OECD/NEA Working Group on Risk Assessment (WGRISK) – Overview of Recent PSA Activities

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Abstract: The overall aims of the OECD Nuclear Energy Agency (NEA) Working Group on Risk Assessment (WGRISK) are to advance the understanding of probabilistic safety assessment (PSA[1]) and to support the application of PSA results to ensure the safety of nuclear installations. WGRISK therefore carries out tasks to support the exchange of information among experts from the member countries and other organizations, to assess the state-of-the-art and share experience from ongoing efforts to address current technical challenges related to risk analysis methodology, insights, and the application of PSA results.

This paper presents an overview of recently completed activities and their main conclusions and findings. The Working Group has updated its periodic status report "Use and Development of PSA", which presents a survey of PSA-related developments in the countries participating in WGRISK. Other tasks addressed the "Safety Assessment of Nuclear Installations Regarding Combinations of External Hazards", "Dynamic PSA – Preparing for the Future", which examined the outlook and challenges for the application of Dynamic PSA in risk-informed decision-making (RIDM), and a "Level 3 PSA Modelling Benchmark". Work related to risk assessment for new and advanced reactors included "PSA for Reactors of Singular Designs" and "Treatment of Novel Aspects of Uncertainties in PSA." Additionally, the topics of three activities nearing completion and their progress are discussed; these activities deal with digital I&C modelling approaches, passive systems performance and reliability, and the treatment of uncertainties for novel aspects of PSAs.

1. INTRODUCTION

The recent activities of the WGRISK address topics that reflect a continuing focus on PSA in connection with the safety management of existing reactors and other nuclear facilities as well as emerging topics associated with new and advanced reactors. The updated "Use and Development of PSA" report [1] provides a comprehensive overview on the status of PSA in participating member and non-member countries as of 2024, see Section 2. The analysis of external hazards in PSA received renewed attention following the Fukushima Dai-ichi accidents. Combinations of external hazards with other external or internal hazards in PSAs were reviewed, extended, or added to the scope of the studies; while there is a strong experience base for single hazards, the analysis of hazard combinations (also called combined hazards) was and still is more limited. The progress, experience and gaps identified in connection with their analysis are subject of Section 3. The sustained interest in Dynamic PSA methodologies, a long-term object of research and development, led to an assessment of the outlook concerning its potential role in risk-informed decision-making (RIDM), see Section 4.

Turning to new reactors and advanced reactor technologies in the context of climate change and programs for new builds, the WGRISK addressed the application of PSA for the design and licensing of advanced/novel reactors in the "Symposium on PSAs for Reactors of Singular Designs" (Section 5). The specific issue of addressing uncertainties in connection with new designs and non-light water

[1] Note that PSA and PRA (*P*robabilistic *R*isk *A*ssessment) are used in this context interchangeably.

reactor technologies and accounting for these uncertainties in decision-making was the subject of a WGRISK task with an expert workshop, see Section 6. In addition to the use of Level 3 PSA (addressing offsite health and environmental impacts) for emergency planning, the design and licensing of new and advanced reactors may increasingly incorporate Level 3 PSA results. A benchmark of consequence modelling codes for Level 3 PSA is presented in Section 7. Finally, three further WGRISK activities close to completion are outlined in Section 8.

2. STATUS OF PSA IN PARTICIPATING WGRISK COUNTRIES

During the annual meetings of the WGRISK, the participants highlight recent developments related to PSA in their organizations and countries over the past year in a “round table” exchange of information. The scope of the highlights ranges from new and updated PSA studies, development of analytical methods and data, to results and applications of PSA for safety management and RIDM. Approximately every five years, a report providing an overview of the status of PSA programs in WGRISK member countries is updated and published. The most recent overview of the status was completed in 2025 [1]. A separate contribution at this conference presents the topic of Safety Goals and Risk Metrics [2] based on the status report.

A consistent trend, observed also in previous versions of this status report, is the increasing role of PSA in all 22 responding countries. Notable is the use of PSA in the licensing of new reactor designs and power plants, where PSA is in some cases applied more explicitly and directly in the design of the reactor and safety systems and the development of the safety case. This contrasts with the established use of PSA to assess the risk of the as-built plant.

Secondly, the increased depth and breadth of the PSA scope can be seen. Following Fukushima, many countries and economies took actions to review and/or extend their safety assessments. Many PSAs were updated to better consider single as well as combined external hazards, and to address the risk from the entire nuclear site with multiple co-located radioactive sources (reactors as well as non-reactor installations). These PSA extensions have largely been completed by now, with corresponding evolutions in national as well as international (e.g. by the IAEA) regulatory requirements.

3. HAZARD IMPACT ASSESSMENT AND PSA FOR COMBINATIONS OF EXTERNAL HAZARDS

This topic was addressed jointly by the WGRISK and the Working Group on External Events (WGEV). The objectives of the task were

a) to collect information on regulatory practices and technical approaches applied in hazard assessment for combinations of external hazards and in assessing integrated hazard impacts, and identify key issues in these areas (WGEV),
b) to develop an overview of the state-of-the-art for the risk analysis of combinations of external hazards, with a view to identifying gaps (WGRISK),
c) to derive a common understanding for the two groups of experts, with their diverse backgrounds and methods.

In the first phase, the status and experience in the participating countries were examined through a survey covering technical areas, spanning from the regulatory framework to hazard identification through risk quantification. Fifteen sets of country responses were analyzed in detail, including multiple responses from most participating countries. The findings of the survey are published in [3]; overviews and conclusions correspond to the following eight areas: (1) regulatory framework and environment, (2) terminology, (3) hazard identification and screening, (4) hazard assessment, (5) plant response and fragility analysis, (6) modelling of accident sequences induced by combinations of external hazards, (7) risk quantification, and (8) ongoing developments and studies. The survey findings were used to select key issues and methodological gaps to be addressed in the second phase in a workshop hosted by the IRSN (*I*nstitut de *R*adioprotection et de *S*ûreté *N*ucléaire – ASNR (*A*utorité de *S*ûreté *N*ucléaire et de

*R*adioprotection) today) in France in September 2023. In the following, selected conclusions from the final task report / proceedings of the workshop [4] are discussed.

Regarding the PSA scope, accident sequences induced by combinations of external hazards had been modelled in PSA in several countries. For this purpose, no new, specific modelling methods were required although managing the number of additional sequences was sometimes an issue. A combination of generic (event) trees for hazards on the one hand and the identification of bounding sequences on the other hand, a conservative approach used for other types of PSA accident sequences could be applied to limit the number of sequences that need to be treated in detail.

Turning to risk quantification, the methods and formalisms used in contemporary external hazards PSA are generally applicable. However, there appears to be a need for upgrading the method of convoluting hazard and fragility functions to the multivariate cases arising from combinations of external hazards. An unresolved issue is the aggregation of risk from correlated hazards and the risk from single hazards that are included in a combined hazard. The overview of ongoing developments in the survey [3] provided an indication of further specific challenges.

4. DYNAMIC PSA – PREPARING FOR THE FUTURE

This activity was focused on assessing the potential role of currently available and emerging dynamic PSA tools and methodologies for RIDM. While a common and updated understanding of the state of dynamic PSA tools and application experience forms an important element for assessing this potential role, a key objective was to identify practical challenges for the use of dynamic PSA in RIDM as well as the outlook and potential path forward to overcoming these challenges. The challenges go beyond computational requirements and complexity; they include not only technical but also organizational hurdles. A survey was carried out to characterize the status quo and the extent of experience with dynamic PSA studies and their application. On this basis, the WGRISK organized a workshop "Dynamic Probabilistic Safety Assessment and its Role in Risk-Informed Decision Making" in November 2023, hosted by the U.S. Nuclear Regulatory Commission (NRC). The final report of the task [5] was completed in 2025.

Concerning the technical state-of-the-art, at least eight methodologies / software tools are available that have been demonstrated and applied with published case studies. Those studies related to reactor risks address core damage as well as plant/containment response to core damage (i.e. Level 1, Level 2 PSA). They provide differentiated findings or new insights that might not be as evident in a conventional (static) PSA due to the limitations of how dynamics are modelled in them, notably on PSA success criteria, the relative contributions to risk, the role of human actions and emergency procedures, and safety-related scenario outcomes (e.g. hydrogen generation). Some outstanding technical challenges include the derivation of safety-related insights, the identification of important risk contributors, and the estimation of importance and sensitivity. These challenges stem in part from the large amount of data generated by the dynamic PSA model, i.e. the coupled logical (failure) and physical simulation models and the absence of PSA outputs such as minimal cut sets.

With respect to RIDM, potential PSA submitters (parties that would make a safety argument relying on a dynamic PSA) and reviewers identify the uncertainty regarding the resources, criteria, and duration for an acceptance and review process as significant hurdles. As a result of this task, the WGRISK is initiating an activity to organize a Dynamic PSA benchmark exercise focused on the post-processing phase as well as preparing a high-level 'Topical Opinion Paper' on the status of Dynamic PSA with an outlook. A longer-term recommendation is the organization of a pilot case for the review/acceptance process for a risk-informed decision based on Dynamic PSA.

5. PSA FOR NEW AND ADVANCED REACTORS (SINGULAR DESIGNS)

Many WGRISK activities focus on the application of PSA for safety management and RIDM for existing reactors. New and advanced reactor technologies are increasingly being considered for future nuclear power plants in the member countries, with diverse technology test and demonstration projects underway and, in some cases, first-of-a-kind (FOAK) projects. Accordingly, the exchange of information and experience on the application of probabilistic risk assessment for novel designs and non-light water reactor technologies is a newer focus area for WGRISK activities.

For most existing commercially operated reactors and evolutionary designs based on these, carrying out, reviewing, and applying PSA for RIDM benefits from a broad-based international body of experience that is codified in diverse standards. For newer and novel designs, including but not limited to advanced reactors, there are significant challenges. In June 2022, the OECD NEA WGRISK held a symposium on “PSA for Reactors of Singular Designs” in collaboration the International Atomic Energy Agency (IAEA) and hosted by the United Kingdom Office of Nuclear Regulation (ONR). PSA analysts, practitioners, and reviewers from reactor designers, vendors, technical safety organizations (TSOs), owners/operators, and regulators from 28 organizations participated in the symposium the scope of which included research, demonstration/prototype and FOAK reactors, small modular reactors (SMRs) and Generation IV reactors. In the following, some of the main findings presented in the summary/proceedings of the symposium [6] are provided.

- There is a consensus among the participants that developing PSA for reactors and facilities of singular design allowed for significant benefits to be realized through risk-informing decisions related to their design, operation, and safety management.
- While PSA is used to confirm or verify the compliance of a design against risk targets, there is also significant benefit in risk-informing the design process, developing the PSA in an iterative way alongside the design and using the PSA as an input in the design process.
- Current PSA methodologies remain generally applicable and there are resources and sources of guidance to support the development of PSAs (these are identified in the symposium summary/proceedings).
- Key technical challenges include the selection / definition of risk metrics, which in some cases may require Level 3 PSA. It is expected that initiating event identification and quantification is likely to be more resource intensive while attention to the development of data for novel structures, systems and components (SSC) or where SSC are deployed into new environments. The same applies to the qualification and validation of codes (e.g., for thermal hydraulics, severe accidents). Finally, if digital or remote-control rooms are used or if long time windows are claimed, the applicability and adequacy of current human reliability analysis (HRA) methods may need to be re-assessed.
- An ongoing area of research is the assessment and modelling of passive systems reliability in PSA, including the identification and evaluation of failure modes. To this end, the WGRISK and the Working Group on Analysis and Management of Accidents (WGAMA) jointly organized a workshop in March 2026 (see Section 8).

While these findings are the outcome of focusing on the challenges for PSAs for reactors of singular designs, many apply to conducting PSAs in general as well.

6. TREATMENT OF UNCERTAINTIES FOR NOVEL ASPECTS OF RISK ANALYSES

The main objectives of the WGRISK activity “Treatment of Uncertainties for Novel Aspects of Risk Analyses “ initiated by the WGRISK in 2022, were to assess the treatment of uncertainties in PSAs for new and advanced reactor technologies as well as for novel aspects of risk analysis and to identify decision-making cases where uncertainty analysis methods provided additional insights or their shortcomings posed challenges. Completeness, modelling, parametric uncertainties and all PSA scopes (PSA levels, plant operational states (POSs), etc.), the associated nuclear safety issues, and diverse risk-informed, and often also performance-based decisions made by stakeholders were considered within the scope. Following a WGRISK member survey and a resulting WGRISK Technical Note, WGRISK organized a workshop hosted by the Consejo de Seguridad Nuclear (the Spanish regulatory body CSN) in 2025. The overall task report including the workshop summary was completed and endorsed by the CSNI in 2025 [7].

In addition to the PSA challenges identified in the Symposium summary/proceedings [6] (namely limited data, limited operational experience, and passive safety systems reliability, as discussed in the preceding Section 5), the treatment of uncertainties across the interfaces between the different PSA levels and their cumulation was highlighted as a continuing challenge. The increased role of Level 2 PSA (plant releases and source terms) and Level 3 (health and environmental impacts) in decision-making accentuates the need to better address this challenge.

Overall, the workshop participants agreed on the need to develop consistent approaches for treating uncertainties and for integrating uncertainty insights into the decision-making process. Guidance appears to be needed at two levels: (1) overall for the use or integration of uncertainty insights into decision-making as well as (2) application-specific guidance and methods.

7. BENCHMARK OF CONSEQUENCE CODES FOR LEVEL 3 PSA

Level 3 PSA addresses the offsite health and environmental impacts, building on: (i) Level 1 PSA (core/fuel damage state frequencies), and (ii) Level 2 PSA (accident progression, containment performance, and release characterization), by translating source terms into radiological consequences such as dose and other radiological risk metrics. The number of organizations developing and applying Level 3 PSA is increasing; in many countries, it is needed to demonstrate compliance with regulatory radiological risk criteria. Experience in OECD NEA member countries has indicated that important modelling issues and technical challenges remain; many of them are driven by atmospheric transport and dispersion, and radiological consequence assessment modelling and codes and their underlying assumptions.

WGRISK organized a benchmark to compare Level 3 PSA consequence modelling codes as well as to examine the impact of the modelling approaches. The benchmark, started in late 2023, was recently completed and the task report [8] endorsed by the CSNI in June 2026, which also in part updates and extends an older report on the status of Level 3 PSA in countries producing nuclear energy [9]. Six organizations from five countries formed a benchmark group, each using a different consequence code for Level 3 PSA. In light of the focus on the models and modelling approaches, the chosen benchmark calculation case is generic, with the following main characteristics:

- Generic, fictional radiological release (simple stack release, flat terrain);
- Source term: Xe-133 (gas), I-131 (aerosol), Cs-137 (aerosol), 1-hour release;
- 12 meteorological cases (Pasquill stability class A–F, with/without rain);
- 14 logarithmically spaced distances along plume axis (183 m to 100 km).

The main findings for the three outcomes of interest – atmospheric dispersion, dose assessment, and risk assessment – are briefly highlighted in the following. For atmospheric dispersion, the benchmark showed a strong alignment (agreement) under unstable meteorological conditions and greater divergence under stable conditions, where the results were sensitive to model-specific parametrizations. The model choice was impactful for the overall outcomes. Turning to dose assessment, the two main dose pathways show a strong commonality across the models. Long-term ground shine differs due to time-dependent environmental treatments and ingestion dose notoriously hard to evaluate due to the complexity of the models. Since the risk outcomes integrate differences over dispersion, dose and risk models, the results span larger ranges. These ranges are driven by national (modelling team) and model-specific risk factors. Overall, the ingestion dose shows the largest spread due to food-chain model assumptions. The user effect (interpretation/parametrization) significantly influences the outcomes. To address these, iterative clarification drove three calculation rounds, reducing variability, such that the user effect could be reduced. One area for future work could be follow-up benchmarks on the high-variability endpoints.

8. OUTLOOK

Three WGRISK activities, partly conducted jointly with other OECD NEA Working Groups or the Joint Database Projects, are nearing completion, addressing the topics of Digital I&C (DI&C) modelling in PSA, passive systems and safety and the application of operating experience collected in the OECD NEA Database Projects ICDE, FIRE and CODAP in the frame of PSA.

- WGRISK task "*DIGMORE – A Realistic Comparative Application of DI&C Modelling Approaches for PSA*"
  To develop recommendations for the modelling of safety-related digital I&C (DI&C) systems in nuclear power plant PSAs, a benchmark application was initiated in late 2021. It is a follow-up to a previous WGRISK benchmark, aiming to increase the realism of the case. A reference case was first developed, followed by two modelling phases in 2024 and 2025, respectively. The reference case is based on a simplified boiling water reactor plant, considering a primary reactor protection system (RPS), a diverse (alternate) RPS, an operational I&C system, a hard-wired backup system, and prioritization and actuation control (PAC) systems. The PSA model specifically addressed a loss of main feedwater initiating event. Five organizations participated in the benchmark. This activity is in its final reporting phase; endorsement by the CSNI is expected by end-2026.
- Joint WGAMA and WGRISK Task "*Passive Systems Performance and Reliability – Deterministic and Probabilistic Safety Cases and the Experimental Basis*"
  Passive systems are central to the safety design of many SMRs and advanced reactors, but harmonized assessment and crediting approaches are still lacking. To obtain a multi-discipline overview from the perspectives of experimentalists, practitioners and experts in deterministic safety analysis and PSA, the WGRISK, WGAMA and the project "Ensuring Assessment of Safety Innovation for SMR" (EASI-SMR) co-funded by the European Union (EU) jointly organized the international "Passive Systems Performance and Reliability Workshop Safety Performance and Reliability" in Paris in late March 2026. A clear shift of focus from design feasibility to evidence-based reliability demonstration has been observed. Experiments, verification and validation of codes, and failure mode modelling are seen as essential for regulatory confidence, although data gaps particularly remain with novel passive systems and the performance of passive systems in long-mission scenarios. Finally, a strong need for a shared international roadmap linking experiment, modelling, and licensing has been expressed. The workshop proceedings are in preparation.
- Joint task "*Expert Workshop on Applicability and Applications of Operating Experience from the OECD/NEA Database Projects to Probabilistic Risk Assessment (PSA)*" of the WGRISK and the OECD NEA Database Projects
  Operating experience relevant in the frame of PSA is collected in various established OECD NEA Database projects (e.g., ICDE (*I*nternational *C*ommon Cause Failure *D*ata *E*xchange) on common-cause component failures, FIRE (*F*ire Incidents *R*ecords *E*xchange) on fire events in nuclear reactors, and CODAP (*C*omponent *O*perational Experience, *D*egradation, and *A*geing *P*rogramme). Within this task initiated in late 2024, the WGRISK and the Database Projects jointly organized an expert workshop of WGRISK and Database Project member organizations on applicability and applications of Database Project Products to PSA so far, hosted by GRS in Garching, Germany in May 2026. The workshop addressed more recent applications of data from the three databases in member institutions, the applicability of generic data derived from the databases for nuclear plants conducting PSA, and the challenges in the collection and recording of suitable data in a consistent and quality assured manner for use within PSA in WGRISK member countries. The corresponding task report is in preparation and expected to be published in 2027.

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