Nuclear Reactor Regulation

June 12, 2026

LDR-50 Joint Early Review Closure Report

Executive Summary

Steady Energy Oy (SE) requested the Radiation and Nuclear Safety Authority of Finland (STUK) to coordinate a Joint Early Review (JER) of the LDR-50 reactor concept, involving multiple national nuclear regulatory authorities. The request followed STUK's earlier safety assessment of the LDR-50 conceptual design. The JER was performed under the Terms of Reference (ToR) confirmed at the Kick-off Meeting on 15 October 2025. The ToR defined that the JER is a voluntary, non-binding activity and that it does not aim to produce a common regulatory position or binding decisions for any participant.

In addition to early regulatory feedback on the conceptual design, a central purpose of the JER was to gain practical experience on how a safety assessment performed by one regulator can be leveraged by other regulators as supporting reference material, while preserving national independence. This objective is aligned with the intent of the IAEA's Nuclear Harmonization and Standardization Initiative (NHSI), while the JER itself is not formally a part of NHSI.

The JER was based on three vendor documents provided by SE: the General Plant Description, the Safety Concept and the Operation Concept. These documents were selected based on the vendor's preferences and the availability of corresponding content in the STUK Safety Assessment. The participating authorities conducted their reviews independently against their respective national regulatory frameworks. Differences in scope existed, as participants were instructed to determine their own level of involvement in the review taking into account national priorities and available resources: the Ukrainian and Czech assessments covered all JER topics, the Swedish assessment focused on selected issues within the topics, and the Polish assessment excluded design provisions for operation and emergency preparedness.

The JER was based on documentation issued in early 2025 and therefore reflects the design status at that time. Since then, the design has progressed across several of the areas covered by this review. Pre-licensing activities with STUK have also continued with several individual topics.

The overall outcome across the national assessments was consistent. The LDR-50 documentation was generally considered appropriate for an early conceptual design stage, but not sufficient for licensing-grade conclusions. Common strengths identified across topics included an explicit safety philosophy structured around defence-in-depth, extensive use of inherent and passive features, and design choices intended to reduce reliance on rapid operator action in early accident phases. No participating authority identified fundamental obstacles, i.e. outcomes of such significance that they would preclude a continued development of the concept at the conceptual stage.

At the same time, all authorities emphasised that significant additional work is required to progress from concept-level intent to a licensing-grade safety case. Recurring needs included completion and justification of the initiating event and hazard basis (including combinations and multi-unit effects), definition of representative and bounding scenarios with explicit assumptions, and a more traceable link between requirements, assumptions, analyses and acceptance criteria. Multi-unit / multi-module aspects and shared infrastructure were repeatedly identified as plant-level issues requiring explicit demonstration of independence, management of common-cause vulnerabilities and consistency of operational and emergency arrangements in later stages. Several National Findings Reports also highlighted that concept-level targets and principles must be supported by quantified analyses and plant- and site-specific demonstrations in subsequent licensing phases.

The experience from leveraging the STUK review was generally positive as a means to support topic scoping and early identification of areas requiring deeper evidence. The JER also confirmed that comprehensive regulatory comparison and divergence assessment are resource-intensive and benefit from early planning, clear reporting templates and improved traceability from assessment statements to the regulatory basis and reviewed documentation.

This Closure Report summarises the recurring themes identified across the national assessments by technical topic area. It does not form a common position and does not replace the annexed National Findings Reports, which remain the primary references for detailed country-specific findings and traceability. The National Findings Reports may contain protected information and are therefore not made publicly available.

Contents

List of abbreviations and definitions

ALARA — As Low As Reasonably Achievable

AOO — Anticipated Operational Occurrence(s)

CCF — Common Cause Failure

CDF — Core Damage Frequency

CRS — Control Rod System

DBA — Design Basis Accident(s)

DBC — Design Basis Condition(s)

DEC — Design Extension Condition(s)

ECP — Emergency Control Post

EPZ — Emergency Planning Zone

EPRI — Electric Power Research Institute

HFE — Human Factors Engineering

HMI — Human–Machine Interface

IAEA — International Atomic Energy Agency

JER — Joint Early Review

LBLOCA — Large Break Loss of Coolant Accident

LOCA — Loss of Coolant Accident

LRF — Large Release Frequency

LDR-50 — LDR-50 reactor concept/design

MCR — Main Control Room

NHSI — Nuclear Harmonization and Standardization Initiative

PAA — National Atomic Energy Agency of Poland

PAZ — Precautionary Action Zone

PSA — Probabilistic Safety Assessment

Q/A — Questions-and-Answers

SE — Steady Energy Oy

SMR — Small Modular Reactor

SNRIU — State Nuclear Regulatory Inspectorate of Ukraine

SSM — Swedish Radiation Safety Authority

SSTC NRS — State Scientific and Technical Center for Nuclear and Radiation Safety

STUK — Radiation and Nuclear Safety Authority of Finland

SÚJB — State Office for Nuclear Safety of the Czech Republic

SÚRO — National Radiation Protection Institute of the Czech Republic

TECDOC — IAEA Technical Document

ToR — Terms of Reference

1. Background to the Joint Early Review

The Joint Early Review (JER) of the LDR-50 small modular reactor concept was initiated following the completion of the Safety Assessment of the LDR-50 Conceptual Design conducted by the Radiation and Nuclear Safety Authority of Finland (STUK). After receiving this assessment, the vendor Steady Energy Oy (SE) requested STUK to coordinate an international review effort involving several national nuclear regulatory authorities.

The review was carried out within the framework defined in the Terms of Reference (ToR), which were confirmed at the Kick-off Meeting held on 15 October 2025. The ToR defined the scope of the review, participating organisations, reviewed documentation and working arrangements. In accordance with the ToR, the JER was not a licensing activity and did not produce binding regulatory decisions or commitments for any participating authority.

The JER was organised as a voluntary collaborative process in which each participating regulatory authority conducted its assessment independently in accordance with its own national regulatory framework. At the same time, the process provided a structured forum for information exchange and discussion through coordinated technical meetings. This allowed emerging observations and questions to be discussed collectively, while preserving the independence of national assessments.

Through this arrangement, the JER established a common basis for comparing and synthesising national findings within the agreed scope. The process also enabled early interaction between the vendor and participating regulatory authorities within a clearly defined, non-binding framework, providing context for the assessment results presented in this report.

1.1. Objectives and Outputs

The objective of the JER was to facilitate early, non-binding regulatory feedback on the LDR-50 conceptual design by supporting independent national assessments and structured information exchange, with the aim of identifying safety-relevant issues and clarifying regulatory expectations, including points of convergence and divergence between participating authorities, prior to later licensing stages. The JER was not intended to result in regulatory approval, licensing decisions or binding positions.

Another objective of the JER was to gain practical experience in leveraging a safety assessment performed by another regulatory authority. In particular, the process aimed to explore to what extent the STUK Safety Assessment could be used as supporting reference material by other authorities without compromising the independence of their national assessments, an approach aligned with the objectives of the IAEA's Nuclear Harmonization and Standardization Initiative (NHSI), although the JER itself was not formally part of the NHSI.

The JER produced several outputs intended to support experience sharing, traceability, and efficient synthesis:

- National Findings Reports - Each participating authority produced a National Findings Report summarising its independent observations and conclusions within its chosen scope. These reports constitute the authoritative record of country-specific findings. These findings may contain confidential information and are therefore not made publicly available.

- Closure Report - STUK, as the overall coordinator, produced the Closure Report to consolidate recurring themes across National Findings Reports by technical topic area. The National Findings Reports are provided as annexes to support traceability.

- Structured Q/A log - During the technical meetings, a structured question-and-answer log was maintained in an Excel format to capture clarification questions and responses. The Q/A log supported consistency in handling clarifications and supported the synthesis work by enabling efficient retrieval of previously discussed clarifications and their outcomes.

- Lessons learned on leveraging and collaborative review practice - As part of the JER, experience was collected on practical aspects of collaborative review work and leveraging, including observations on timing, reporting structures, traceability, and communication practices that supported the process. These lessons are summarised in chapter 5.

1.2. Participating Organisations

The Joint Early Review involved several national nuclear regulatory authorities and their associated technical support organisations. The national regulatory authorities participating in the review were the Swedish Radiation Safety Authority (SSM), the National Atomic Energy Agency of Poland (PAA), the State Office for Nuclear Safety of the Czech Republic (SÚJB), and the State Nuclear Regulatory Inspectorate of Ukraine (SNRIU). A national coordinator was appointed by each authority to manage participation in the Joint Early Review, coordinate expert input, and prepare a National Findings Report. STUK acted as the overall coordinator of the process and was responsible for the synthesis of the national findings into the Closure Report.

In addition, the Technical Support Organisation of SNRIU, the State Scientific and Technical Center for Nuclear and Radiation Safety (SSTC NRS), and the Technical Support Organisation of SÚJB, the National Radiation Protection Institute of the Czech Republic (SÚRO), participated in the review activities in support of their respective national regulators.

Steady Energy, as the vendor, participated in the process by providing the documentation subject to review and by contributing technical expertise during the Joint Early Review meetings.

1.3. Reviewed Documentation

The Joint Early Review was based on three conceptual design documents provided by Steady Energy: the General Plant Description, the Safety Concept, and the Operation Concept. In addition, the previously completed STUK Safety Assessment of the LDR-50 Conceptual Design was used as supporting reference material to help structure the review and focus attention on safety-relevant issues. All the above mentioned documentation was provided to participants by SE according to the agreements between SE and each participating regulatory authority outside Finland. Furthermore, information provided in the structured Q/A log, which was prepared during the JER, was also taken into account.

The use of the STUK Safety Assessment as reference material did not harmonise regulatory interpretations or predetermine conclusions. Each authority applied its own legislation, regulatory guidance and safety objectives when forming its findings and identifying issues requiring further consideration.

2. Scope of the Joint Early Review.

The scope of the Joint Early Review differed between the participating regulatory authorities, as participants were instructed to determine their own level of involvement in the review taking into account national priorities and available resources. All participants based their assessments on the General Plant Description, Safety Concept, Operation Concept and the structured Q/A log. The STUK safety assessment was also leveraged as supporting reference material.

As agreed in the ToR, the topics covered in the JER were:

- Design bases: Safety objectives, design criteria, conditions, events and hazards considered,
- How safety functions are provided for and how the principle of Defence-in-Depth is implemented,
- Application of safety principles (redundancy, separation, diversity),
- Top level layout and separation, principles of protection against internal and external hazards,
- Design provisions for operation,
- Design provisions for emergency preparedness.

The Ukrainian and Czech assessments covered all above-mentioned topics. The primary objective for the Swedish side was to gather regulatory experience on collaborative reviews. Their assessment therefore neither aimed to be exhaustive nor address all aspects within the topics, i.e. it focused on aspects that felt within the participants’ availability as well as field of expertise. The Polish assessment focused on plant-level design basis, safety objectives, safety functions and safety principles, defence-in-depth and top-level layout and separation, while design provisions for operation and emergency preparedness were excluded. These differences in scope reflect national priorities and available resources and were consistent with the voluntary and non-binding nature of the JER.

3. Review outcomes

This chapter presents a summary of the findings made in the JER, based on the independent national assessments performed by the participating regulatory authorities within the defined scope. The chapter is structured by technical topic areas.

The summaries in this chapter are intended to capture the main observations raised across the National Findings Reports in a consolidated form. It does not represent a common or joint regulatory position, and it does not create any binding conclusions for any participating authority, as was agreed in the ToR.

The detailed bases, national regulatory references, and full sets of findings remain in the National Findings Reports, which are provided as annexes to this Closure Report and should be consulted for country-specific context.

3.1. Plant-Level Design Basis, Hazards and Initiating Events

This section summarises the findings of the Joint Early Review related to the plant-level design basis, including the identification of hazards and initiating events considered in the LDR-50 conceptual design. The topic covers the general safety objectives, the treatment of internal and external hazards, and the approach used to define and justify initiating events at the conceptual stage. This topic was covered by all participants.

All participating authorities considered that the LDR-50 conceptual design addresses plant-level design basis, hazards and initiating events at a level broadly appropriate for an early design stage. Frequently noted themes included a safety philosophy structured around defence-in-depth and extensive reliance on inherent and passive features. The Ukrainian report also highlighted the integral reactor configuration, approach as eliminating Large Break LOCA scenarios.

At the same time, all authorities highlighted that the initiating-event and hazard basis remains incomplete and will require further development as the design matures. A recurring theme was the need for a clearer and more traceable scoping and screening basis for initiating events, including transparent motivations for excluding scenarios at concept stage. The Swedish assessment noted that the basis for excluding initiating events such as reactor pool leakages across plant operational states should be motivated in the scoping or screening process. The Czech assessment similarly noted that the documentation lists design basis events and hazards and links them to safety functions but lacks sufficiently clear representative scenarios with defined initial states, explicit failure assumptions and a clear sequence of system responses over time, it also noted that Design Extension Conditions are not comprehensively included in the event lists at this stage.

External hazards were consistently treated as an area where the concept documentation remains preliminary. While hazards were identified at a high level, the National Findings Reports noted that site-specific parameters and numerical values for loads and combinations are necessary for a licensing-grade demonstration, and several detailed requirements could not be assessed at this stage due to the general nature of the information provided. This is highlighted in the Czech and Polish assessments, which note that several external-event requirements are inherently site-specific and were therefore reviewed only partially at the conceptual stage, additional information will be needed later to support a comprehensive demonstration of compliance against detailed requirements on protection against internal and external hazards.

Plant-level interactions in a multi-unit / multi-module configuration were repeatedly highlighted as a key topic for later justification. The Swedish assessment emphasised that “multi-unit” and “multi-module” have different implications for separation and for how external hazards may affect the plant and noted that while LDR-50 is described as multi-unit it has characteristics of multi-modular design due to shared infrastructure, which will require clear justification. The Czech report emphasised that combinations of hazards and multi-unit impacts were acknowledged but not described in detail and that cross-unit effects should be assessed systematically for a multi-unit site. Poland noted that Steady Energy treats the Core Damage Frequency and Large Release Frequency limits as plant-level values covering all reactor units on the site. The PAA considered that this plant-level approach may require further justification to ensure that per-unit risks remain acceptable under Polish requirements.

Several authorities highlighted the need for explicit acceptance criteria and supporting safety demonstrations to substantiate plant-level design basis claims. Poland was explicit in that concept-level objectives (including ALARA and dose limitation) are design targets at this stage and that compliance must be demonstrated later through plant- and site-specific radiological analyses, bounding consequence assessments, and conservative deterministic analyses with explicitly defined initiating events, initial conditions and failure assumptions. Sweden likewise highlighted “must be demonstrated later” items, including CRS shutdown capability, and noted the referenced passive reliability assessment methodologies (IAEA-TECDOC-1752, EPRI 1016747) are under consideration by SSM.

Overall conclusion is that, at the current conceptual stage, the participating authorities did not identify any fundamental obstacles, i.e. outcomes of such significance that they would preclude a continued development of the concept at the conceptual stage related to plant-level design basis, hazards and initiating events. However, all authorities emphasised that significant additional technical justification, supporting analyses and more detailed documentation will be required in subsequent design and licensing stages.

3.2. Safety Functions and Safety Principles

This section summarises the findings related to how the LDR-50 conceptual design addresses the three fundamental safety functions (reactivity control, residual heat removal and confinement) and how Defence-in-Depth, redundancy, separation and diversification are applied at a conceptual level. This topic was covered by all participants.

All four nuclear safety authorities conclude that the LDR-50 conceptual design identifies and addresses the three fundamental safety functions — reactivity control, residual heat removal, and confinement of radioactive materials — and that the key safety principles of Defence-in-Depth, redundancy, separation and diversification are embedded in the safety approach.

The three fundamental safety functions are discussed below. Regarding the safety principles in general, the authorities made the following observations:

- Independence and separation must be considered both for one reactor and for the multi-module configuration.

- Since systems are used across defence in depth levels, evaluation of the redundancy is non-trivial and requires extensive justification.

- The sufficiency of diversification cannot yet be assessed due to limited design details. In particular, the absence of a clearly defined list of DEC A events and the treatment of DBC2/DBC3 events combined with potential CCF scenarios require further clarification. The same applies for separation, the actual assessment of sufficient separation would require more detailed design information.
- With respect to redundancy, the Czech legislation does not explicitly prescribe a specific N+X redundancy requirement. However, established regulatory practice typically assumes that active safety systems should be capable of fulfilling their safety function even with two divisions unavailable (N+2), reflecting the combination of the single failure criterion and the possibility of maintenance or testing during operation. The current design appears to rely primarily on an N+1 approach for certain safety functions. While this approach is not excluded, its acceptability would need to be supported by a comprehensive justification demonstrating that reliability targets, single failure criterion, and operational conditions are adequately addressed.
- Current Polish regulations require the fulfillment of the N+2 criterion (single failure combined with unavailability due to maintenance, repair or testing) for the safety systems necessary to reach and maintain a safe shutdown state of the nuclear facility. However, under new regulations, this applies only where operational limits and conditions allow such activities during normal operation when the element is needed for the postulated event.
- In the Polish regulatory framework, the classification of DEC and Severe Accidents is different from what is used in LDR-50 design. For licensing, the applicant needs to take this into account.

Control of reactivity

It was acknowledged that the design provides two independent and diverse systems for reactor shutdown. No contradictions with requirements were identified at this stage; however, additional information will be required in future stages to support a comprehensive demonstration of compliance with the requirements.

Residual heat removal

The authorities recognized several strengths in the design provisions. These were for example the utilization of passive systems, large water reservoirs compared to the reactor thermal power, diverse heat sinks (reactor pool, atmosphere) and several alternative heat transfer paths during normal operational states.

All the participants brought up the use of the same passive heat removal system in several Defence-in-Depth levels. It was not considered a fundamental obstacle, but its reliability must be shown with extreme confidence.

The use of the reactor pool as an ultimate heat sink was raised by some of the participating authorities. It is not a non-compliance with the requirements but a question needing further justification and demonstration due to its importance and considering also long-term behaviour.

Containment/confinement function (confinement of radioactive material)

The participating authorities identified some open questions regarding the concept of employing a containment vessel combined with a reactor hall for confinement.

Uncertainties remain especially regarding the isolation, leak-tightness, and leak-tightness testing of systems forming the containment boundary. The reactor building is assumed to function as a hermetically sealed space, while certain design features, such as non-testable penetrations, may compromise its intended confinement function. This may adversely affect the performance of safety systems, including filtered venting and hydrogen recombiners. Having several reactors in the reactor hall adds complexity. During the maintenance of one reactor, it may be necessary to open the reactor hall and thus weaken the confinement function for the operating reactors.

Some non-compliances were identified. They were not considered as fundamental obstacles as it may be possible to justify them. The deviations are discussed in the chapter “Overall conclusions on Structural Defence-in-Depth”.

Despite the concerns, all the participating authorities conclude that the proposed concept for confining radioactivity may be acceptable, but further conclusions are not possible based on the available information.

Overall conclusion is that the participating authorities did not identify any fundamental obstacles in the implementation of safety functions and the safety principles. However, at this design stage it was not possible to draw any further conclusions.

3.3. Structural Defence-in-Depth

This section summarises the findings related to structural Defence-in-Depth at a conceptual level, including the definition and intended roles of physical barriers, the overall confinement/containment concept, and the main areas where additional evidence and design detail are expected in later phases. This topic was covered by all participants.

All participating authorities agree that the LDR-50 conceptual design adopts a structural Defence-in-Depth approach, consistent with international nuclear safety principles. The structural Defence-in-Depth in LDR-50 has some non-traditional solutions (integral primary system, confinement function shared between containment and reactor hall, shared reactor hall among several reactors). While regulations in all four countries allow nonstandard barrier configurations, regulators stress that such solutions require sound justification and high level of evidence of their safety.

No participating authority has at this stage, within the assessed topic, identified any fundamental obstacles. Open question is especially the leak-tightness of the reactor building, the methods for its verification, or how leak-tightness will be maintained under all operating states of the individual reactors sharing the same space.

Some potential non-compliances with the national regulations were found. The absence of an independent severe accident primary circuit depressurization system does not align with Czech legislation. Furthermore, the necessity and functional role of filtered venting should be clearly justified. Regarding containment isolation, the use of a check valve as an isolation device is currently not considered a fully adequate in the Czech regulatory framework. In Poland, the deviations concern the arrangement of the containment isolations valves. The Polish legislation requires isolation valves to be located as close as possible to the containment wall penetration and an update of the legislation will probably require having isolation valves both inside and outside of the containment. However, these potential deviations were not seen as fundamental obstacles, as it may be possible to justify them. For Ukraine, definition of the physical barriers is of concern: LDR-50 safety concept defines Reactor Hall as the fifth physical barrier preventing the release of radioactive materials but according to the Ukrainian regulatory framework the fifth physical barrier is defined as the biological shielding. This discrepancy in the definitions requires further discussion to ensure a consistent application of the Defence-in-Depth concept within the national licensing framework.

Despite the potential deviations, no fundamental obstacles have been identified by any of the participating authorities.

3.4. Top-Level Layout and Separation, Protection Against Internal and External Hazards

This section summarises the findings related to the conceptual plant layout, separation of safety-relevant systems and functions, and the treatment of internal and external hazards (including combinations and multi-unit considerations) as described in the national assessments. This topic was covered by all participants.

All the participating authorities agree that the LDR-50 conceptual design solutions regarding layout and separation support ensuring the availability of the safety functions in all situations, including internal and external hazards.

However, the review identified several aspects where additional information, clarification, and further justification will be required to confirm the adequacy of the proposed solutions. In particular, it was pointed out that the identification of hazards is not yet complete. Combinations of hazards and hazards impacting multiple reactor modules simultaneously are not yet comprehensively addressed.

All authorities acknowledge that the underground layout offers inherent protection against several external hazards but emphasize that shared underground spaces may also introduce new common cause vulnerabilities (e.g. flooding, fire, smoke propagation, seismic interactions).

In general, all the regulators find that the safety impacts of having several reactors in the same infrastructure need to be carefully analyzed and addressed. The regulators need to consider the question too, because the existing regulatory frameworks were largely developed for one reactor per nuclear installation or clearly independent units on a site.

Regarding fire protection, Poland indicated that in their regulatory framework it may be of concern that fire protection tanks have a double function – reservoir of the water in case of fire and to maintain sufficient water volume in the reactor pool.

Based on the information currently available, no fundamental obstacles have been identified but all regulators conclude that compliance with national requirements cannot yet be evaluated in any detail.

3.5. Design Provisions for Operation

This section summarises the findings related to design provisions for the operational concept at a conceptual level, including control room arrangements, staffing and human factors, reliance on automation and operator actions, and maintainability/inspectability considerations. This topic was covered in the Ukrainian, Czech and Swedish assessments.

The authorities considered that the LDR-50 documentation provides a high-level operational concept that is sufficiently described at conceptual stage, but that the level of detail is not sufficient to confirm compliance with national requirements or to fully substantiate key operational assumptions. A recurring theme was that the multi-unit operating concept, particularly centralised control of multiple reactor modules from a shared Main Control Room and the use of an Emergency Control Post, will require further justification and validation in later stages, including consideration of scenarios that increase operator workload or introduce common-cause challenges. The Swedish and Czech assessments both highlighted that multi-reactor operation from a single control room is a central feature that drives open questions and will need later demonstration of acceptability under normal and accident conditions.

Staffing and human factors were repeatedly identified as areas requiring stronger substantiation. Sweden raised the need to justify staffing headcount, including the role of field activities during disturbances and routine inspection needs, while the Czech assessment noted that the proposed staffing model for supervising multiple units would require justification through human reliability analysis, benchmarking and simulator-based validation. The Swedish assessment also highlighted that credited manual actions should be prepared and demonstrated as proven, and noted Swedish expectations related to a full-scale simulator that were not addressed in the submitted material. Generally, the reports indicated that the division of responsibility between automatic system responses and credited operator actions, together with timing assumptions and the information available to operators, will need to be clearly defined, justified and validated as the operating concept matures.

Finally, maintainability and inspection feasibility were raised as important enabling assumptions if specific structures or features are credited in the safety case. Sweden noted that if pools or bedrock are credited (e.g., for heat removal), inspection and maintenance must be demonstrably feasible and supported by appropriate technical specifications, while the Czech and Ukrainian assessments identified a need for further detail on maintenance and in-service inspection strategies under the design constraints.

Based on the assessed National Findings Reports, no fundamental obstacles were identified for this topic at the conceptual stage, however, the operational concept will require additional justification and validation in later design and licensing stages, particularly for multi-unit operation, HFE, credited operator actions, and inspection/maintenance feasibility.

3.6. Design Provisions for Emergency Preparedness

This section summarises the findings related to design provisions for emergency preparedness. The topic covers conceptual provisions for emergency planning and response, including planning zones, emergency facilities and control capabilities, and the assumptions used to justify emergency arrangements at the current design stage. This topic was covered in the Ukrainian, Czech and Swedish assessments.

The participating authorities that assessed emergency preparedness considered that the LDR-50 documentation identifies key emergency preparedness concepts at a high level, but that the level of detail is not sufficient to confirm compliance with national requirements or to substantiate claims related to reduced emergency planning needs. A recurring observation was that emergency preparedness depends strongly on plant-level assumptions, such as the source term basis, acceptance criteria, plant states and the credibility of practical elimination claims, and that later stages would therefore require quantified analyses and traceable assumptions to support licensing-grade conclusions. The Swedish assessment noted that the submitted material does not propose an emergency preparedness category and therefore does not provide a sufficient basis to conclude whether reduced emergency planning zones are intended.

A second common theme concerned the derivation of Emergency Planning Zones and Precautionary Action Zones (EPZ/PAZ). The Czech and Swedish assessments both emphasised that EPZ/PAZ justification would need to be supported in later stages, including site-specific arrangements and a robust treatment of bounding cases for emergency planning. Sweden noted that frequency arguments alone are not sufficient to justify practical elimination and that excluded scenarios, including reactor pool leakage, require stronger substantiation. The Czech assessment, applying a graded approach due to the reactor’s lower thermal power, similarly concluded that the proposed EPZ/PAZ sizes are smaller than those in current plants and would need to be justified during licensing.

The reports also noted that the documents mention emergency facilities, but do not yet explain in sufficient detail how emergency response would be organised and carried out in practice. The Czech assessment notes that further specification is needed in later stages to confirm that response arrangements for one unit do not adversely affect safety of other units on the same site and that site-specific procedures and arrangements can be implemented. The Swedish assessment likewise highlighted that the documentation does not yet provide sufficient detail to support conclusions regarding the extent and organisation of emergency arrangements.

The Ukrainian review aligns with these general observations and additionally emphasises that several core elements are not yet described in sufficient detail at the current stage, including the justification basis for EPZ/PAZ sizing, the treatment of multi-unit accident scenarios in emergency planning, emergency classification and activation criteria, and emergency command-and-control arrangements.

Based on the National Findings Reports that assessed design provisions for emergency preparedness, no fundamental obstacles were identified at the conceptual stage. However, the reports consistently emphasised that emergency preparedness claims, especially those linked to EPZ/PAZ sizing, bounding scenario selection, multi-unit event treatment, and the definition of emergency arrangements and capabilities, will require substantial additional justification, quantified analyses and more detailed documentation in later stages.

3.7. General and Cross-Cutting Findings

In their cross-cutting observations, the National Findings Reports did not identify fundamental obstacles at the current conceptual stage. Instead, these sections were used mainly to highlight limitations in the current documentation and to indicate where additional definition, justification and supporting evidence would be needed for licensing-grade submissions as the design matures. Only the Czech report presents technical findings on this section. In particular, on radiation protection, power supply and instrumentation, control & reactor protection related aspects.

4. Experience from Leveraging the STUK Safety Assessment

The JER examined whether a safety assessment performed by one regulator could be used by other authorities as supporting reference material, while maintaining full independence of national assessments and conclusions.

Across the National Findings Reports, leveraging of the STUK Safety Assessment was generally described as useful, mainly as a structured reference to support topic scoping and to pre-identify areas where more evidence would be needed later. The Swedish assessment described STUK's review as providing a good overview of areas that may require more evidence in licensing. The Polish assessment described leveraging as a comparison of STUK's findings against Polish regulations; where assessments were consistent, it increased confidence, and where they differed, the differences were largely attributed to national regulatory frameworks and in some cases forthcoming updates. The Ukrainian assessment likewise used STUK's review as supporting material and treated differences as arising from national criteria and regulatory context.

The Czech assessment emphasised that comprehensive regulatory comparison and divergence identification are resource-intensive and require time to complete. In practice, due to time and resource constraints, the Czech approach focused on a full-scale assessment of the design with only partial, expert-discretionary use of STUK's review, to avoid risks associated with incorrect leveraging and weakened independent verification. At the same time, the Czech report stated that STUK's review provides a structured and technically substantiated basis that can, to a large extent, be relied upon at the current stage, and that most observations and technical conclusions could be adopted for further regulatory consideration within the conceptual-stage.

Lessons learned from the leveraging experience were also identified:

1. The experience suggested that work related to the IAEA leveraging steps as described in IAEA TECDOC-2098 on regulatory framework comparison and divergence assessment were resource intensive and could have been initiated significantly earlier, potentially before distribution of the actual review materials, so that national differences could be mapped in a more systematic way when the technical review work began.

2. The experience suggested that a stronger front-loaded planning phase could have improved efficiency, in particular by locking the national reporting template before review work began and by requiring short, clearly delimited "report-ready" text blocks per topic for direct transfer into the Closure Report. While the ToR included the use of a template to support uniformity and synthesis, more prescriptive "copy-ready" sections could have reduced later synthesis effort when producing the Closure Report under a tight schedule.

3. While there was an opportunity during the process to seek clarifications on the STUK Safety Assessment during and between meetings (e.g., via email), this opportunity was used only to a limited extent. The Terms of Reference provided for ongoing coordination and exchange of questions with STUK and the vendor, but the experience suggests that the use of dedicated informal clarification channels during the review period could have lowered the barrier and improved efficiency.

4. Traceability could be strengthened in future collaborative reviews by ensuring that statements within the leveraged assessment are systematically linked to the relevant regulatory basis including compliance of addressed requirements and to the specific

sections of the reviewed documentation. This would support efficient independent cross-checking when leveraging another authority's review.

Taken together, the National Findings Reports indicate that leveraging the STUK Safety Assessment supported efficiency and early identification of issues requiring further justification at the conceptual stage, but it did not replace national regulatory judgement or compensate for limited design maturity and the absence of plant- and site-specific analyses. In practice, the experience showed that "full" leveraging, including systematic regulatory framework comparison and divergence mapping, is resource-intensive and could not be implemented comprehensively by most participants within the available time and resources. Even so, using STUK's assessment as a shared reference improved consistency of early discussions and the synthesis of findings into the Closure Report.

Finally, it should be noted that, alongside the JER, an extensive leveraging-focused report was produced under a separate bilateral arrangement between the Ukrainian side and the vendor. The detailed results of that work are being discussed outside the scope of the JER Closure Report and are therefore not reflected here but could nevertheless prove useful for further collaborative review projects and development of the leveraging process.

5. Conclusion.

The Joint Early Review (JER) provided an early, structured exchange of regulatory observations on the LDR-50 conceptual design, based on independent national assessments performed within the scope defined in the Terms of Reference (ToR). The JER was not a licensing activity and did not aim to produce binding regulatory decisions or a common regulatory position. Each participating authority remained responsible for its own conclusions under its national framework.

The present Closure Report therefore serves as a consolidated summary of recurring themes raised across the National Findings Reports. The detailed national reasoning, country-specific regulatory references, and full sets of findings remain in the National Findings Reports annexed to this document. In addition, a key purpose of the JER was to gain practical experience on how a safety assessment performed by one regulator could be leveraged as supporting reference material by other regulators, while preserving national independence.

Across the reviewed topic areas overall, the LDR-50 concept documentation was generally considered adequate for an early conceptual stage, but not sufficient to support licensing-grade conclusions at this time. Common strengths identified across topics included an explicit safety philosophy structured around defence-in-depth, extensive use of inherent and passive features, and a design approach that aims to reduce reliance on rapid operator actions in early accident phases. No participating authority identified fundamental obstacles at the conceptual stage that would prevent continued development within the reviewed topics however, the National Findings Reports consistently emphasised that key aspects of the safety demonstration remain at a high level and require significantly more technical substantiation, supporting analyses, and design detail before regulatory compliance could be demonstrated in a national licensing context. It should be noted that the findings summarised in this report are based on documentation issued in early 2025 and therefore reflect the design status at that time. Subsequent design development and pre-licensing progress with STUK are not reflected in this Closure Report.

A recurring conclusion in several topic areas was that completeness and traceability of the design basis and safety demonstration need to be strengthened as the design matures. This includes, for example, clearer and more traceable initiating-event scoping/screening, explicit representative and bounding scenarios (with defined initial states and failure assumptions), and quantified hazard and load definitions (including combinations) sufficient for licensing-grade assessment. Several reports also linked the credibility of planning assumptions and operational/emergency arrangements to quantified evidence (e.g., consequence evaluations, PSA maturity, and explicit acceptance criteria), noting that concept-level objectives should be treated as design targets rather than demonstrated compliance.

Another cross-cutting theme was the plant-level impact of multi-unit / multi-module configuration and shared infrastructure. While multi-unit operation and shared structures were not treated as preventing further development at this stage, the reports repeatedly highlighted that independence, common-cause vulnerabilities, and cross-unit effects must be explicitly analysed and justified at plant level in later stages, including in hazard combinations and accident management contexts. This observation also applies to operational and emergency arrangements, where shared control concepts and shared spaces introduce dependencies that must be demonstrated acceptable under national expectations.

The reports also demonstrated that national frameworks could drive different emphases and expectations, even when high-level safety objectives are broadly aligned. Examples include differences in the treatment and categorisation of plant states and design extension conditions, different expectations for how probabilistic targets are defined and reported (e.g., per unit vs. per site), and different detailed requirements for confinement/containment performance and associated testability. These differences do not imply inconsistency in overall safety intent, but they underscore the need for transparent “mapping” of definitions, criteria and reporting conventions if the design is pursued in multiple national contexts.

A further important point for interpreting the results is that the depth of assessment varied between authorities due to the voluntary nature of participation and differences in scope. The Closure Report therefore summarises only those findings that were within each authority’s stated scope.

From a process perspective, the JER met its intended purpose of enabling early dialogue and cross-authority learning. The experience from leveraging STUK’s prior assessment was generally positive: access to another regulator’s review supported topic scoping and early identification of areas needing deeper evidence, and it provided a useful reference for cross-checking conceptual-stage reasoning. At the same time, the experience confirmed that full leveraging in the sense described by IAEA TECDOC-2098 is resource-intensive, especially for regulatory framework comparison and divergence assessment, and that such work would benefit from earlier planning and dedicated effort. The process also highlighted practical improvements for future collaborative reviews, including earlier agreement on report structures and “report-ready” text blocks to support timely synthesis, and stronger traceability within the leveraged review itself, so that key assessment statements are explicitly linked to the underlying regulatory basis and the specific sections of the reviewed vendor documentation.

The JER provided a structured, early-stage consolidation of national regulatory observations on the LDR-50 concept and identified a broadly consistent set of areas where further demonstration will be required for licensing-grade conclusions. The Closure Report documents these themes without forming a common position, and the annexed National Findings Reports remain the primary references for detailed, country-specific findings and traceability.

Based on the findings in this work, it can be concluded that the efficiency of the leveraging process would benefit from a common framework for design assessment. In addition, discussions with the regulatory authority responsible for the assessment to be leveraged should be considered an important part supporting the understanding of the results in the assessment.

List of Annexes

Annex I: LDR-50 Joint Early Review National Findings Report: Czechia

Annex II: LDR-50 Joint Early Review National Findings Report: Poland

Annex III: LDR-50 Joint Early Review National Findings Report: Sweden

Annex IV: LDR-50 Joint Early Review National Findings Report: Ukraine

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