § 2.18 & 4.20
13.3. Does your national regulation define the SSCs important to safety to be included in the AMP?	SSG-10 § 2.2
13.4. Does national regulation establish specific requirements for addressing extended shutdown in the AMP?	SSG-10 § 4.1
13.5. Intentionally blank – This question is for operators only	
13.6. Intentionally blank – This question is for operators only	
13.7. Intentionally blank – This question is for operators only	

Questions for regulators	Basis
13.8. Are there requirements in place for operators to adjust operation in case when old reactor designs cannot fulfil modern safety requirements?	

6. Emergency Preparedness

Questions for regulators	Basis
14. Are there legal requirements in place for license holders to make on-site or even off-site emergency arrangements properly co-ordinated with competent authorities?	NSD Article 8d GSR Part 7 § 1.5 SSR-3 § 7.90
14.1. What are the national requirements on the emergency preparedness for RRs (e.g., organization, staff, procedures, facilities and equipment, trainings and drills, etc.)?	SSR-3 § Req's. 55 & 81 (with subordinate req's)
14.2. Are emergency response procedures required to be in place, and are these required validated during training and drills?	SSR-3 § Req's. 81 (with subordinate req's)
14.3. Does the regulatory authority participate in the nuclear emergency drills?	SSR-3 § Req's. 81 (with subordinate req's)
14.4. Which other external organizations and local authorities participate in these drills?	SSR-3 § Req's. 81 (with subordinate req's)
15. Are there national requirements in place for RR on preventing accidents with early radioactive releases that could not be handled by off-site emergency measures in due time or in limited area?	NSD Article 8a SSR-3 § 2.2, 2.6, 6.1, 6.13
15.1. Are requirements from previous question applicable to old and new RRs in your country?	NSD Article 8a

ANNEX IV: THE QUESTIONNAIRE FOR THE OPERATORS

Safe, sustainable operation of research reactor facilities in the EU

Questionnaire to Member States for regulators about Research Reactors safety

Country:

Organisation:	
Reactor name:	
Reactor power:	
Start of operation:	

1. Legal and Regulatory Framework

Questions for operators	**Basis**
1. Which legally binding safety requirements you have to follow in different stages of lifecycle of your Research Reactor (RR)? Please provide the reference to existing laws/regulation.	NSD Article 4 GSR Part 1 § Req. 2
1.1. Intentionally blank – This question is for regulators only	NSD Article 5 GSR Part 1 § Req. 3 & 18 SSR-3 § 3.10
1.2. What kind of licenses did your facility obtain in order to get operating licence and to operate, and how often it needs to be renewed?	NSD Article 4 GSR Part 1 § Req. 4 SSR-3 § 3.1 – 3.5
1.3. Intentionally blank – This question is for regulators only	NSD Article 5 GSR Part 1 § Req. 4
1.4. Does the regulatory authority perform inspections at your RR to verify the compliance with safety requirements?	NSD Article 4 GSR Part 1 § Req. 2 & 27 SSR-3 § 3.13 – 3.16
1.5. How many inspections do you receive per year by the regulatory authority and/or other authorised authorities?	NSD Article 4 GSR Part 1 § Req. 2 & 27 SSR-3 § 3.13 – 3.16

2. Responsibilities and Conditions for Nuclear Safety

Questions for operators	Basis
2. Is your organisation (i.e., the manager as responsible individual) the only one responsible for safety of your RR (even in the case, that you rely on subcontractors for certain activities)?	NSD Article 6 GSR Part 1 § Req. 5&6 SSR-3 § Req. 2 & 67 (with subordinate req's)
2.1. Does your organisation have safety policy in place, which gives safety an overriding priority in all RR activities and requires continuous improvement of nuclear safety? If yes, please attach a copy of it to the questionnaire.	WENRA Issue A SSR-3 § 4.1, Req.3 (with subordinate req's)
2.2. What is the process of independent review of issues relevant to safety (e.g., modifications) at your RR, i.e., by your staff, that were not involved at original review and/or decision making or by external staff/bodies? If latter, how do you select those?	WENRA Issue B2 SSR-3 § Req. 5 & 6 + 4.27
2.3. Does your organisation have an independent safety advisory committee encompassing external experts?	SSR-3 Req. 6
3. Does your organisation have an Integrated Management System (IMS) in place?	WENRA C3.1 SSR-3 Req. 4 (with subordinate req's)
3.1. Does your organisation have any certification of your IMS? If yes, against which standard?	SSR-3 Req. 4 (with subordinate req's)
3.2. What is your IMS based on (which standard)? What are the processes your IMS covers?	WENRA C SSR-3 Req. 4 (with subordinate req's)
3.3. Does your organisation have a procedure describing how to manage documentation, including records?	WENRA C 3.12 GSR Part 2 Req. 8 (with subordinate req's)
4. How does your organisation recruit, train and retrain your personnel?	NSD Article 8b.2 SSR-3 § Req. 69 & 70 (with subordinate req's)
4.1. What kind of qualifications and authorizations your staff members that carry out tasks important to safety are required to possess (knowledge, skills, safety attitude, etc.)?	WENRA Issue D2.1, D4.1 7.14, 7.15, 7.16, 7.21, 7.23, Req. 70, 7.28 – 7.31

Questions for operators	Basis
4.2. Does your organisation systematically, regularly analyse the number of staff needed for safe operation, and their competence?	WENRA B3.1&3.2 SSR-3 § 7.14, 7.30 & 7.31
5. Does your organisation have sufficient financial and human resources for fulfilment of your nuclear safety obligations?	NSD Article 6 GSR Part 1 § 4.3(f) SSR-3 § 4.15
6. Does your organisation collect, screen, analyse, trend, document operating experience also at similar facilities in a systematic way?	NSD Article 8b.2
6.1. How many such events were recorded during last 12, 48 months?	SSR-3 § Req. 88 (with subordinate req's) SSG-50
6.2. Is your organisation reporting about safety significant events to your regulatory body?	NSD Article 8b.2 SSR-3 § 7.126
6.3. How frequently you have done so in last 10 years?	SSG-50 § 3.11 – 3.14
6.4. What were the most significant events reported and what were lessons learned from them?	NSD Article 8b.2 SSR-3 § 7.126, 7.127, 7.128

3. Safety Analyses

Questions for operators	Basis
7. Did your organisation perform thorough safety analyses of your RR when you applied for different licenses, and periodically, especially in a case of major modifications or other changes from previously licenced status?	NSD Article 6 GSR Part 1 § Req. 24 (with subordinate req's) SSR-3 § Req. 5
7.1. Does your RR have an up-to-date Safety Analysis Report (SAR)? If yes, to which standard/requirements is it developed? How often is it updated/reviewed? When was it last time updated? What were the main reasons for the update?	WENRA N1.1 SSR-3, Req. 1 (with subordinate req's)
7.2. Is the SAR for your RR developed to address a list of Postulated Initiating Events (PIE) that covers all events that could affect the safety of your reactor?	WENRA E4.1 and E4.2 SSR-3 § Req. 18 (with subordinate req's)

Questions for operators	Basis
7.3. Has the seismic impact been analysed as a part of the safety justification of your RR?	WENRA T4.2 SSR-3 § Req. 19 + para 6.52 – 6.57
7.4. Does your organisation have a process in place ensuring all modifications, including experimental devices and experiments meet relevant safety requirements?	WENRA Q & X SSR-3 § Req. 83 (with subordinate req's)
7.5. How many temporary modifications including specific experimental set-ups, are typically in place at your RR and for how long?	WENRA Q5.3 SSR-3 § 7.104
7.6. What kind of investigations and assessments your organisation performs before making decisions on safety matters?	WENRA B2 GSR Part 2 § 4.9(d), 4.14
7.7. Did you perform the fire safety or hazard analysis for your RR? What measures are in place to prevent and limit the consequences of fires that may challenge safety at your RR?	WENRA S1.1. SSR-3 § 6.48 – 6.51, Req. 79 (with subordinate req's)
8. When was the last time your organisation has performed the safety self-assessment of your RR? When (and which) was the last international peer review mission you hosted?	NSD Article 8e GSR Part 1 § Req. 14 & para 3.2
8.1. What were the main improvements as a result of the last review mission (e.g., INSARR)?	NSD Article 8e GSR Part 1 § Req. 14 & para 3.2
9. As per international recommendations, "Graded approach" reflecting possible risks should apply to RRs. How are the following requirements implemented in your RR:	NSD Articles 6, 8b WENRA Issues E, G, K IAEA SSR-3
9.1. What are design basis accidents (DBA) for your RR? Were all of those analysed in your safety assessments?	SSR-3 § Req. 20 & 41 (with subordinate req's)
9.2. What are design extension conditions that apply to your RR? Were all of those analysed in your safety assessments?	SSR-3 § Req. 22 (with subordinate req's)
9.3. Which external hazards (natural, man-made) are analysed for your RR and what are the provisions in place to protect against these?	SSR-3 § 5.6, 5.9, Req. 18 (with subordinate req's)

Questions for operators	Basis
9.4. Are structures, systems and components (SSCs) important for safety in your RR classified into safety classes?	SSR-3 § Req. 16 (with subordinate req’s)
9.5. Which features are in place at your RR to prevent, detect and control abnormal operation and failures, design basis accidents and severe accidents?	SSR-3 § Req. 23, 45, 46, 48, 49 & 50 (with subordinate req’s)
9.6. Is the single failure criterion used in the safety analysis of your RR and are common cause failures (CCF) considered as well?	SSR-3 § Req. 25&26 (with subordinate req’s)
9.7. Are SSCs of your RR important to safety designed to take into account redundancy, diversity, and independence and for defence in depth?	SSR-3 § Req. 17, 27 & 43 (with subordinate req’s)
9.8. Compliance with operational limits and conditions (OLCs)?	WENRA H2.2, H2.3 SSR-3 § 7.20, Req. 71 (with subordinate req’s)
9.9. Are OLCs updated regularly to incorporate any RR changes and operating experience?	WENRA H2.2, H2.3 SSR-3 § 7.20, Req. 71 (with subordinate req’s)
9.10. Are modifications of OLCs adequately justified by safety analysis and independent safety review?	WENRA H2.2, H2.3 SSR-3 § 7.20, Req. 71 (with subordinate req’s)
9.11. Does your organisation have programmes in place, which establish the requirements for maintenance, testing, surveillance, and inspection of SSCs important to safety (including in-service inspection) to ensure that their availability, reliability, and functionality remain in accordance with the design?	WENRA K1.1, K2.2, K2.4, K3.2 SSR-3 § Req’s 31, 74 & 77 (with subordinate req’s) + 7.38, 7.39
9.12. Are procedures for conducting these activities established, reviewed, and validated?	WENRA K1.1, K2.2, K2.4, K3.2 SSR-3 § Req’s 31, 74 & 77 (with subordinate req’s) + 7.38, 7.39

Questions for operators	Basis

4. Periodic Safety Review and Other Reviews

Questions for operators	Basis
10. When were the last and previous Periodic Safety Reviews (PSR) of your RR performed?	NSD Article 8c SSR-3 § 4.25, 7.121, 7.122
10.1. How did you define the scope and the methodology for your last PSR?	IAEA Safety Reports Series No. 99
10.2. Which safety factors did you address during the last PSR?	IAEA Safety Reports Series No. 99
10.3. Did you check the basic justification principle during the last PSR, ie. that the further operation of the reactor outweighs the associated risks?	IAEA Safety Reports Series No. 99, 3.6(g)
11. Were there any other safety reviews (stress tests, topical peer reviews, INSARRs etc.) required and/or performed at your RRs?	NSD 8e
12. What were the key improvements (improvements that had the most benefit for the safety of the RR) that were decided on the basis of the outcome of the last PSR or other safety reviews?	IAEA Safety Reports Series No. 99 SSR-3 § 7.121, 7.122

5. Ageing Management

Questions for operators	Basis
13. Does your organisation have an Ageing management Programme (AMP) in place, to ensure safety functions through the entire life time of the RR, as well as address technological obsolescence?	WENRA I1 SSR-3 § Req. 86, 7.120 SSG-10 § 1.2
13.1. How often is your AMP reviewed, updated and is AMP independently reviewed?	WENRA I1 SSG-10 § 2.18 & 4.20
13.2. What are origins of inputs for AMP updates?	WENRA I1 SSG-10 § 2.18 & 4.20

Questions for operators	Basis
13.2.1. Independent assessment of AMP by the safety committee (Y/N)	
13.2.2. Non-conformances and implementation of corrective actions (Y/N)	
13.2.3. Audits to determine the adequacy and effectiveness of AMP (Y/N)	
13.2.4. Other (please describe)	
13.3. Which type of SSCs important to safety are included in the AMP for the RR, and which (and with which justification) are not? If possible, provide some examples of SSCs in each category.	SSG-10 § 2.2
13.3.1. concrete structures (Y/N)	
13.3.2. mechanical components and equipment (Y/N)	
13.3.3. electrical equipment (Y/N)	
13.3.4. instrumentation equipment (Y/N)	
13.3.5. control equipment (Y/N)	
13.3.6. cables (Y/N)	
13.3.7. Others: (please describe)	
13.4. In a case your RR would be in an extended shutdown, how does the AMP address eventual degradations and/or stressors during that period?	SSG-10 § 4.1
13.5. How long do you intend to operate your RR? Please inform us about the foreseen shut-down date.	
13.6. What is your usual regime of operation, ie. what percentage of time your reactor operates at power? How does the operation regime influence safety factor, for example how does it influence the embrittlement of structures?	
13.7. Do you experience problems related to the obsolescence of design, material replacement like-for-like or challenges with upgrades?	
13.8. Did you ever have to adjust operation of your reactor because its old design could not fulfil modern safety requirements?	

6. Emergency Preparedness

Questions for operators	Basis
14. Does your organisation have on-site and off-site emergency arrangements in place properly co-ordinated with competent authorities?	NSD Article 8d GSR Part 7 § 1.5 SSR-3 § 7.90
14.1. Do your emergency arrangements include provisions for organization, staff, procedures, facilities and equipment, trainings and drills, etc.?	SSR-3 § Req's. 55 & 81 (with subordinate req's)
14.2. Does your organisation perform periodic emergency drills based on these procedures? How often?	SSR-3 § Req's. 81 (with subordinate req's)
14.3. Intentionally blank – This question is for regulators only	
14.4. Are you inviting external organizations/ local authorities to participate or observe your emergency drills?	SSR-3 § Req's. 81 (with subordinate req's)
15. Is your RR designed to prevent accidents with radioactive releases, which would require off-site emergency measures? Have you been introducing safety improvements to prevent such radioactive releases	NSD Article 8a SSR-3 § 2.2, 2.6, 6.1, 6.13

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