[How to read the table]

The recommendations from International Review Team (IRT) to NUMO described in the OECD/NEA review report are listed in the middle column, and the observations from IRT related to those recommendations are listed in the left column (section numbers and pages in the review report are listed together).

NUMO's response to each recommendation is listed in the right column.

2. Findings according to the remit of the review

2.1 Safety strategy

No.	Observations from IRT		Recommendations from IRT		NUMO’s responses to comments
2.1-1	2.1 p.17	The IRT notes that, overall, NUMO relies on the most up-to-date science and technology for methods implemented in developing safety assessments and safety cases.	2.1 p.17	The IRT recommends that NUMO continue to establish the reliability of geological disposal based on the latest scientific knowledge and on continuous reviews.	In line with the basic strategies described in Chapters 2 and 7 of the NUMO Safety Case, NUMO will continue to collect the latest scientific knowledge from both Japan and abroad and to develop the technology required for implementation of the project. This will be facilitated by the Coordination Council on Research and Development of Geological Disposal (hereinafter "the Coordination Council") and the Overall Research and Development Plan for the Geological Disposal Program, which will be formulated by the Coordination Council working with relevant organisations. NUMO will develop a safety case at project milestones and present technical confidence in geological disposal to stakeholders. During these technology and safety case development activities, we will obtain expert advice and external reviews to confirm their reliability.
2.1-2	2.1.1 p.17	NUMO relies on regulatory requirements published by various national authorities in other countries or guidance from international organisations involved in the development of geological disposal projects, pending the establishment of dedicated regulatory requirements in Japan. The characteristics of the waste forms are broadly defined at this stage. However, waste inventory imposes key requirements on the waste management programme.	2.1.1 p.17	More details on the waste types from Japan’s waste producers; on their physical, chemical and radiological properties; and on the potential evolution of these inventories would facilitate NUMO’s continued waste management work. The IRT recommends carrying out sensitivity analyses in order to bound the hypotheses and to have more comprehensive representations of the geological repository’s safety boundaries and safety assessment. Such a sensitivity analysis could also help demonstrate the flexibility of the geological repository design approach and the robustness of the safety case, in particular with regard to future changes in the regulatory framework and the inventory and characteristics of waste to be disposed of. This is an asset that a generic safety case could provide. A clear example concerns the inventory data, not only in terms of volumes of waste but also on their nature and evolution (e.g. possibility to include MOX fuel, to consider other types of spent fuel or TRU waste), including the durations of storage before disposal.	To evaluate the effects of potential variations in the waste inventory on both design and safety of the geological repository, NUMO has gathered information on uncertainties in the characteristic of vitrified HLW and TRU waste (burnup conditions of spent fuel, reprocessing conditions such as cooling time before reprocessing, storage period after reprocessing, variability of physical and chemical properties and volume of TRU waste) in cooperation with the waste producers. NUMO has also developed methodologies to assess the characteristics of wastes. NUMO continues these technical developments as mentioned in the “Overall Research and Development Plan for Geological Disposal Programme (FY2023–FY2027)” (hereinafter "the Overall R&D Plan"). Considering the potential impacts of these uncertainties, a sensitivity analysis using the NUMO Safety Case as a reference is planned in order to assess the effects on the repository design and the pre- and post-closure safety assessment. The results will be used for an assessment of the robustness of the disposal concept, repository design optimisation and development of waste acceptance criteria. Technical issues regarding assessing future waste characteristics will be identified and required R&D initiated. The results of this work will be reflected in the future safety case. R&D on reprocessing of spent MOX fuel is underway. NUMO recognises that potential impacts on the repository concept and safety assessment due to including wastes generated by MOX fuel reprocessing should be assessed in the future. We will continue to enhance the reliability and robustness of the geological disposal programme by keeping in mind possible changes in the waste inventory.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
2.1-3	2.5.1 p.28	The methodology seeks completeness and a consistent treatment of uncertainties. Many assumptions leading to conservatism are consistently utilised. This makes the conclusions robust as regards the potential for long-term safety, but also reduces the ability to distinguish between different design and host rock options. The IRT expects that future models and datasets will be more specific once the number of candidate sites/host formations, with associated repository designs, is narrowed down.	2.1.2 p.18	The IRT recommends that NUMO further highlight the importance of delaying and mitigating the migration of radionuclides in the geosphere. The identification and evaluation of related site characteristics could be decisive in the search for a site.	As no site has been identified at this stage, we focus on a repository design that can be flexibly adapted to a wide range of geological environments. Thus, in the NUMO Safety Case, we demonstrated the feasibility of a geological disposal system by considering geosphere containment performance conservatively, due to large uncertainties in this at the present time. However, as the IRT points out, the nuclide migration characteristics of the geosphere from the host rock around the repository to the biosphere could be a decisive factor in determining the suitability of a site. Therefore, after the site is specified, especially in the Preliminary Investigation and later stages, NUMO will investigate and evaluate key nuclide migration characteristics of the geosphere, including the uncertainties associated with them. NUMO is currently developing a method to analyze three-dimensional nuclide migration behavior on the large scale extending from underground facilities to the biosphere and continuous refinement of this work is included in the Overall Plan.
2.1-4	2.1.2 p.18	The two key safety functions adopted by NUMO are isolation and containment. These encompass the requirements for operational safety as well as for post-closure safety. From these key functions, second or even lower-level functions are identified that have also been taken into account to verify or ensure the proper functioning of the disposal system over time.	2.1.2 p.18	In order to assess efficiency of the developed system for geological disposal, the IRT recommends to NUMO for the following stages of the project development to define safety function indicators or, when relevant, minimum acceptable performance target, also as a function of time.	In the NUMO Safety Case, dose was evaluated as an indicator to assess long-term, post-closure safety of the geological disposal system. In the future, according to the recommendations from IRT, NUMO will consider performance indicators that can more efficiently evaluate the functions of each component contributing to the safety of the entire geological disposal system. For example, we will study application and establishment of target values for indicators of rock properties that have a significant impact on the containment function of the host rock (e.g., permeability, chemical composition of ground water), performance indicators associated with components of the engineered barrier system (e.g., lifetime of overpack or container of TRU wastes), and site characteristics such as travel time from waste package to the biosphere depending on the layout of underground facilities. These studies are described in the Overall R&D Plan.
2.1-5	2.1.4 p.19	The repository's design is adapted to the characteristics of each SDM, aiming to contain radionuclides and limit their migration. At the current stage, the design approach aims for robust solutions, offering a sufficient margin given the inherent uncertainties both in the geological data and in the concepts themselves.	2.1.4 p.19	Starting from an initial outline of design solutions, a representation of the disposal facility architecture and its components is proposed. As knowledge of the sites is acquired, and regulations and requirements become clearer, the choices of technological solutions are refined. The IRT suggests keeping the design options open for as long as possible in order to retain the ability to adapt to potential evolutions in the project.	NUMO is developing design options such as the development of protective coating for overpacks and retrievable PEMs for TRU waste, expanding from the design specifications given in the H12 Report (JNC, 2000) and TRU-2 Report (JAEA and FEPC, 2007). JAEA (Japan Atomic Energy Agency) is also continuing to study direct disposal of spent fuel and investigate deep borehole disposal. NUMO will retain as many design options as possible in order to secure flexibility to respond to changing circumstances. In addition, NUMO will study strategies for narrowing down design options and development targets as site selection progress. We also take into account the possibility that, in the future, the regulatory body may require selection of the best design based on comparison of a range of design options. Furthermore, in order to compare designs, a methodology for selecting the most appropriate options will be developed, based on established design factors (operational safety, long term safety, engineering feasibility, retrievability, economic rationality, environmental impact, monitoring etc.). These technical developments are described in the Overall R&D Plan.
2.1-6	3.2 p.37	The political and social context of the development of geological disposal projects also has its own requirements and dynamics that must be taken into account. Management systems have been put in place to adequately integrate all the information available at any one time and to reproduce the studies and their results. NUMO has set up these systems to allow it to ensure good control of its projects. It will be able to continue its studies in later phases, ensuring adequate quality management.	2.1.4 p.19	Requirements management, including knowledge management, will be key to support future development of the geological repository project. The IRT notes that the teams in charge of the project promote a systematic search and use of the best available technology, which is highly recommendable.	The Overall R&D Plan indicates that NUMO will further strengthen its framework for identifying evolving requirements as the project progresses, acquiring and producing knowledge to meet these requirements, and managing intra-generational knowledge preservation and communication. Through active participation in international projects, such as NEA's WP-IDKM activities, systematic mining and utilisation of the latest national and international knowledge and technology will be facilitated. The general use of advanced knowledge engineering technologies will be promoted, including the development of tools for these specific purposes.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
2.1-7	2.1.4 p.19	The retrievability of waste is taken into account in the facility design. The aspect of the reversibility of decisions is more a matter of management issues that will need to be investigated in due course, requiring strong interaction with stakeholders and future decision makers. Monitoring and surveillance are also well taken into account.	2.1.4 p.19	Monitoring and surveillance are above all intended to ensure that the geological repository operates under conditions that comply with those sought by design. They are therefore also intended to detect as early as possible any anomaly that could lead to additional preventive measures in relation to long-term safety. The programme should also be explicitly linked to the issue of the reversibility of decisions, consistent with NEA definitions (NEA, 2012a), and the retrievability of waste packages. Monitoring and surveillance programmes should be developed and started at an early stage in order to produce a baseline of the sites being investigated before any major field work.	Since monitoring and surveillance strategies are highly dependent on site-specific conditions, the corresponding repository design, and expected safety features, these are only briefly outlined in the NUMO Safety Case at this time. More specific and detailed considerations of these topics will occur after sites are identified. By the time of initiation of the Preliminary Investigation phase, a comprehensive strategy will be developed for each phase of the project, including baseline monitoring, performance confirmation monitoring leading to a final closure decision, and post-closure monitoring for the sites to be studied. In doing so, in line with the Basic Policy on Final Disposal of Designated Radioactive Wastes (hereinafter "Basic Policy on Final Disposal") that requires to ensure the reversibility of the project and the retrievability of the waste in order to reserve options for future generations, we will make these requirements clearly linked to the monitoring and surveillance strategies, as IRT recommended. Development of the measurement technology for determining baseline underground characteristics at the site (temperature, groundwater pressure, water quality, etc.), as required for the first step of the Preliminary Investigation phase, has already been initiated. Here we will verify the applicability and durability of the monitoring equipment and management of accumulated data through demonstration tests. Monitoring and surveillance strategies and the development of corresponding technology are issues that will require particular focus in the future and are clearly stated in the Overall R&D Plan.

2.3 Repository Design Approach

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
2.3-1	2.3 p.24	The IRT recognises the considerable work that NUMO has already produced to date. NUMO's work also outlines the next steps to be addressed when more information on waste inventory and on potential sites for geological disposal becomes available.	2.3.1 p.24	A major input data for repository design is, as already indicated, the waste inventory. The IRT stresses the importance of improving the existing knowledge base and of continuing studies on increasingly reliable data. The waste management strategy before disposal is also decisive information that will need to be clarified, in particular for heat-emitting waste.	As mentioned in the response to comment 2.1-2, to evaluate the effects of potential variations in the waste inventory on both design and safety of the geological repository, NUMO has gathered information on uncertainties in the characteristic of vitrified HLW and TRU waste (burnup conditions of spent fuel, reprocessing conditions such as cooling time before reprocessing, storage period after reprocessing, variability of physical and chemical properties and volume of TRU waste) in cooperation with the waste producers. NUMO has also developed methodologies to assess the characteristics of wastes. NUMO continues these technical developments as mentioned in the Overall R&D Plan. Considering the potential impacts of these uncertainties, a sensitivity analysis using the NUMO Safety Case as a reference is planned in order to assess the effects on the repository design and the pre- and post-closure safety assessment. The results will be used for an assessment of the robustness of the disposal concept, repository design optimisation and development of waste acceptance criteria. Technical issues regarding assessing future waste characteristics will be identified and required R&D initiated. The results of this work will be reflected in the future safety case. R&D on reprocessing of spent MOX fuel is underway. NUMO recognises that potential impacts on the repository concept and safety assessment due to including wastes generated by MOX fuel reprocessing should be assessed in the future. We will continue to enhance the reliability and robustness of the geological disposal programme by keeping in mind possible changes in the waste inventory.
2.3-2	2.3 p.24 2.3.1 p.25	Tests and studies undertaken, as well as modelling, allow the progressive characterisation of the phenomena to be evaluated – facilitating future tasks. Major phenomena have at this stage been taken into account. Knowledge of waste behaviour is expected to guide the development of the repository concepts so that the main functions, particularly in the post-closure phase, are satisfied. Much data is already available; their major characteristics, essentially in terms of stability, are taken into account in a satisfactory manner for the design of disposal facilities.	2.3.1 p.25	In developing subsequent phases of the project, the IRT recommends considering more in-depth studies of certain phenomena such as radiolysis, gas generation and comprehensive couplings or interactions between barrier system materials.	NUMO will continue to develop numerical models for analyzing processes occurring in the repository, supported by laboratory and in-situ experiments, often in cooperation with related organisations. This will allow us to deepen our understanding of key processes and to reflect these in developing repository designs and safety assessment scenarios. Key issues mentioned by the IRT, especially those related to complex processes occurring in the near field, are shown below and included in the Overall R&D plan. NUMO will evaluate potential effects of radiolysis for these issues. ・ Improvement of RN release and transport models ・ Improvement of models of interaction / coupling between near field components and processes ・ Further development and assessment of models of gas generation and migration ・ Development of evaluation methods for colloids, organics and microorganisms ・ Development of nitrate impact models. NUMO will develop models of such processes and accumulate required model parameters together with the technology to integrate them in order to more realistically describe the evolution of the near field.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
2.3-3	2.3 p.24	Repository design follows the progressive strategy put in place by NUMO, with development gradually integrating knowledge acquired on site and evaluated through safety assessments. At this stage of NUMO's SDM-based safety case, the design bases stem from achievements of previous studies presented in reports H12 (JNC, 2000a; JNC, 2000b; AEASJ, 2019) and TRU-2 (JAEA, 2007), after having verified that requirements and functions sought are met. They are brought together in a catalogue of options, including innovative solutions developed by NUMO. The design bases are adapted to the three studied geological formations: Plutonic rocks, Neogene sedimentary rocks and Pre-Neogene sedimentary rocks.	2.3.2 p.25	The IRT draws attention to the fact that the choice between ramp and shaft may be impacted by the real hydrogeologic conditions of the host site (e.g. ramp can be more challenging to implement if permeable water-bearing formations are crossed).	The choice between ramp (which may be spiral or straight) and shaft, and their layout, will be designed with due attention to the hydrogeological conditions at the host site, as noted by the IRT. In addition to this, the design of access tunnels will be optimised by considering various aspects such as safety and efficiency of wastes transportation, impacts on the local environment and construction costs. To implement these, the comprehensive design methodology based on design factors presented in the NUMO Safety Case will be further developed.
2.3-4	2.3.4 p.26	The technical design solutions proposed by NUMO make it possible to reconcile safety requirements, which must in no way be altered, with retrievability objectives. Developments and technological tests are still planned in order to verify the conditions of retrievability, and to optimise them. NUMO has embarked on an encouraging technological programme relating to retrievability.	2.3.4 p.26	To inform future decisions, the IRT recommends that the observation and monitoring programme for disposal facilities explicitly take into account the question of reversibility, in addition to generating information on the performance of the geological repository. Finally, the question of the future investigation of reversibility needs to be clarified and proposed for social debate. NUMO should be proactive in proposing options in this field.	Reversibility is related to the issue of decision-making in society. We will specify which cases and what options need to be considered for our specific project boundary conditions and implementation. As pointed out by the IRT, we will proactively develop a dialogue on this issue with stakeholders, in parallel to the development of related retrieval technologies and monitoring strategies, as mentioned in the response to comment 2.1-7.

2.4 Operational Safety Assessment

No.	Observations from IRT		Recommendations from IRT		NUMO's response to comments
2.4-1	2.4 p.27 p.27	The approach to operational safety is at a preliminary stage. The focus of the operational safety assessment at this stage is the development of concepts and methodologies of radiological safety assessment, and the evaluation of the robustness of the conceptual design. The IRT notes that at the current stage of the programme, the evaluations remain hypothetical and the realism of the operational safety assessment would be greatly improved with concrete site configurations.	2.4 p.27	With respect to the waste inventory, it will be important for NUMO to identify the radionuclides, determining the potential impacts during the operating phase. It will then be possible to verify whether the provisions envisaged in the conceptual design are likely to limit the impacts sufficiently, or even eliminate them.	Waste inventories play an important role not only in repository design and post-closure safety assessment, but also in operational technology and safety assurance, as noted by the IRT. In the future, as mentioned in the response to comment 2.1-2, safety measures will be further studied by examining the impact of inventory variability / uncertainties on the operational concept, as presented in the NUMO Safety Case. In addition, with regard to the pre-closure safety assessment methodology presented in the NUMO Safety Case, we are continuing to develop a methodology to produce more comprehensive operational safety assessment scenarios and quantitative evaluation techniques. Together with such assessment development, we will promote the design of more robust and resilient operational system.
2.4-2			2.4 p.27	For future safety cases, the IRT also recommends considering additional design options for mitigation of operational risks (e.g. fire).	In the design study for operations, risks during operations will be reduced through the stepwise refinement of the repository design and operation methods as site selection progresses. The effectiveness of the design and safety measures to the identified risks will be confirmed using advanced safety assessment methodologies, as described in the response to the comment 2.4-1. Design options that effectively contribute to reducing the identified risks should be considered, utilising the latest knowledge at each stage, for example, for fire risks, the use of fire-resistant equipment and incombustible materials.
2.4-3	2.4 p.27	Worker exposure was not calculated as no perturbation scenario considered at this preliminary stage resulted in a loss of containment of radionuclides, based on the assumption of a robust design with remote handling wherever practical and adequate protection measures. At this stage, NUMO considers that there are no potential releases of radionuclides, and only the potential direct exposure of the public to radiation outside the boundary fence is analysed.	2.4 p.27	Quantitative analyses are recommended for assessing the performance of operational safety measures.	As mentioned in the response to comment 2.4-1, the pre-closure safety assessment methodology, presented in the NUMO Safety Case, will be continuously improved. We have quantitatively evaluated the effects of some extreme safety assessment scenarios, such as the impact force on waste packages due to falls, and the thermal effects on waste in the event of fire. In accordance with the Overall R&D Plan, we will continue to develop safety measures for the design options of facilities and equipment for a series of operational processes, including waste reception, inspection, packaging, transportation in access tunnels, and emplacement in disposal tunnels, focusing on operational failures with relatively high risk of releasing radioactive materials. We will also develop a method to quantitatively evaluate the performance of these measures.
2.4-4	2.4 p.27	NUMO plans to extend this analysis once site-specific information becomes available, by more comprehensively considering scenarios leading to a potential release of radionuclides and their impact on the public near the repository. The IRT notes that at the current stage of the programme, the evaluations remain hypothetical and the realism of the operational safety assessment would be greatly improved with concrete site configurations.	2.4 p.27	The IRT also recommends that the safety assessment be supplemented by including additional scenarios, such as potential failures of the protections envisaged by the conceptual design, and by including all potential exposure pathways to workers, to the public and to the environment.	As mentioned in the response to comment 2.4-1, and in line with the Overall R&D Plan, the safety assessment scenarios considered will be further expanded to improve the coverage of external events such as earthquakes and tsunamis, together with internal perturbing events that are expected to occur in the repository. In addition, we will develop scenarios for common-factor failure modes that could cause loss of multiple safety functions. We intend also evaluate potential impacts of radionuclide release, even in only as what-if scenarios. Based on such a more comprehensive scenario setting, we will analyze exposure pathways to workers and the public, based initially on examples of repository designs presented in the NUMO Safety Case. This will allow us to study necessary safety counter-measures, as well as utilising safety assessment to plan measures to be taken in the event of a hypothetical release of radionuclides.

2.5 Post-closure Safety Assessment

No.	Observations from IRT		Recommendations from IRT		NUMO's response to comments
2.5-1	2.5.1 p.27 2.5.2 p.28	The post-closure safety assessment methodology is well-designed and informed by best practices and international recommendations (NEA/IAEA). The analysis of the complex systems of a geological repository for radioactive waste, where a multitude of phenomena have to be taken into account on considerable spatial and temporal scales, is, in accordance with international practice, done by NUMO by defining a set of evolution scenarios. The scenarios resulting from the application of NUMO's scenario developing methodology are generally consistent and sound.	2.5.2 p.28	Tools and concepts like integrated FEPs, state variables and impact analyses are useful in the derivation of scenarios from FEPs and the IRT encourages the further development of these techniques.	NUMO-FEPs are expanded and revised regularly, based on the international state-of-the-art, and will be updated to reflect the site-specific characteristic when developing site-specific safety cases. Additionally, the next generation of scenario development tools will improve usability and traceability. These are mentioned in the Overall R&D Plan.
2.5-2	2.5.2 p.28	In the bottom up approach, FEPs are screened from a long-term safety point of view. The starting point of analysis is the NEA International FEP list (NEA, 2019; NEA, 2020). This list is adapted on the basis of the specificities of the Japanese programme: FEPs are selected and removed from, and newly added to, the list in function of the boundary conditions for waste and system characteristics.	2.5.2 p.29	All decisions to screen any FEPs out should be systematically supported by arguments on their irrelevance. More detailed FEP description in underlying reports should be referenced, summarising the main arguments in the safety case main report. This would increase the transparency and traceability of the screening process for the next stages.	FEPs that are irrelevant to state variables defining safety functions are screened out in the NUMO Safety Case. The approach and result of screening are described in Supporting Report 6-5. To improve the transparency and traceability of the screening process, in the future better descriptions, e.g., further explanation of the reasons for the exclusion of each FEP, will be provided both in supporting reports and the scenario development section of the main safety case reports. The computerised information management tool, which enables tracking relevance and evidence, is under development to integrate the relationships between FEPs and state variables with information on how these can support development of scenarios, including associated uncertainties. The practical application of this tool will improve the transparency and traceability of scenario development, including FEP screening. In the future, the NUMO FEP list will be provided to the international OECD/NEA FEP database, so that international experts will be able to view it. This will contribute to NUMO's arguments that this reflects the latest international knowledge.
2.5-3	2.5.2 p.29	As mentioned above, the set of scenarios appears generally to be comprehensive at this stage of NUMO's programme.	2.5.2 p.29	A possible additional variant scenario that could be considered is one where the buffer is lost due to chemical erosion in the long term. This, as recognised by NUMO, could occur if the buffer is exposed to low salinity groundwater. The bounding lower limit salinities considered by NUMO are in fact such that erosion may occur. Future iterations of the safety case could preferably include a variant scenario where advective rather than diffusive conditions arise in the buffer.	NUMO is developing a quantitative evaluation method for buffer erosion, supported by laboratory and/or in-situ experiments, considering the groundwater chemistry and hydrology in Japan. This is supported by a natural analogue study in a Japanese bentonite mine, as noted in the Overall R&D Plan. As well as selecting a location for the repository where the potential for buffer erosion is as low as possible, safety assessment for advective conditions within the buffer will be considered in any site-specific case where such a scenario is credible.
2.5-4	2.5.3 p.29	The IRT appreciates the decision to present scenarios in post-closure system behaviour in the form of storyboards, similar to several international examples (e.g. France and the United States). This approach could be extended to all scenarios and made more selfexplanatory for an external reader. Segmentation of representations in space is likely to facilitate the analysis of relevant physical phenomena, supporting the development of a comprehensive assessment.	2.5.3 p.29	The storyboards are a valuable tool for communication across different disciplines involved in the description of the evolution of the repository on a range of spatial scales. The IRT understands that NUMO intends to further develop the storyboard technique so that it may, in future assessments, also contribute in a technical and scientific way to an improved understanding of the system, and this development is encouraged.	NUMO also recognises the storyboards are a valuable tool as the IRT noted. Following the Overall R&D Plan, the storyboard technique is being improved to describe the understanding of system temporal and spatial information in a more detailed and visually-attractive manner. In addition, storyboards that comprehensively represent the behavior of geological disposal systems are used to guide the development of computerised tools, described in the response to comment 2.5-2, that link the processes of scenario development, modelling and dataset of nuclide migration analysis, which will efficiently manage information related to their decision-making and evidence. NUMO will develop this tool in line with the Overall R&D Plan.

No.	Observations from IRT		Recommendations from IRT		NUMO's response to comments
2.5-5	2.5.3 p.29	The IRT notes that the proper consideration of the main phenomena and processes, at different space and time scales, shows a good command of analysis in the geological repository project.	2.5.3 p.29	During later phases of development, the importance of phenomena considered secondary at this stage must systematically be assessed in relation to the major processes and phenomena taken into account in the present assessment. Among the secondary phenomena, the IRT notes all interactions between materials of different natures, and also those on a large scale, such as, for example, the modifications of hydrodynamic regimes linked to climate change. The key to the analysis is assessing whether the functions sought at each stage of the repository's life are maintained. Also, a more comprehensive account of the gradual deterioration in the ability of the components to fulfil their functions would enhance the set of scenarios analysed.	NUMO recognises that it is necessary to analyse primary and secondary processes in a comprehensive and systematic manner. Secondary phenomena which will occur in the repository are treated rather simply in the NUMO Safety Case, but these will receive more attention in future safety cases as part of our goal to enhance assessment reliability. In collaboration with partner organisations, NUMO is developing technologies which evaluate evolution and degradation processes occurring in near field more realistically (see the response to comment 2.3-2). We are also developing a site descriptive model which can include changes of deep subsurface environments in time and space in a realistic manner (4-dimensional site descriptive model). Generally, NUMO will develop technology for evaluation of interaction between processes occurring in the repository as specified in the Overall R&D Plan, together with revision of relevant FEPs (see the response to comment 2.5-1), to improve the reliability of assessment of long-term safety function evolution.
2.5-6	2.5.4 p.30	The high level of conservatism at this stage of the assessment is expected to tend towards more realism, based on less conservative assumptions. To facilitate the analysis of the geological disposal performance, NUMO relied on the implementation of simplified models which are suitable for the current generic phase.	2.5.4 p.30	In the IRT's view, a brief summary in the main report of the mathematical models and their limitations (assumptions, simplifications) vis-à-vis the conceptual process models would improve clarity of the safety case. A chart of the models implemented would also be useful to illustrate the link between the complexity of the physical processes analysed and simplifications essential for a macroscopic representation. Both these measures would make the safety case clearer for generalists, and also provide context for specialists involved in detailed analyses.	Based on IRT's recommendation, NUMO has begun to construct a flowchart which describes all the models and codes for assessing the THMC evolution of the repository within the NUMO Safety Case. This includes analysis of radionuclide migration for scenarios developed on the basis of such THMC evolution and resultant calculated dose rates, with explicit illustration of input and output links between assessment models. Models and codes developed or improved after the NUMO Safety Case are being added to the flowchart implemented in NUMO's information management system for post-closure safety assessment (see the responses to comments 2.5-2 and 2.5-4). To improve the transparency of our safety case, NUMO is planning to enhance the flowchart by adding brief descriptions for all models and codes used to support the safety case. This will be complemented by information on all safety case models and codes within NUMO's information management system.
2.5-7	2.1.1 p.17	NUMO relies on regulatory requirements published by various national authorities in other countries or guidance from international organisations involved in the development of geological disposal projects, pending the establishment of dedicated regulatory requirements in Japan.	2.5.4 p.30	For future assessments, the IRT recommends taking into account the chemical toxicity aspects of the waste, as well as the chemical risks associated with non-radioactive elements. If these aspects are required by future regulations in Japan, their inclusion would of course be mandatory.	At present, the specifications for some TRU wastes are limited or incomplete, in particular with regard to chemotoxic components. We plan to extend studies of the risks of radioactive elements to include the identification of toxic chemical substances, and their release and migration characteristics, in cooperation with the reprocessing plant operators who produce this waste. In addition, consideration will be given to trends in domestic and international regulations on hazardous chemical substances and their handling within safety cases in other countries, as well as wider consideration of chemical risk assessment methods.
2.5-8	2.5.4 p.30	For radionuclide migration, as well as for the biosphere model in general, future improvements will mainly be required in the quality or representativity of data and assumptions.	2.5.4 p.30	It will also be appropriate to extend the analysis of transfers in the biosphere by considering the geochemical mechanisms of reconcentration of chemical forms, for example at an interface between soil horizons or along redox fronts.	In order to enhance confidence of reliability biosphere assessment, as recommended, NUMO will consider geochemical mechanisms that cause reconcentration of chemical forms at locations such as interfaces between soil horizons or along redox fronts when developing the current biosphere model further.
2.5-9	2.1.1 p.17	NUMO relies on regulatory requirements published by various national authorities in other countries or guidance from international organisations involved in the development of geological disposal projects, pending the establishment of dedicated regulatory requirements in Japan.	2.5.4 p.30	The potential impact on non-human organisms should also complete the analysis, in particular if an evaluation of impact is required by future legislation.	The need for radiological protection of the environment, including non-human species, has been suggested in recommendations by international organisations such as ICRP, but is not specifically addressed in many international safety regulations and the nuclear regulations in Japan. It is thus not considered in the NUMO Safety Case. However, in the future, we will pay close attention to international discussions and national and international regulatory trends regarding impact analyses on non-human biota and introduce such considerations as necessary.

2.6 Management systems

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
2.6-1	2.6 p.30	It is recognised by the IRT as being in line with good practice, including its inherent set of iterations. It is notably aimed at ensuring adequate coupling and maintaining flexibility. Flexibility is seen as a way to adapt the project to site characteristics, to developments in science and technology, and to evolving regulations and societal demands. A major type of input data for this management strategy regards the characteristics and inventory of radioactive waste, for which knowledge will evolve over time.	2.6 p.30	The IRT recommends that a system be considered and implemented in order to co-ordinate well with the authorities and producers of radioactive waste the fundamental assumptions on waste inventories on which the whole project is based.	NUMO has cooperation agreements with the waste producers - Japan Nuclear Fuel Limited (JNFL), JAEA and electric power companies. Based on these agreements, we discuss with them on how to share information necessary for setting up waste inventories for repository design and safety assessment (e.g., spent fuel reprocessing conditions and quality records during waste package production). We also consider with them how to improve methodologies of waste characterisation and waste package production that contribute to repository safety (e.g., reducing hydrogen gas production associated with radiolysis). We will strength such collaboration further in the future. NUMO needs to explain in detail the rationale and processes for setting the reference waste inventory in the safety cases. We will consider with the government what kind of communication with the regulatory authorities is possible in order to understand their expectations for this.
2.6-2	3.2 p.37	The political and social context of the development of geological disposal projects also has its own requirements and dynamics that must be taken into account. Management systems have been put in place to adequately integrate all the information available at any one time and to reproduce the studies and their results. NUMO has set up these systems to allow it to ensure good control of its projects. It will be able to continue its studies in later phases, ensuring adequate quality management.	2.6 p.30	Given the large number of cases studied within the framework of the geological disposal project, and in order to find one's way among the different versions, each with different input data and different results, the IRT recommends that in addition to the requirements management system, NUMO develop a configuration management system.	A wide range of studies will need to be carried out in response to various conditions in the future, such as changes of waste inventory, updates of the Site Describe Model to reflect the progress of site investigations. We assess impacts on repository design and safety assessment based on this information. To ensure that changes to the safety cases due to these studies are implemented consistently and transparently, and to manage the complexity of handling different versions of input data and resulting output from these studies, we agree with the comment from the IRT that it is necessary to apply a configuration management system. This will be integrated with requirements management, so that evolving case studies can be managed in an integrated manner throughout the entire lifecycle. Therefore, we will continue to study the development of a system suitable for geological disposal projects, referring to examples of the application of configuration management systems in general industry and related nuclear facilities.

2.7 Research and Development

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
2.7-1	2.7 p.32	In the presented documents, NUMO lists a large series of scientific and technological topics that would deserve further R&D; however, relatively little mention on key R&D programme priorities for the next development stage is made.	2.7 p.32	The R&D programme calls appropriately for the study of alternative materials for engineered barriers, in particular for the reduction of corrosion-induced gas build-up or for cost reasons. The IRT is again of the opinion that sensitivity analyses could help NUMO focus its R&D programme.	To select potential materials for engineered barriers, which is necessary to focus R&D, as mentioned in the response to comment 2.1-4, NUMO agree to specify indicators and criteria that express sufficiency of design requirements based on sensitivity analysis. NUMO will progress these activities.
2.7-2	2.3 p.24	Repository design follows the progressive strategy put in place by NUMO, with development gradually integrating knowledge acquired on site and evaluated through safety assessments. At this stage of NUMO's SDM-based safety case, the design bases stem from achievements of previous studies presented in reports H12 (JNC, 2000a; JNC, 2000b; AEASJ, 2019) and TRU-2 (JAEA, 2007), after having verified that requirements and functions sought are met. They are brought together in a catalogue of options, including innovative solutions developed by NUMO. The design bases are adapted to the three studied geological formations: Plutonic rocks, Neogene sedimentary rocks and Pre- Neogene sedimentary rocks.	2.7 p.32	The IRT also suggests that the research explore alternative materials better suited to safe disposal in the geological medium to be studied. An interesting point of the programme concerns the packaging of TRU waste, particularly with regard to gas generation. This aspect, which had also been raised by the IRT, must be the subject of attention for long-term safety.	As recommended, especially for the TRU waste package, NUMO recognises the importance of future studies of alternative materials to reduce amount of gas generation and also alternative packaging containers enhancing confinement in the case of gas pressurisation, considering applicability of these for relevant geological environments. For this reason, from the viewpoint of further improvement of safety arguments, NUMO will continue to study alternative materials for primary engineered barriers, backfill, and supplementary materials for construction and operation (such as grouting material), aiming to balance contributions to both operational safety and long-term safety. NUMO will also monitor international trends in this topic.
2.7-3	2.3.3 p.26	An interesting issue addressed by NUMO relates to the arrangement of disposal structures in relation to the possible characteristics of the sites to be studied. NUMO is also developing its capacity in this area, which it will be able to mobilise during the next phases of the geological disposal project.	2.7 p.32	From the facility design point of view, the IRT recommends integrating the geological and hydrogeological characteristics of the site into the general architecture of the repository and the design of its various components.	The features of design options tailored to the hydrogeological environment were illustrated in the NUMO Safety Case. For example, the PEM has advantages in terms of reducing the risk of erosion of the bentonite buffer in case of water inflow during waste emplacement in the disposal tunnel, while dead-end type disposal tunnels have more flexibility in terms of avoiding highly permeable hydrogeological structures. NUMO will develop the facility design methodology to tailor the various design concepts and their components to the features of geological environment in a more concrete and detailed manner.
2.7-4	2.3.4 p.26	The technical provisions intended to ensure the retrievability of disposed waste are taken into account at the design study stage. Retrievability is a practical way to implement the reversibility of some decisions, which is a responsibility of society, including key stakeholders, local communities as well as NUMO. It is important to consider what information might be needed for future decision-making steps, and which stakeholders should be consulted.	2.7 p.32	Retrievability is also considered; on this issue, the IRT recommends integrating disposal monitoring and following up with relevant parameters in terms of retrievability. The information generated will be able to feed into decision-making in terms of reversibility, an issue that remains to be investigated.	NUMO recognises that monitoring as a means of surveying the conditions of the disposal system can be linked to retrievability, in order to respond if an unacceptable perturbation (i.e., one which exceeds design specification) occurs in the repository before closure. NUMO will develop a monitoring strategy in accordance with the Overall R&D Plan to make clear what information should be monitored to assess key conditions of the repository system. As mentioned to the response to comment 2.3-4, the process of evaluation of the repository performance based on monitoring as part of the decision-making process for process reversal will be discussed with stakeholders during such studies.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
2.7-5	2.5.3 p.29 p.29	The formulation and illustration of the system behaviour through storyboards is informative and useful. The IRT appreciates the decision to present scenarios in post-closure system behaviour in the form of storyboards, similar to several international examples (e.g. France and the United States). This approach could be extended to all scenarios and made more selfexplanatory for an external reader. Segmentation of representations in space is likely to facilitate the analysis of relevant physical phenomena, supporting the development of a comprehensive assessment. The IRT notes that the proper consideration of the main phenomena and processes, at different space and time scales, shows a good command of analysis in the geological repository project. During later phases of development, the importance of phenomena considered secondary at this stage must systematically be assessed in relation to the major processes and phenomena taken into account in the present assessment.	2.7 p.32	Safety assessments are also the subject of the research effort relating to improved consideration of the phenomenological evolution of the disposal system and its modelling, in line with the opinions of the IRT. It also calls for the improvement of information management tools for the migration of radionuclides and FEPs, in particular through storyboards. The examples presented in the SDM-based safety case illustrate that this work is underway, and the IRT strongly encourages its continuation.	As mentioned in the response to the comment 2.3-2, NUMO will continue to develop numerical models for analysing processes occurring in the repository, supported by laboratory and in-situ experiments, often in cooperation with related organisations. This will allow us to deepen our understanding of key processes and to reflect these in developing repository designs and safety assessment scenarios. Key issues mentioned by the IRT, especially those related to complex processes occurring in the near field, are listed below and included in the Overall R&D plan. NUMO will evaluate potential effects of radiolysis for these issues. ・ Improvement of RN release and transport models ・ Improvement of models of interaction / coupling between near field components and processes ・ Further development and assessment of models of gas generation and migration ・ Development of evaluation methods for colloids, organics and microorganisms ・ Development of nitrate impact models. NUMO will develop models of such processes and accumulate required model parameters together with the technology to integrate them in order to more realistically describe the evolution of the near field. In addition, as mentioned in the response to comment 2.5-4, storyboards that comprehensively represent the behaviour of geological disposal systems are used to guide the development of computerised tools that link the processes of scenario development, modelling, and dataset production for radionuclide migration analysis. This also efficiently manages information related to decision-making and the evidence used to support such decisions. NUMO will carry out this work in line with the Overall R&D Plan.
2.7-6	2.5.4 p.30	The set of calculations carried out for different disposal configurations and conditions illustrates the capability of NUMO to adequately represent the system for various conditions, and to carry out the required set of consequence calculations underpinning a safety case. The numerical modelling seems mature enough to simulate site-specific systems, and to consider different disposal configurations and conditions.	2.7 p.32	The IRT recommends a sustained effort be made to validate models and codes intended to evaluate disposal behaviour and performance. This is all the more important since the spatial and temporal scales in question are outside the usual scope, and it is therefore essential to strengthen the confidence of all stakeholders.	As IRT noted, validation of simulation models and codes is crucially important to build confidence in the safety case. We are developing a systematic methodology of verification and validation, including both testing against observational data and critical expert review. According to the Overall R&D Plan, NUMO will continue to expand verification and validation of simulation models and codes in the future.
2.7-7	2.7 p.31	The IRT notes the Coordination Council on R&D of Geological Disposal between METI, NUMO, JAEA and other R&D organisations. Additionally, the IRT understands that NUMO's primary role is to identify R&D needs and integrate results in the safety case. The expression of R&D needs should be a logical result of the SDM-based safety case.	2.7 p.33	The five-year R&D plan will terminate shortly. The recommendations resulting from this review could preferably be integrated in a new forthcoming R&D programme.	With the completion of the Overall R&D Plan for FY 2018-2022, the subsequent Overall R&D Plan for FY 2023-2027 was published on the website of the Agency for Natural Resources and Energy (ANRE) of the Ministry of Economy, Trade and Industry (METI) in March 2023 (Coordination Council, 2023). In the process of developing the Overall R&D Plan (FY2023-2027) by the Coordinating Council, the recommendations of the NEA Review Report on the NUMO Safety Case published in January 2023 were explicitly considered and acted upon.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
2.7-8	2.7 p.31	The R&D programme for geological disposal in Japan and its funding are established under the leadership of METI. The IRT notes the Coordination Council on R&D of Geological Disposal between METI, NUMO, JAEA and other R&D organisations. Additionally, the IRT understands that NUMO's primary role is to identify R&D needs and integrate results in the safety case. The expression of R&D needs should be a logical result of the SDM-based safety case. In the presented documents, NUMO lists a large series of scientific and technological topics that would deserve further R&D; however, relatively little mention on key R&D programme priorities for the next development stage is made.	2.7 p.33	Moving from a generic safety case to site- and waste-specific safety case(s) would require strong steering by NUMO on R&D priorities and their adequacy. To advise METI on the R&D programme and associated budget, the IRT recommends that NUMO develop an R&D proposal based on the current safety case. Such a proposal should clearly define and substantiate key R&D priorities to inform the next phase of siting and the next safety case.	NUMO identified many important technical issues through the process of developing the Safety Case and discussed their priority for improving confidence of future safety cases at Coordination Council meetings, together with METI and related R&D organisations. The Overall R&D Plan (FY 2018-2022) was revised based on these discussions and NUMO conducted R&D activities on this basis. While formulating the Overall R&D Plan (FY2023-FY2027), R&D achievements from the previous Overall Plan and recent changes related to progress of the program (e.g., the initiation of the Literature Survey and the Nuclear Regulation Authority's decision on "the Considerations to ensure nuclear safety in the site selection phases for geological disposal") have been taken into account. Necessary R&D topics to address recommendations from the NEA international review have been also included. As recommended by IRT, NUMO will continue the process of identifying key issues within developing safety cases and reflecting these into the Overall R&D Plan via the Coordinating Council. Thus we can appropriately play our implementer role in steering R&D planning in Japan.

3. Conclusion and recommendations

Summary of key observations and recommendations

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
3-1	3.1 p.35	The IRT recognises that the SDM-based safety case is an adequate iterative way to describe and integrate existing knowledge at various time and space scales. The IRT notes the "more realistic" nature of the SDMs vis-à-vis the previous safety cases for geological disposal in Japan (JNC, 2000a; JAEA, 2007). NUMO has demonstrated its capability and maturity in developing a safety case, including the methodologies and tools that will be used for the assessment at specific sites, which is consistent with international practice.	3 p.34	To continue efforts to further increase its understanding of the systems in order to be able to analyse them.	As mentioned in the response to comment 2.3-2, NUMO will continue to develop numerical models for analyzing processes occurring in the repository, supported by laboratory and in-situ experiments, often in cooperation with related organisations. This will allow us to deepen our understanding of key processes and to reflect these in developing repository designs and safety assessment scenarios. Key issues related to complex processes occurring in the near field are shown below and included in the Overall R&D plan. NUMO will evaluate potential effects of radiolysis for these issues. ・ Improvement of RN release and transport models ・ Improvement of models of interaction / coupling between near field components and processes ・ Further development and assessment of models of gas generation and migration ・ Development of evaluation methods for colloids, organics and microorganisms ・ Development of nitrate impact models. NUMO will develop models of such processes and accumulate required model parameters together with the technology to integrate them in order to more realistically describe the evolution of the near field. NUMO is also currently developing a method to analyze three-dimensional nuclide migration behavior on the large scale extending from underground facilities to the biosphere and continuous refinement of this work is included in the Overall Plan (see the response to comment 2.1-3).
3-2	2.7 p.31	The R&D programme for geological disposal in Japan and its funding are established under the leadership of METI. The IRT notes the Coordination Council on R&D of Geological Disposal between METI, NUMO, JAEA and other R&D organisations. Additionally, the IRT understands that NUMO's primary role is to identify R&D needs and integrate results in the safety case. The expression of R&D needs should be a logical result of the SDM-based safety case. In the presented documents, NUMO lists a large series of scientific and technological topics that would deserve further R&D; however, relatively little mention on key R&D programme priorities for the next development stage is made.	3 p.34	To reinforce its role as specifier of R&D studies and integrator of the results obtained with the support of specialised research institutions in Japan. To rely on the lessons of the SDM-based safety case to specify R&D needs, prioritise them and submit them to the institutions in charge of conducting studies and research.	As mentioned in the response to comment 2.7-8, NUMO identified many important technical issues through the process of developing the Safety Case and discussed their priority for improving confidence of future safety cases at Coordination Council meetings, together with METI and related R&D organisations. The Overall R&D Plan (FY 2018-2022) was revised based on these discussions and NUMO conducted R&D activities on this basis. While formulating the Overall R&D Plan (FY2023-FY2027), R&D achievements from the previous Overall Plan and recent changes related to progress of the program (e.g., the initiation of the Literature Survey and the Nuclear Regulation Authority's decision on "the Considerations to ensure nuclear safety in the site selection phases for geological disposal") have been taken into account. Necessary R&D topics to address recommendations from the NEA international review have been also included. As recommended by IRT, NUMO will continue the process of identifying key issues within developing safety cases and reflecting these into the Overall R&D Plan via the Coordinating Council. Thus we can appropriately play our implementer role in steering R&D planning in Japan.
3-3	3.1 p.34	NUMO has conducted significant work to produce the SDM-based safety case. This is based on the experience developed over the years from previous safety cases, adequate consideration of foreign practices, extensive R&D, experiments in URLs and NUMO's sustained activities within international bodies.	3 p.34	To continue its investments in international activities, both with the international bodies, the NEA, IAEA and the EC, and with the organisations abroad working on geological disposal projects.	International cooperation is an extremely important element in advancing Japan's geological disposal program. NUMO is currently an active participant in most OECD/NEA working groups and expert groups related to radioactive waste disposal. NUMO is also an active member of EDRAM, participating in collaboration activities of the leading national geological disposal implementers. We are also involved in expert meetings and international conferences organised by the IAEA. In addition, joint research and other activities are conducted based on bilateral Cooperation Agreements with overseas implementers and research institutions. This international network enables us to learn from the latest developments in other countries, as well as to share the results of technological development and experiences in dialogue and communication with various stakeholders. We will certainly continue to participate in such international cooperation and activities.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
3-4	3.3 p.37	The IRT understands that the NRA is in the process of developing dedicated DGR regulations and would like to emphasise the importance of having a first set of such regulations as early as possible. International experience shows that regulatory requirements can and should evolve as knowledge of disposal increases. With this approach, the first set of regulatory requirements would not need to cover all detailed level requirements related to the DGR safety. International experience shows that a pre-licensing dialogue between the implementer and the nuclear regulatory authority (without compromising the independency of the regulatory authorities) provides the implementer with an understanding of regulatory expectations, and is an important element for successful DGR development.	3 p.34 翻訳版 p.41	To use the NUMO pre-siting SDM-based safety case to guide dialogue with the NRA. The pre-license dialogue's objective is to clarify expectations and steps until formal licensing phases.	In August 2022, NRA issued "the Considerations to ensure nuclear safety in the site selection phases for geological disposal". In creating this NRA guide, METI and NUMO openly exchanged opinions with the NRA, following an invitation from them. We hope that the dialogue between NRA and NUMO will continue and be strengthened in the future, while ensuring that transparency is preserved. In order to enhance dialogue with the NRA, NUMO will actively provide information on how dialogue between regulatory authorities and implementors is implemented at the international level, as well as on the efforts in this area in different countries. Also, NUMO will actively communicate the process of responding to the IRT recommendations on the NUMO Safety Case, particularly in terms of related R&D plans and expected output, so that opinions on these can be obtained from the NRA.
3-5	3.3 p.38	Regarding waste inventory and characterisation, the IRT recognises that NUMO works within the boundaries of Japan's Final Disposal Act (METI, 2000 and 2015) and Final Disposal Plan. The IRT notes that the utilised inventory in the safety case dates back to 2008 and is generic in nature.	3 p.34	To organise the exchange between waste producers and NUMO in order to refine the data on the characteristics and inventory of radioactive waste to be disposed of in the geological repository. Requested data should also ideally cover potential evolutions of waste inventories and characteristics.	As mentioned in the response to commnet 2.6-1, NUMO has cooperation agreements with the waste producers - Japan Nuclear Fuel Limited (JNFL), JAEA and electric power companies. Based on these agreements, we discuss with them on how to share information necessary for setting up waste inventories for repository design and safety assessment (e.g., spent fuel reprocessing conditions and quality records during waste package production). We also consider with them how to improve methodologies of waste characterisation and waste package production that contribute to repository safety (e.g., reducing hydrogen gas production associated with radiolysis). We will strength such collaboration further in the future.
3-6	3.3 p.38	Based on international experience, a national framework including stepwise licensing and clear roles for different organisations is a prerequisite for the successful implementation of a DGR.	3 p.34	To consider, for the next phase of site selection, an international peer review (such as an IAEA Artemis mission) focused on the overall program and regulatory framework of the DGR, which is useful to support the successful development of the DGR.	We recognise the value of the suggestion of an international peer review (such as an IAEA Artemis) focusing on the overall DGR programme. This would include R&D frameworks covered by the Coordination Council (as described in the response to the comment 2.7-8), regulatory frameworks and roles of related agencies. We will discuss this further with METI in the future.

3.1 General

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
3.1-1	3.1 p.35	The IRT recognises that NUMO has compiled a sufficiently comprehensive safety case for the current programme stage.	3.1 p.35	Given the large uncertainties associated with the basis for NUMO's SDM-based safety case, including fundamental programme uncertainties related to the waste inventory and regulatory requirements, the IRT also considers that NUMO's programme development could benefit from extending its safety case with additional sensitivity studies. Such studies could, for example, cover a range of inventories, different levels of requirements, data ranges of site properties such as rock permeability, or variation of technical specification like engineered barrier thicknesses. Such an approach, used in other countries in the framework of pre-licensing studies, would be an effective way to illustrate the flexibility and the robustness of the proposed geological disposal concepts and of the methodology used in the safety case.	Based on the experience gained during the development of the NUMO Safety Case, as IRT noted, it is recognised that future safety cases should include a range of sensitivity analyses. These will help understand the impacts of the possible range of waste inventories, geological environmental characteristics (such as permeability of the rock that can have a significant impact on radionuclide migration), and engineered barrier specifications on performance of the geological disposal system as a whole, or of individual components of this. Such studies will demonstrate flexibility and robustness regarding the concept of geological disposal and the methodology used in the safety case and we will continue to develop the technical basis for this purpose. Therefore, we will continue to study indicators that can evaluate the performance of each component in terms of the safety function of the overall system (as described in the response to comment 2.1-4) and to develop analytical models that can more realistically evaluate system performance without excessive conservatism (as described in the response to comment 2.3-2).
3.1-2	3.1 p.35	The IRT recognises that the SDM-based safety case is an adequate iterative way to describe and integrate existing knowledge at various time and space scales. The IRT notes the "more realistic" nature of the SDMs vis-à-vis the previous safety cases for geological disposal in Japan (JNC, 2000a; JAEA, 2007). NUMO has demonstrated its capability and maturity in developing a safety case, including the methodologies and tools that will be used for the assessment at specific sites, which is consistent with international practice.	3.1 p.35	The IRT's recommendation to NUMO is to continue its efforts and further increase its understanding of the systems in order to be able to analyse repository performance to an adequate level for future decision-making. To do this, NUMO should have access to key capabilities nationally and continue to draw on the potential of international collaboration. The IRT encourages NUMO to continue its investments in international activities, both with the reference bodies represented by the NEA and the IAEA and with organisations abroad working with geological disposal projects.	As mentioned in the response to comment 3-1, NUMO will continue to develop numerical models for analyzing processes occurring in the repository, supported by laboratory and in-situ experiments, often in cooperation with related organisations. This will allow us to deepen our understanding of key processes and to reflect these in developing repository designs and safety assessment scenarios. Key issues related to complex processes occurring in the near field are included in the Overall R&D plan. For this, as IRT noted, international cooperation is extremely important. As mentioned in the response to comment 3-3, NUMO is currently an active participant in most OECD/NEA working groups and expert groups related to radioactive waste disposal. NUMO is also an active member of EDRAM, participating in collaboration activities of the leading national geological disposal implementers. We are also involved in expert meetings and international conferences organised by the IAEA. In addition, joint research and other activities are conducted based on bilateral Cooperation Agreements with overseas implementers and research institutions. This international network enables us to learn from the latest developments in other countries, as well as to share the results of technological development and experiences in dialogue and communication with various stakeholders. We will certainly continue to participate in such international cooperation and activities.

3.3 Key points related to the safety case framework

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
3.3-1	3.3 p.37	The IRT understands that the NRA is in the process of developing dedicated DGR regulations and would like to emphasise the importance of having a first set of such regulations as early as possible. International experience shows that regulatory requirements can and should evolve as knowledge of disposal increases. With this approach, the first set of regulatory requirements would not need to cover all detailed level requirements related to the DGR safety. International experience shows that a pre-licensing dialogue between the implementer and the nuclear regulatory authority (without compromising the independency of the regulatory authorities) provides the implementer with an understanding of regulatory expectations, and is an important element for successful DGR development.	3.3 p.38	The IRT recommends that NUMO proactively engage with the necessary organisations for the establishment of a pre-licensing dialogue with the regulator based on the current safety case. Such exchanges prior to the development of the successive safety cases would reduce the risk of NUMO's future work deviating from the regulator's expectations.	As mentioned in the response to comment 3-4, in August 2022, NRA issued "the Considerations to ensure nuclear safety in the site selection phases for geological disposal". In creating this NRA guide, METI and NUMO openly exchanged opinions with the NRA, following an invitation from them. We hope that the dialogue between NRA and NUMO will continue and be strengthened in the future, while ensuring that transparency is preserved. In order to enhance dialogue with the NRA, NUMO will actively provide information on how dialogue between regulatory authorities and implementors is implemented at the international level, as well as on the efforts in this area in different countries. Also, NUMO will actively communicate the process of responding to the IRT recommendations on the NUMO Safety Case, particularly in terms of related R&D plans and expected output, so that opinions on these can be obtained from the NRA.
3.3-2	3.3 p.38	Regarding waste inventory and characterisation, the IRT recognises that NUMO works within the boundaries of Japan's Final Disposal Act (METI, 2000 and 2015) and Final Disposal Plan. The IRT notes that the utilised inventory in the safety case dates back to 2008 and is generic in nature.	3.3 p.38	The IRT recommends that this be updated, taking into consideration the full spectrum of current waste inventory and possible future waste from different streams.	NUMO will design a DGR that can accommodate the required volumes of the specified wastes, which are currently more than 40,000 canisters of HLW (vitrified waste) and more than 19,000m^3 of TRU waste, defined by the Designated Radioactive Waste Final Disposal Plan (hereinafter "Final Disposal Plan"). Regarding the details of the waste inventory and its characteristics (as indicated in the responses to comments 2.1-2 and 2.3-1), NUMO promotes information exchange with the reprocessing operators and waste producers in order to further develop methodologies for estimation of inventories and will improve our knowledge base by making it more realistic. NUMO will also examine the possibility of changes in waste inventories and specific waste characteristics that could result from plans for the future use of nuclear power.
3.3-3	3.2 p.37	Numerous studies in support of the safety demonstration, and the resulting models, illustrate NUMO's ability to represent geological disposal and to describe and analyse its possible evolutions. Here again, the limitations of the exercise are due to its generic nature. This results in high levels of uncertainty: however, many of these will be gradually reduced over the successive phases of investigation. Phenomena considered non-determining at this stage can be analysed during the later phases of the development of the geological disposal project. In addition, certain aspects need to be clarified independent of site data. These are related specifically to the regulatory requirements and the inventory data of the waste that will have to be disposed of. As the implementer and considering its experience, NUMO has an important role in analysing and specifying these needs and informing the authorities and waste generators, which will have to establish requirements and specify waste inventories.	3.3 p.38	The IRT also recommends that NUMO carry out sensitivity studies regarding the consequences of potential evolutions in the inventory in terms of e.g. design, safety and disposability. This will make it possible to identify the areas where uncertainty needs to be reduced most and to test the robustness and the flexibility of the safety case methodology, design options and repository capacity. Such sensitivity studies would also foster a dialogue with the waste producers (i.e. the JNFL, JAEA and utility companies in NUMO's case) regarding the optimisation and disposability of potential waste types to be disposed of by NUMO. Such exploratory analyses would also be useful in specifying the limits of inventories to be retained for future geological disposal studies.	As noted in the response to comment 2.1-2 and 3.1-1, and as recommended by IRT, future safety cases will include sensitivity analyses on the impacts of inventory changes on the design, safety and practicality of implementation of the repository system. This will allow us to identify areas where uncertainty needs to be reduced the most. It would also provide input for the robustness and flexibility of the methodologies and design options used to develop future safety cases, as well as with respect to repository capacity. In addition, NUMO will further promote collaboration with waste producers to develop optimisation of future waste management and establish waste acceptance criteria based on such sensitivity analyses.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
3.3-4	3.2 p.37	Having reviewed the various points necessary for the realisation of geological disposal of radioactive waste, and taking into account the geological context of Japan, the IRT considers that elements of its feasibility have been demonstrated. The fact remains that many studies are still necessary for the next steps, in particular according to the characteristics of the sites that will be considered. NUMO has demonstrated its ability to fulfil such a mission.	3.3 p.38	Moving from a generic safety case to site- and waste-specific safety case(s) would require strong steering from NUMO on R&D priorities. The IRT recommends that NUMO develop an R&D proposal based on the current safety case in order to advise METI on the nationwide R&D programme for DGRs. Such a proposal should clearly define and substantiate key R&D priorities to inform the next phase of siting and the next safety case. According to international experience, an implementer (in this case, NUMO) should indeed have a major responsibility in defining and steering the R&D for geological disposal.	As mentioned in the response to comment 2.7-8, NUMO identified many important technical issues through the process of developing the Safety Case and discussed their priority for improving confidence of future safety cases at Coordination Council meetings, together with METI and related R&D organisations. The Overall R&D Plan (FY 2018-2022) was revised based on these discussions and NUMO conducted R&D activities on this basis. While formulating the Overall R&D Plan (FY2023-FY2027), R&D achievements from the previous Overall Plan and recent changes related to progress of the program (e.g., the initiation of the Literature Survey and the Nuclear Regulation Authority's decision on "the Considerations to ensure nuclear safety in the site selection phases for geological disposal") have been taken into account. Necessary R&D topics to address recommendations from the NEA international review have been also included. As recommended by IRT, NUMO will continue the process of identifying key issues within developing safety cases and reflecting these into the Overall R&D Plan via the Coordinating Council. Thus, we can appropriately play our implementer role in steering R&D planning in Japan.
3.3-5	3.3 p.38	Based on international experience, a national framework including stepwise licensing and clear roles for different organisations is a prerequisite for the successful implementation of a DGR.	3.3 p.38	The IRT focused its peer review work on NUMO's generic safety case, but observed the above-mentioned elements of the national framework that might need enhancement. To further evaluate these aspects, the IRT also notes that an international peer review (such as an IAEA Artemis mission) focused on the overall DGR programme and regulatory framework would be useful and would support the successful development of the DGR.	We recognise the value of the suggestion of an international peer review (such as an IAEA Artemis) focusing on the overall DGR programme. This would include R&D frameworks covered by the Coordination Council (as described in the response to the comment 2.7-8), regulatory frameworks and roles of related agencies. We will discuss this further with METI in the future.

3.4 Technical recommendations to NUMO

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
3.4-1	3.4 p.39	NUMO has carried out an in-depth analysis of the safety-related functions expected for a geological repository.	3.4 p.39 p.39	(Summary in the box in the page 39) Safety-related functions expected for a geological repository: for future phases, where possible, to match the safety functions with quantitative performance indicators and, when possible, with criteria for acceptable performance. (In the text) NUMO has carried out an in-depth analysis of the safety-related functions expected for a geological repository. For future phases, the IRT recommends, where possible, matching the safety functions with quantitative performance indicators and criteria for acceptable performance.	As mentioned in the response to Comment 2.1-4, in the future, consistent with the recommendations from IRT, NUMO will consider performance indicators that can more efficiently evaluate the functions of each component contributing to the safety of the entire geological disposal system. For example, we will study application and establishment of target values for indicators of rock properties that have a significant impact on the containment function of the host rock (e.g., permeability, chemical composition of ground water), performance indicators associated with components of the engineered barrier system (e.g., lifetime of overpack or container of TRU wastes), and site characteristics such as travel time from the waste package to the biosphere as a function of the layout of underground facilities. These studies are described in the Overall R&D Plan.
3.4-2	2.2 p.20	It is worth noting that one of the objectives of the Preliminary and Detailed Investigations stages is to iteratively improve state-of-the-art knowledge for the relevant scientific disciplines and related technologies so that the site suitability will be ensured for operational and post-closure safety, based on a tailored design of the repository. It is meant to reduce the residual uncertainties through the implementation process, guaranteeing efficiency and cost-effectiveness. NUMO's approach to integrating current geoscientific knowledge into a model of the host rock and its geological environment is traceable, well-documented and well-illustrated.	3.4 p.39	The IRT encourages NUMO to continue using the SDM approach to iteratively integrate geoscientific knowledge as it is acquired during the different stages of the site-selection process. Such an approach will ensure a coherent and multidisciplinary description of the different volunteer sites.	Based on the developed generic SDMs for three rock types, which are widely distributed at relevant depths in Japan, these SDMs will be continuously improved to reflect the latest scientific knowledge. This provides a basis for site specific SDMs to be developed by iterating synthesis of specific site information obtained during characterization during the stepwise site-selection process, as describing in Chapters 2 and 7 of the NUMO Safety Case. Such structured procedures are applicable to all volunteer sites, and so are consistent with IRT recommendations.
3.4-3	3.2 p.36	Though appropriate at this stage of DGR development, the SDMs remain generic in nature; the introduced conservativeness and arbitrary choices may therefore obscure specific rock characteristics. Future challenges include ensuring the capacity of sites located in the territory of voluntary municipalities to provide the key safety functions: namely, according to NUMO terminology, isolation and containment. With the knowledge already available, NUMO is able to mobilise teams capable of pursuing increasingly detailed site investigations and assessments. It is also able to specify the needs for additional knowledge on the sites, in particular through performance and safety assessments of individual sites. The IRT considers that, at this stage, the tools and technologies for field data acquisition and for their processing are available.	3.4 p.39 p.40	(Summary in the box in the page 39) Capacity of the geological medium to provide an appropriate delay of radionuclide transport: to be taken into account more specifically during site evaluations. This may prove to be a discriminating criterion in the event several volunteer communities arise. (In the text) The capacity of the geological medium to provide an appropriate delay of radionuclide transport will have to be taken into account in more detail during site-specific evaluations, and this may prove to be a discriminating criterion.	As mentioned in the response to comment 2.1-3, because no site has been identified at this stage, we focus on a repository design that can be flexibly adapted to a wide range of geological environments. Thus, in the NUMO Safety Case, we demonstrated the feasibility of a geological disposal system by considering geosphere containment performance conservatively, due to large uncertainties in this at the present time. However, as the IRT points out, the nuclide migration characteristics of the geosphere from the host rock around the repository to the biosphere could be a decisive factor in determining the suitability of a site. Therefore, after the site is specified, especially in the Preliminary Investigation and later stages, NUMO will investigate and evaluate key nuclide migration characteristics of the geosphere, including the uncertainties associated with them. NUMO is currently developing a method to analyze three-dimensional nuclide migration behavior on the large scale extending from underground facilities to the biosphere and continuous refinement of this work is included in the Overall Plan.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
3.4-4	2.1.4 p.19	The repository's design is adapted to the characteristics of each SDM, aiming to contain radionuclides and limit their migration. At the current stage, the design approach aims for robust solutions, offering a sufficient margin given the inherent uncertainties both in the geological data and in the concepts themselves.	3.4 p.39 p.40	(Summary in the box in the page 39) Design options: to be kept open as long as possible in order to keep flexibility in design as additional knowledge is acquired. (In the text) In terms of repository design, and given the uncertainties inherent in the system, the IRT encourages NUMO's plans to keep the various options open as long as possible in order to keep flexibility of design evolution as additional knowledge is acquired.	As mentioned in the response to comment 2.1-5, NUMO is developing design options such as the development of protective coating for overpacks and retrievable PEMs for TRU waste, expanding from the design specifications given in the H12 and TRU-2 Reports. JAEA (Japan Atomic Energy Agency) is also continuing to study direct disposal of spent fuel and investigate deep borehole disposal. NUMO will retain as many design options as possible in order to secure flexibility to respond to changing circumstances. In addition, NUMO will study strategies for narrowing down design options and development targets as site selection progress. We also take into account the possibility that, in the future, the regulatory body may require selection of the best design based on comparison of a range of design options. Furthermore, in order to compare designs, a methodology for selecting the most appropriate options will be developed, based on established design factors (operational safety, long term safety, engineering feasibility, retrievability, economic rationality, environmental impact, monitoring etc.). These technical developments are described in the Overall R&D Plan.
3.4-5	3.2 p.37	The political and social context of the development of geological disposal projects also has its own requirements and dynamics that must be taken into account. Management systems have been put in place to adequately integrate all the information available at any one time and to reproduce the studies and their results. NUMO has set up these systems to allow it to ensure good control of its projects. It will be able to continue its studies in later phases, ensuring adequate quality management.	3.4 p.39 p.40	(Summary in the box in the page 39) Flexibility of design options requires monitoring of changes, which can be ensured using a configuration management system. (In the text) Such flexibility also requires monitoring of changes, which can be ensured using a configuration management system, also covering the various interdependencies between knowledge of the waste and the geological environment, design of the disposal facilities, relevant phenomena, and the integration of these aspects through safety studies.	As mentioned in the response to comment 2.6-3, a wide range of studies will need to be carried out for various conditions in the future, such as the change of waste inventory, updating of the Site Descriptive Model to reflect the progress of site investigations, and the implementation of repository design and safety assessment based on this information. To ensure that changes to the safety cases due to these studies are implemented consistently throughout the entire process, and to manage the complexity of the series of input data and versions of results used in the studies, we agree with the comment from the IRT that it is necessary to apply a configuration management system together with requirements management, so that these can be managed in an integrated manner throughout the entire lifecycle. At a later stage, we will apply a configuration management system that will include monitoring, relating to changes of the SDM and developed design options tailored to it, which would ensure appropriate integration of such changes into future safety assessments.
3.4-6	3.1 p.35	The approach for reversibility (NEA, 2012a) and stepwise decision-making regarding DGR is not reported. It could benefit from a comprehensive description of the process leading to reverse decisions.	3.4 p.39	(Summary in the box in the page 39) Reversibility of disposal decisions: to make proposals, in particular by proposing decision-making processes that can mark out the life of the geological disposal, and keeping options open for future generations.	As stated in the NUMO Safety Case, the Basic Policy for Final Disposal requires that the project be reversible and the waste package retrievable until the repository is closed in order to preserve options for future generations. In order to assure practicality of reversal in geological disposal projects, it is necessary to develop a decision-making process that determines how the project will ultimately be terminated (lifecycle decisions), while retaining options for future generations. Based on this, it is necessary to clarify how to implement the plan (policy of reversibility including retrievability) at each decision milestone. We recognise the need for consensus building in the decision-making process and associated reversibility requirements, through dialogue involving various stakeholders, and that NUMO, as the implementer, has an important role to play in making concrete proposals to form the basis for such dialogue. In considering the decision-making process and the proposed approach to reversibility, various scenarios should be considered, taking into account the long project period and acknowledging that the scientific, technological, and social boundary conditions for the project will change with time.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
3.4-7	2.1.4 p.19	The retrievability of waste is taken into account in the facility design. The aspect of the reversibility of decisions is more a matter of management issues that will need to be investigated in due course, requiring strong interaction with stakeholders and future decision makers. Monitoring and surveillance are also well taken into account.	3.4 p.39 p.40	(Summary in the box in the page 39) Monitoring: to integrate retrievability into the objectives of monitoring, (In the text) NUMO addresses well the retrievability of waste in disposal and takes this into consideration in the repository design approach. The IRT recommends integration of monitoring aspects into the reversibility and retrievability objectives.	Information and data are necessary to determine required reversibility / retrievability in the decision-making process for a DGR programme (see the response to comment 3.4-6). As mentioned in the responses to comments 2.1-7 and 2.3-4, it is important to relate reversibility and retrievability to a comprehensive monitoring strategy, which includes determination of changes in the condition of the geological environment, the engineered barrier systems and underground facilities. This needs to extend from the site investigations through construction, operation and closure of the repository, and even feasibility at some point after repository closure. Studying such a comprehensive monitoring strategy is explicitly described in the Overall R&D Plan and will be done in coordination with the study of the decision-making process, as described in the response to comment 3.4-6.
3.4-8	3.2 p.37	The political and social context of the development of geological disposal projects also has its own requirements and dynamics that must be taken into account. Management systems have been put in place to adequately integrate all the information available at any one time and to reproduce the studies and their results. NUMO has set up these systems to allow it to ensure good control of its projects. It will be able to continue its studies in later phases, ensuring adequate quality management.	3.4 p.40	An integrated management system is in place to support the efficient implementation of activities. In order to properly trace the numerous case studies and calculations, each with their own sets of data and hypotheses, the IRT recommends, as mentioned above, the implementation of a configuration management as part of the overall management system. The configuration management should be coupled with requirement management and enable recording of the various technical options studied as well as the sets of calculations associated with each of them. The scope of configuration management should be adequately adjusted, considering the nature of the DGR and the phase of implementation.	As mentioned in the response to comment 2.6-2, a wide range of studies will need to be carried out in response to various conditions in the future, such as changes of waste inventory, updates of the Site Describe Model to reflect the progress of site investigations. We assess impacts on repository design and safety assessment based on this information. To ensure that changes to the safety cases due to these studies are implemented consistently and transparently, and to manage the complexity of handling different versions of input data and resulting output from these studies, we agree with the comment from the IRT that it is necessary to apply a configuration management system. This will be integrated with requirements management, so that evolving case studies can be managed in an integrated manner throughout the entire lifecycle. Therefore, we will continue to study the development of a system suitable for geological disposal projects, referring to examples of the application of configuration management systems in general industry and related nuclear facilities.
3.4-9	3.2 p.36	NUMO has demonstrated its ability to conduct safety studies. NUMO conducts its safety assessments and draws up its safety cases consistent with international recommendations and practices, in particular those proposed by the NEA (NEA, 2005) and the IAEA (IAEA, 2012) as well as with other international practices. Numerous studies in support of the safety demonstration, and the resulting models, illustrate NUMO's ability to represent geological disposal and to describe and analyse its possible evolutions. Here again, the limitations of the exercise are due to its generic nature. This results in high levels of uncertainty: however, many of these will be gradually reduced over the successive phases of investigation.	3.4 p.39 p.40	(Summary in the box in the page 39) Additional phenomena: to explore the phenomena considered at this stage as non-dominant or non-determining in order to assess how they should or should not be taken into account in subsequent phases. (In the text) The design of the repository is, at this early stage, accompanied by numerous uncertainties. NUMO has considered major phenomena likely to affect the evolution of the repository and therefore its safety. For subsequent phases, the IRT sees a need to evaluate also phenomena that have at the present stage been disregarded with the justification that they are of secondary importance for the system evolution.	As mentioned in the response to comment 2.5-5, NUMO recognises that it is necessary to analyse primary and secondary processes in a comprehensive and systematic manner. Secondary phenomena which will occur in the repository are treated rather simply in the NUMO Safety Case, but these will receive more attention in future safety cases as part of our goal to enhance assessment reliability. In collaboration with partner organisations, NUMO is developing technologies which evaluate evolution and degradation processes occurring in near field more realistically (see the response to comment 2.3-2). We are also developing a site descriptive model which can include changes of deep subsurface environments in time and space in a realistic manner (4-dimensional site descriptive model). Generally, NUMO will develop technology for evaluation of interaction between processes occurring in the repository as specified in the Overall R&D Plan, together with revision of relevant FEPs (see the response to comment 2.5-1), to improve the reliability of assessment of long-term safety function evolution.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
3.4-10	3.1 p.34	NUMO benefits from national experience, notably in terms of radioactive waste and studies in underground laboratories. It also has access to many institutions able to support it in its scientific and technological developments, whether geological, physical, chemical or digital. NUMO also has access to underground working technologies and nuclear technologies that could effectively contribute to the development of the geological disposal project in Japan.	3.4 p.39 p.40	(Summary in the box in the page 39) Handling and emplacement of waste packages in disposal tunnels/vaults: to be studied, with tests in an underground environment. (In the text) Studies on disposal packaging should continue, in particular with handling and emplacement tests in an underground environment.	Demonstration tests of handling and emplacement of an overpack encapsulating simulated vitrified waste in the underground environment have been conducted by JAEA at 350 m depth at the Horonobe URL. NUMO will determine our needs for such demonstration tests in the underground environment when planning operational process confirmations to be carried out by related domestic R&D organisations and reflect them in the future Overall R&D Plans. In addition, NUMO will analyse a wide range of information about demonstration tests of emplacement for waste similar to encapsulated vitrified waste or TRU waste packages, which are planned in underground research laboratories in Japan and overseas. NUMO will, to the extent possible, also participate in such collaborative research. In the second half of the Detailed Investigation stage, NUMO will demonstrate the techniques for handling and emplacement of vitrified waste the overpack and TRU waste package to confirm quality control processes in the specific underground environment at selected sites. Such knowledge will feedback for improvement of handling and emplacement techniques.
3.4-11	3.2 p.36	Disposal design, while again generic by nature, also appears to be at an advanced stage of maturity. It builds on international experience, but is also based on targeted developments, as illustrated by the concept of PEM. The studies carried out and the tests and models show that the needed technologies are available, and, above all, that the teams are able to develop them to meet the specific needs that could arise during subsequent phases of the geological disposal project. One of the major challenges, when real sites are studied, will consist in adapting the concepts to the real characteristics of the geological environment in order to ensure post-closure safety over a very long-time frame.	3.4 p.39 p.40	(Summary in the box in the page 39) Design developments: to be continued, particularly with a view to adapting to the characteristics of the sites that will be considered for future studies. (In the text) The IRT encourages NUMO to continue its design developments, particularly with a view to adapting to the characteristics of the sites that will be considered for future studies.	The design methodology developed in the NUMO Safety Case will be applied to the geological characteristics obtained from site investigations and modified to meet site-specific challenges. Repository design tailoring to the geological environment conditions will be performed step-by-step, with iterative feedback to the site investigation. NUMO will continue to develop the design system based on the methodology presented in the NUMO Safety Case, which is stated clearly in the Overall R&D Plan.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
3.4-12	3.4 p.40	The approach to operational safety is also at a preliminary stage. The IRT acknowledges NUMO's development of a preliminary assessment at the current stage of the programme, based on generic assumptions and an early conceptual design.	3.4 p.39 p.40	(Summary in the box in the page 39) Operational safety: to be supplemented by design features allowing the reduction of operational risks, and operational safety assessment to be supplemented by taking into account possible failures of the protections envisaged by design and by analysing resultant doses to workers and to the public. (In the text) The approach to operational safety is also at a preliminary stage. The IRT acknowledges NUMO's development of a preliminary assessment at the current stage of the programme, based on generic assumptions and an early conceptual design. For future safety cases, the IRT recommends considering additional design options for mitigation of operational risks (e.g. fire). The IRT also recommends that the safety assessment be supplemented by including additional scenarios, such as potential failures of the protections envisaged by design and by including all potential exposure pathways to workers, to the public and to the environment.	As mentioned in the response to comment 2.4-2, in the design study for operations, risks during operations will be reduced through the stepwise refinement of the repository design and operational methodology as site selection progresses. The effectiveness of the design, and safety measures to counter any identified risks, will be confirmed using advanced safety assessment methodologies, as described in the response to comment 2.4-1. Design options that effectively contribute to reducing identified risks should be considered, utilising the latest knowledge at each project stage. Assessment will include facilities and equipment for a series of operational processes, including waste reception, inspection, packaging, transportation in access tunnels, and emplacement in disposal tunnels. For example, identified counter-measures would use of fire-resistant equipment and incombustible materials to combat risks of fires. As mentioned in our response to comment 2.4-4, and in line with the Overall R&D Plan, the safety assessment scenarios considered will be further expanded to improve the coverage of external events such as earthquakes and tsunamis, together with internal perturbing events that are expected to occur in the repository. In addition, we will develop scenarios for common-mode failures that could cause loss of multiple safety functions. We intend to also evaluate potential impacts of radionuclide release, even if only as what-if scenarios. We will also develop a method to quantitatively evaluate the impact based on the safety assessment scenarios considered (see the response to comment 2.4-3). We will analyse exposure pathways for both workers and the general public, based initially on examples of repository designs presented in the NUMO Safety Case. This will allow us to study necessary safety counter-measures, as well as utilising safety assessment to plan measures to be taken in the event of a hypothetical release of radionuclides.
3.4-13	3.4 p.40	The long-term safety assessment is based on many assumptions that are considered very conservative at this stage. Consequently, the results of the different cases studied are often quite similar, and do not provide more detailed information for discriminating among design options and/or potential host geological formations.	3.4 p.39 p.40	(Summary in the box in the page 39) Design and construction procedures to be adapted to the particular characteristics of the geological formations envisaged for the following stages in a way that allows contrast between formations being reflected in the design. (In the text) The long-term safety assessment is based on many assumptions that are considered very conservative at this stage. Consequently, the results of the different cases studied are often quite similar, and do not provide more detailed information for discriminating among design options and/or potential host geological formations. It is reasonable to imagine that the means of design and construction will be adapted to the particular characteristics of the geological formations envisaged for the following stages, and hence that contrasts between formations should be reflected in the design.	As mentioned in the response to comment 2.7-3, the features of design options tailored to hydrogeological structures were illustrated in the NUMO Safety Case. For example, the PEM has advantages in terms of reducing the risk of erosion of the bentonite buffer in case of water inflow during waste emplacement in the disposal tunnel, while dead-end disposal tunnels have more flexibility in terms of avoiding highly permeable hydrogeological structures. NUMO will further develop the facility design methodology to tailor the various design concepts and their components to features of geological environment in more concrete and detailed manner. The very conservative modelling and setting of parameters for the safety assessment resulted in little difference in the results of the radionuclide migration analysis for different geological environments and design options tailored to them (e.g., vertical emplacement versus horizontal PEM for HLW, dead-end tunnels versus panel-type tunnels for underground repository layout, etc.), This made it difficult to obtain information to determine how the geological environment and design features contribute to system performance. NUMO is currently developing a method to analyse three-dimensional nuclide migration behaviour on a large scale extending from the repository to the biosphere, representing design options and geological characteristics as realistically as possible, in accordance with the Overall R&D Plan (see the response to comment 2.1-3). By applying this method, we plan to better analyse the effects of different geological environments and designs on performance of the repository system.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
3.4-14	3.4 p.41	The presentation of cases using storyboards is relevant. It makes it possible to better understand the different phenomena that must be taken into account at each disposal location, but also as a function of time. Their development could be generalised by seeking a more exhaustive representation of the underlying information and the data to be processed.	3.4 p.39	(Summary in the box in the page 39) Development of storyboards to be generalised, by seeking a more exhaustive representation of the underlying information and the data to be processed.	As mentioned in the response to comment 2.5-4, NUMO also recognises the storyboards are a valuable tool. Following the Overall R&D Plan, the storyboard technique is being improved to describe the understanding of system temporal and spatial information in a more detailed and visually-attractive manner. In addition, storyboards that comprehensively represent the behavior of geological disposal systems are used to guide the development of computerised tools, described in the response to comment 2.5-2, that link the processes of scenario development, modelling and dataset of nuclide migration analysis, which will efficiently manage information related to their decision-making and evidence. NUMO will develop this tool in line with the Overall R&D Plan.
3.4-15	2.5.4 p.30	In the IRT's view, a brief summary in the main report of the mathematical models and their limitations (assumptions, simplifications) vis-à-vis the conceptual process models would improve clarity of the safety case. A chart of the models implemented would also be useful to illustrate the link between the complexity of the physical processes analysed and simplifications essential for a macroscopic representation. Both these measures would make the safety case clearer for generalists, and also provide context for specialists involved in detailed analyses.	3.4 p.39 p.41	(Summary in the box in the page 39) Models and couplings: to establish a mapping of the various models included in the assessment, their couplings, and the associated codes. This would provide an overview of modelling efforts, make it possible to illustrate the adaptation of the various tools at the level of analysis, as well as to better understand the simplifications of representations proposed. (In the text) Finally, a mapping of the various models included in the assessment, their couplings and the associated codes would be beneficial. It would provide an overview of modelling efforts, make it possible to illustrate the adaptation of the various tools at the level of analysis, as well as to better understand the simplifications of the proposed representations. In this framework, the IRT recommends taking up arguments from underlying reports to substantiate decisions for screening processes to be considered at the different levels of modelling.	As mentioned in the response to comment 2.5-6, based on IRT's recommendation, NUMO has begun to construct a flowchart which describes all the models and codes for assessing the THMC evolution of the repository within the NUMO Safety Case. This includes analysis of radionuclide migration for scenarios developed on the basis of such THMC evolution and resultant calculated dose rates, with explicit illustration of input and output links between assessment models. Models and codes developed or improved after the NUMO Safety Case are being added to the flowchart implemented in NUMO's information management system for post-closure safety assessment (see the responses to comments 2.5-2 and 2.5-4). To improve the transparency of our safety case, NUMO is planning to enhance the flowchart by adding brief descriptions for all models and codes used to support the safety case. This will be complemented by information on all safety case models and codes within NUMO's information management system.
3.4-16	2.5.4 p.30	The set of calculations carried out for different disposal configurations and conditions illustrates the capability of NUMO to adequately represent the system for various conditions, and to carry out the required set of consequence calculations underpinning a safety case. The numerical modelling seems mature enough to simulate site-specific systems, and to consider different disposal configurations and conditions.	3.4 p.39 p.41	(Summary in the box in the page 39) Validation of the models and the computer codes: to increase efforts to validate models and computing tools in the near future. (In the text) To provide further confidence in the results of modelling, there is also a need to further validate the models and the computer codes used in the safety case. The IRT recommends NUMO increase its efforts on this work in the near future.	As mentioned in the response to comment 2.7-6, as IRT noted, validation of simulation models and codes is crucially important to build confidence in the safety case. We are developing a systematic methodology of verification and validation, including both testing against observational data and critical expert review. According to the Overall R&D Plan, NUMO will continue to expand verification and validation of simulation models and codes in the future.

Annex D. Summary of IRT's comments, findings, recommendations for each of the sections of NUMO's pre-siting safety case

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
D-1	D2.2 p.53	The basic concept for ensuring the long-term safety of geological disposal is expressed in terms of 2 key functions, namely isolation and containment. The latter covers the notion of containment as well as retardation, this being clearly indicated in the report.	D2.2 p.53	However, in order to avoid any risk of confusion, and also to clearly distinguish the physical phenomena and the processes involved in order to be able to analyse them distinctly, it is recommended to adopt the terminology that clearly distinguishes between containment and retardation.	The NUMO safety case uses the term "containment" as a concept that includes both "confinement" and "delaying" of radionuclides, following the IAEA (2011) definition. However, in some countries, "containment" and "retardation" are expressed separately, and for some stakeholders, "confinement" is associated with complete enclosure of radionuclides, which may cause misunderstandings. Therefore, in the future, we will consider better terminology for these functions.
D-2	D2.6 p.55	The safety case strategy consists of assessing operational and post-closure safety based on information on the selected sites and the associated repository designs and available scientific and technological knowledge, in the light of the relevant regulatory standards and the requirements of the stakeholders. In the NUMO Pre-siting SDM-based Safety Case, generic cases are taken into account in order to demonstrate the ability to develop such a safety case on a real site in the near future.	D2.2 p.53	The main functions identified during operation are containment and radiation shielding. It is also suggested to clearly analyse the risks of criticality as well as the risks linked to the gases which could be generated by radiolysis.	The reason for the negligible criticality risk of vitrified waste, due to uranium and plutonium being extracted during reprocessing, was given in the H12 Report, and it is believed that this argument is still supported today. However, in the future, as we proceed with the examination of a more realistic inventory, including TRU waste and uncertainties in radionuclide concentrations in individual packages (see the responses to Comments 2.1-2, 2.3-1, 2.4-1, 2.6-1, 3.1-1, 3.3-2 and 3.3-3), we will more comprehensively develop scenarios for operational safety assessment for specific designs and operation methodology (see the responses to Comments 2.4-3, 2.4-4 and 3.4.12). As part of this, with the goal of improving the completeness of safety cases, criticality risks based on waste inventories that reflect realistic reprocessing conditions will be included in future safety cases. In terms of hydrogen gas generated by radiolysis during operation, as indicated in the response to comment 2.7-2, TRU waste with a particularly high moisture content will be treated to reduce the amount of hydrogen gas generated. We also recognise that alternative materials in the waste package and the development of a package container with enhanced confinement in the case of gas pressurisation are issues to be studied in the future. Along with solving these technical issues, we will analyse risks during operation and study countermeasures within the comprehensive safety assessment scenarios described above.
D-3	D2.6.2 p.55	The numerical values of the calculated doses can be used as an indicator of the expected performance of the repository, but must be used with caution due to uncertainties, in particular regarding the future biosphere and human lifestyle. To determine the safety assessment period, in the absence of national regulations, those of other countries were at this stage taken into account. The main indicator used for post-closure safety assessment is the human radiological dose.	D2.6.2 p.55	Doses to non-human organisms and impacts of nonradioactive hazardous substances are not included. It is recommended for future developments to consider doses to non-human organisms in relation to the food chain and non-radioactive hazardous substances for their chemical hazard.	As mentioned in the response to comment 2.5-9, the need for radiological protection of the environment, including non-human species, has been suggested in recommendations by international organisations such as ICRP, but is not specifically addressed in many international safety regulations and the nuclear regulations in Japan. It is thus not considered in the NUMO Safety Case. However, in the future, we will pay close attention to international discussions and national and international regulatory trends regarding impact analyses on non-human biota and introduce such considerations as necessary. As mentioned in the response to comment 2.5-7, we plan to extend studies of the risks of radioactive elements to include the identification of toxic chemical substances, and their release and migration characteristics, in cooperation with the reprocessing plant operators who produce this waste. In addition, consideration will be given to trends in domestic and international regulations on hazardous chemical substances and their handling within safety cases in other countries, as well as wider consideration of chemical risk assessment methods. As mentioned in the response to comment 2.5-8, in order to enhance confidence of biosphere assessment reliability, as recommended, NUMO will consider geochemical mechanisms that may cause reconcentration of radionuclides at locations such as interfaces between soil horizons or along redox fronts when developing the current biosphere model further.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
D-4	D2.6 p.55	The safety case strategy consists of assessing operational and post-closure safety based on information on the selected sites and the associated repository designs and available scientific and technological knowledge, in the light of the relevant regulatory standards and the requirements of the stakeholders. In the NUMO Pre-siting SDM-based Safety Case, generic cases are taken into account in order to demonstrate the ability to develop such a safety case on a real site in the near future.	D2.6.2 p.56	It is also recommended to justify or to properly document some of the assertions, such as for example that the uplift or the erosion could be negligible from a judicious site selection. Since the criteria are not reported, the evaluation of this type of assertion is challenging.	NUMO agrees with this comment. We think that presentation of evidence for assertions regarding phenomena related to the long-term stability of the geological environment, such as uplift and erosion, need to be explicitly highlighted when constructing safety cases for a geological disposal system in Japan. The SDM should take into account long-term evolution in topography and geological structures due to uplift and erosion and the associated changes in relevant characteristics of the deep geological environment. These processes are, however, strongly dependent on site-specific conditions. As shown in the NUMO Safety Case, appropriate site selection should ensure that any repository host rock considered is sufficiently deep to be unaffected by uplift and erosion, and that favourable geological characteristics will be maintained over a sufficiently long period of time. The SDMs were developed for such a deep host rock, which can be assumed to change slowly, but have little significant impact on the design and safety assessment of the repository. In addition, uplift and erosion over 1 million years has been quantified in the area of "assumed to be favourable" in the "Nationwide Map of 'Scientific Features' relevant for Geological Disposal". This is without consideration of specific topographical and geological factors that represent conditions for particular regions, or the spatial-temporal scale of the evaluation. As a result of such evaluation, the depth of the disposal site after 1 million years should be approximately 300 m or more below the ground surface. This indicates that it can be assumed that stable geological conditions are maintained over this time period. Since Supporting Report 6-10 was not translated into English and not provided to the IRT, arguments on geological stability were not sufficiently conveyed to reviewers. In the development of site-specific safety cases, influence of long-term geological evolution due to uplift, erosion, etc. on geological disposal system will be taken into account. These will be based on evidence from site-specific characterization and will be documented carefully to cover the highlighted concerns.
D-5	D2.7.2 p.56	Given the complexity of the repository system (various processes [THMCR] with couplings, multiple spatial scales and characteristic time scales), it is necessary to identify uncertainties in a systematic way to ensure traceability and completeness of uncertainty management.	D2.7.2 p.56	NUMO presents the concept of management and the treatment for each type of uncertainty, but the description of the method of identification of uncertainty deserves to be enriched. Because of its importance, it might be useful to consider devoting a separate chapter to dealing with high-level uncertainties. Chapters 3, 4, 5 and 6 could benefit from the inclusion of subsections to discuss how uncertainty is managed for site selection, repository design as well as operational safety assessment and post-closure.	NUMO agrees with this recommendation. In future development of the safety case, the description and treatment of uncertainties will be expanded by adding a section focused on this topic in the main report. Also, we will consider describing how uncertainties are managed in the presentations of site selection, repository design, operational and post-closure safety assessments, and the integrated safety case. This will allow clearer explanation of the information and data on which the treatment of uncertainty is based, which is presently described only in the supporting reports.
D-6	D2.7.2 p.56	Given the complexity of the repository system (various processes [THMCR] with couplings, multiple spatial scales and characteristic time scales), it is necessary to identify uncertainties in a systematic way to ensure traceability and completeness of uncertainty management.	D2.7.2 p.56	It might be useful to discuss in more detail the extent of "acceptable" conservatism, for example that models should not include an excessive amount of conservatism. As an illustration, when selecting a site, this could lead to evaluation bias. An important aspect is also how conservatism is explained to the reader, especially the non-technical reader who might be guided on how to understand and interpret the results. For the clarity of the approach, it is also suggested to identify separately what comes under variability from what comes under uncertainty, although the processing may involve identical methods.	NUMO has made progress in understanding uncertainties associated with the waste inventory and its characteristics (see responses to comments 2.1-2, 2.3-1, 2.4-1, 2.6-1, 3.1-1, 3.3-2 and 3.3-3) and developing analytical models that can more realistically assess performance of repository system (see responses to comments 2.3-2 and 2.5-5). For these evaluations, we will clarify what causes uncertainties associated with the evaluations, including the inherent uncertainty of the fields and phenomena to which these analytical models and associated data are focusing on, and the technology will be developed to quantify such information so that evaluations can be performed without over-conservatism. NUMO aims to explain a sequence of work based on this approach to different stakeholders in a transparent and traceable manner.

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
D-7	D2.7.7 p.57	The IRT noted NUMO's commitment to basing its studies on the best available technologies.	D2.7.7 p.57	However, it would seem judicious to NUMO to also consider the scheme adopted in many large-scale projects with the technology readiness level (TRL) Scale to assess the evolution and maturity of the geological disposal project.	As recommended, when integrating the latest scientific knowledge and past R&D on geological disposal and preparing to advance stepwise site investigations, repository design, and safety assessment, we will consider the objective assessment of the maturity of all technologies using the TRL scale. This can contribute to improving the efficiency of technical work and also supporting arguments for safety cases. We will consider introducing the TRL scale (or an equivalent measure) in the future.
D-8	D2.7.9 p.57	The sensitivity of the various stakeholders and populations to nuclear issues, and therefore in this case to the disposal of radioactive waste, means that the information, communication and dialogue should be proposed and presented. The societal approach is also part of the safety case, as indicated in numerous publications under the aegis of the NEA, and also taken up by the NUMO teams during the Global 2015 Conference.	D2.7.9 p.57	The IRT recommends that NUMO consider this issue as soon as possible and devote the necessary development to it in the next phases of the safety case.	NUMO recognises that promoting dialogue and communication with stakeholders using the safety case is an important issue. For example, NUMO has been participating in OECD/NEA FSC activities for many years. In addition, the Japan Atomic Energy Society has also established a special committee to support research on the social science aspects of this issue and to study methodologies for promoting communication of the safety case for geological disposal to various stakeholders. This committee includes both experts in the social sciences and other relevant fields. We will continue to strengthen these activities based on the advice of domestic and international experts.
D-9	D3 p.58	The site descriptive model (SDM) approach developed by NUMO seems suitable. Models make it possible to provide design and safety assessment with fully integrated comprehensive data rather than field data. Models will be refined along with the progress in siting and field survey. The generic safety case developed in the SDM-based Safety Case is based on three typical models covering various types of potential geological formations encountered in Japan. Chapter 3 justifies in detail the elaboration of these models. This approach is relevant at this stage.	D3 p.58	For Neogene/Pre-Neogene volcanic and metamorphic rocks, the decision was made at this stage to not elaborate specific SDMs as three representative SDMs are considered to cover the characteristics of these rocks. It is however recommended that, as soon as field data become available, the characteristics of these formations be differentiated from those of volcanic and igneous rocks.	As recommended, if information on Neogene/Pre-Neogene volcanic and metamorphic rocks is obtained, either from specific site investigations or from future additions to information in the general literature, consideration will be given to developing these specific SDMs if this is of relevance to any sites.
D-10	D3.3 p.60	For the development of SDMs for representative host rock settings, several characteristics are compiled and then selected to provide as much representative cases as possible. Conceptual models are proposed, but they would gain in justification with a finer description of the methodology of their development. In particular, it will be necessary to describe how the field data will be used to arrive at the conceptual model. For Neogene/Pre-Neogene volcanic and metamorphic rocks, no specific SDM is elaborated. Three representative SDMs are considered to cover the characteristics of these rocks and used for design and safety assessment for the safety case. For the specific sites, respective SDMs are developed based on the literature and characterisation.	D3.3 p.60	Hydraulic conductivity is a key parameter for the different geological formations and could be very discriminating in terms of post-closure containment performance. It is thus recommended to use the most possible representative values rather than having almost the same value for all.	Representative hydraulic conductivities for Neogene/Pre-Neogene volcanic and metamorphic rocks were obtained. If further information on these rocks is obtained, either from specific site investigations or from future additions to information in the general literature, we will consider refining the SDMs for Neogene/Pre-Neogene volcanic and metamorphic rocks. In the SDMs for specific sites, the heterogeneity of hydraulic conductivity of geological formations will be determined based on borehole data and directly considered when addressing safety-relevant issues, such as more realistic assessment of radionuclide migration characteristics. Here we consider impacts on performance indicators for the host rock and surrounding formations. Thus, in addition to refinement of the radionuclide migration model in the geosphere (see responses to comments 2.1-3, 2.1-4, 3.4-1 and 3.4-3), we take such heterogeneity into account during tailoring designs (see responses to comments 2.3-3 and 2.5-5), setting of parameters for sensitivity analysis, and general treatment of uncertainty (see comment 3.1-1).

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
D-11	D6.3 p.68	Storyboards are mostly used to describe the behaviour of the system after the disposal facility is closed. This is a relevant way of illustrating the successive periods of disposal evolution.	D6.3 p.69	Such storyboards would also be a good basis for analysing the effects of uncertainties. The IRT strongly recommends developing the work already well underway from the storyboards for the next stages of the geological repository project in Japan. These can also be a good way to communicate with stakeholders and the public, making it clear that storyboards help to understand all of the underlying processes and assumptions that need to be considered.	As mentioned in the responses to comments 2.5-4, 2.7-5 and 3.4-14, storyboards, as knowledge management and communication tools, are recognised as valuable to promote common understanding of evolution of the repository system on a range of temporal and spatial scales. These can also contribute to effective integration of safety case development by the site investigation team, the repository design team and the safety assessment team. Additionally, as IRT noted, the storyboard can function as a tool which promotes communication with various stakeholders and, in particular, the general public. With a focus on the function as a communication tool, the storyboards shown in the NUMO Safety Case are planned to be improved to visually illustrate temporal and spatial evolution of geological repository in much more detail. This can also cover the representation of uncertainties, particularly in terms of long-term evolution.
D-12	D6.2 p.68 D6.3 p.69	The role of the integrated FEPs is to group the FEPs in blocks to structure the impact analysis. As they are general in nature, e.g. "water chemistry", they do not seem to be used as such in the impact analysis. The role of the integrated FEPs vs the individual FEPs in the impact analysis should be developed. An example of a list of FEPs that are grouped into one integrated FEP would help illustrating the approach. The NUMO FEP list used in the SDM-based safety case would be useful; it may be updated next on the basis of more recent publications by the NEA.	D6.3 p.69	NUMO applies a structured approach to the development of scenarios, using safety functions, state variables, factor analysis diagrams and impact analyses, and the IRT encourages the further development of these tools.	The NUMO FEP knowledge base will be regularly expanded and updated to represent the latest scientific knowledge, while introduction of digital tools aims to improve the transparency and traceability of FEP screening and integration into scenarios (see responses to comments 2.5-1 and 2.5-2). Moreover, based on this knowledge base, the methodologies and tools related to the scenario development process, such as setting up state variables, factor analysis, impact analysis, and clarifying the relationship with safety functions, will be further developed. The update of this knowledge base will also include detailed studies on FEPs which are currently considered as secondary, as described in the responses to comments 2.5-5 and 3.4-9. All this will proceed in parallel to the development of tools for the integrated knowledge management extending from the development of FEP lists to final scenario development (see responses to comments 2.5-4, 2.7-5 and 3.4-14).
D-13	D6.6 p.70	Based on the experience of the present safety case, future development needs can be ranked in terms of their perceived importance, and also according to the overall agenda of geological disposal in Japan. The most sensitive phenomena and processes will be a first key for ranking, but other criteria will also be defined. In any case, the development programme will be built so that major milestones are met.	D6.6 p.70	In addition to the development needs identified by NUMO, the IRT emphasises the need to improve the understanding of microbial processes. The impact of microbial processes on the performance of the overpack (especially corrosion), buffer and backfill and on radionuclide transport in the geosphere will have to be evaluated.	We recognise the need to better understand the effects of microbial activity on corrosion and, more generally, the impacts of microbial activity in buffer materials and on the underground migration of radionuclides. This is indicated in the Overall R&D Plan. NUMO will continue to expand its knowledge in this area, including utilising joint research with relevant organisations, academic societies, universities and other professional agencies.
D-14	D7.1 p.72	As an alternative dose indicator, NUMO considers transfer of radionuclides to the biosphere in a stylised release to a river, demonstrating that dilution reduces concentrations to insignificant levels.	D7.1 p.72	The IRT encourages NUMO to further develop such cases, e.g. the possibility of accumulation of radionuclides into specific compartments of the biosphere.	NUMO will continue to study complementary safety / performance indicators, in particular by monitoring safety cases developed by other countries. As mentioned in the response to comment 2.5-5, we are developing site descriptive models which can realistically describe changes in time and space on the large scale extending from deep underground to the biosphere (4-dimensional site descriptive model). NUMO will improve the biosphere assessment model by considering long-term evolution of the surface environment (derived from the 4-D SDM) as well as any geochemical mechanisms that might cause reconcentration of radionuclides at locations such as interfaces between soil horizons or along redox fronts (mentioned in response to comment 2.5-8). In addition, NUMO will also study the approach to assess the cases in which radionuclides accumulate into specific compartments in the biosphere while improving biosphere assessment model mentioned .

No.	Observations from IRT		Recommendations from IRT		NUMO's responses to comments
D-15	D6.2 p.68 D6.3 p.69	The role of the integrated FEPs is to group the FEPs in blocks to structure the impact analysis. As they are general in nature, e.g. "water chemistry", they do not seem to be used as such in the impact analysis. The role of the integrated FEPs vs the individual FEPs in the impact analysis should be developed. An example of a list of FEPs that are grouped into one integrated FEP would help illustrating the approach. The NUMO FEP list used in the SDM-based safety case would be useful; it may be updated next on the basis of more recent publications by the NEA.	D7.2 p.73	NUMO has introduced the concept of state variables and factor analysis diagrams as tools for evaluating safety functions in the development of scenarios, and, as mentioned, the IRT encourages the further development of these tools.	As mentioned in the response to comment D-12, NUMO will continue to develop and improve tools for evaluating safety functions as part of scenario development. This runs in parallel with work to continuously update the FEP knowledge base, while also improving traceability and user-friendliness by introducing modern digital technology.

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