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Strategy for implementing TSO`s R&D programmes

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Abbreviations

CNCS	Canadian Nuclear Safety Commission
DGD	deep geological disposal
EBS	engineered barrier system
ELI	Ministerie Van economischeZaken, Landbouw en Innovatie, Netherlands
FANC	Federal Agency for Nuclear Control, FANC, Belgium
FEP	Features, Events, Processes
HLW	high level waste
GD	geological disposal
GRS	Gesellschaftfür Anlagen-und-Reaktorsicherheit, GRS, Germany
IAEA	International Atomic Energy Agency
IGDTP	Implementing deep geological disposal platform
IRSN	Institut de Radioprotection et de Sûreté Nucléaire, IRSN, France
LEI	LietuvosEnergetikosInstitutas, Lithuania
NEA	Nuclear Energy Agency
NWMO	nuclear waste management organisations
OECD	Organisation for Economic Co-operation and Development
PA	performance assessment
R&D	research and development
SC	safety case
SF	spent fuel
SRA	Safety Research Agenda
SUJB	Czech regulatory body
THMC	thermo-mechanical-chemical
TSO	technical support organization
URL	underground research laboratory
WIPP	Waste Isolation Pilot Plant
WMO	Waste Management Organisation

2 Foreword

The objective of the FP7 program SITEX project is to set up a network capable of harmonizing European approaches to safety review of geological disposals for radioactive waste. Lasting 24 months, SITEX brings together 15 organisations representing technical safety organisations (TSOs) and safety authorities, as well as civil society outreach specialists. In particular, SITEX plans to help establishing the conditions required for developing a sustainable network of technical safety experts who have their own scientific skills and analytical tools, independently of the operators, and who are capable of conducting their own research programs.

3 Summary

This report proposes the framework for developing and implementing the scientific research needed by the expertise function in order to developing at the appropriate level the skills and independency of the experts in charge of reviewing the safety case. This strategy relies on the outcomes from SITEX deliverables D3.1 and D3.2 and from the exchanges with waste management organisations through the IGD-TP Exchange Forum 4 and with representatives of civil society organisations met at the SITEX meeting organised in SENEC.

SITEX developed a common view on the scientific and technical knowledge needed by the expertise function for reviewing the safety case. SITEX identified available resources/installations/codes that are already used in order to develop scientific skills of experts where needed. **This cartography will be further used to identify potential for cooperation ad sharing of resources amongst SITEX**.

A SITEX **Strategic Research Agenda** (SRA) will be further developed that will outline the research and development activities that are currently performed or should be further undertaken to gain independent understanding of key safety topics and issues. The SRA should be framed considering the concerns from experts that justify running scientific research programs or activities. **This justification relies on the needs for investigating specific safety issues that deserve an independent view from the reviewer or are not considered (or not sufficiently) by the implementer, and require a particular attention**.

A key issue is the way of governing the implementation of such SRA in the international context of **EURATOM joint programming**, **in particular with WMOs and stakeholders from the civil society**.

4 Introduction

One objective of SITEX is to set the conditions for building a framework that will allow structuring Expertise Function R&D activities with respect to priorities, dialogue with WMOs and civil society, and considering the available means in terms of technical tools, manpower and funding. Cooperation with WMO's, in particular in the framework of EC joint

programming is a key challenge to develop and maintain scientific skills at the highest international level, when in the meantime the preservation of independency of experts when reviewing the safety case developed by the operators is of key importance.
The purpose of SITEX deliverable D3.3 is to summarize the main technical and scientific areas where experts must be able to deliver their own opinion, to map the available scientific and technical resources within SITEX and to propose the main lines that should drive the development and implementation of the SITEX Strategic Research Agenda (SITEX SRA) for expertise function purpose.

The following organizations contributed to this report:

- Bel V, Belgium
- Canadian Nuclear Safety Commission, CNSC, Canada
- DECOM SA, Slovakia
- Federal Agency for Nuclear Control, FANC, Belgium
- Gesellschaftfür Anlagen-und-Reaktorsicherheit, GRS, Germany
- Institut de Radioprotection et de Sûreté Nucléaire, IRSN, France
- Lietuvos Energetikos Institutas, LEI, Lithuania
- Ministerie Van economische Zaken, Landbouw en Innovatie, ELI, Netherlands
- UJV Rez, a.s. Czech Republic

5 Common views on scientific and technical knowledge needed for reviewing the safety case

Scientific and technical knowledge of major importance, needed for performing a relevant safety review, was identified on the basis of the key safety issues which characterize SITEX partner's national radioactive waste Deep Geological Disposal (DGD) programs.

This analysis addressed long-term safety as well as operational safety. Knowledge needed for reviewing the safety case is classified along the main concerns for the review:

- (A) the quality of the data on which rest the safety demonstration;
- (B) the understanding of the complex processes which may potentially influence the long term safety of the DGD;
- (C) the assessment of the future evolution (in spatial extent and intensity) of these potential processes, as well as the assessment of their impact on the DGD safety;
- (D) the identification and characterisation of the potential hazards to occur during the construction and operation of the DGD.

Such categorization of knowledge is derived from the approach that is followed when reviewing the safety case (see D2.1/D4.1). As a matter of fact, expertise functions aims at assessing in particular the following specific aspects of the safety case demonstration:

- the capability of the implementer to properly justify the methods used to obtain data and the confidence in the data,
- the capability of the implementer to explain the processes that govern the performance of the components and their ability to achieve the safety functions,
- the capability of the implementer to perform the long term evolution of the disposal taking into account the influence of the uncertainties on the different potential evolutions,
- the due consideration of potential hazards that could impair safe operation of the waste emplacement, considering the influence of accidents during operational phase on the long term safety.

Each of these axes is described in the following subsections. For each subsection, a set of scientific knowledge considered as necessary for being able to perform the review is identified. Indications are provided on some concerns of particular interest for further consideration and, where needed, for further research activities.

5.1 QUALITY OF INPUT DATA

The relevance of the long-term and operational safety demonstrations that will be provided by the operator for the DGD notably rests on the quality of the data, which characterize the DGD system. The quality of the data provided by the operator for the operational and long-term safety demonstrations principally depends on their accuracy and relevance, as well as on their representativeness of the in situ properties of the DGD system.

Expertise function must be able to assess whether the methods and tools used to obtain the data for the safety case are appropriate depending on the characteristics of the DGD (variability of natural and exogenous materials, variability of processes, etc…), the purpose of the demonstration and the domain of validity of the method used.

In particular, SITEX is concerned by :

- the upscaling approaches for the data evaluated at small scale and their representativeness for the whole DGD system;
- the methods dealing with system heterogeneity.

5.2 UNDERSTANDING OF COMPLEX PROCESSES

In order to design the DGD and to demonstrate its long-term and operational safety, WMOs have to demonstrate that the key processes (i.e. Thermal, Hydrological, Mechanical and Chemical processes and their related couplings), which govern the evolution of the DGD, are understood and bounded in order to cover the remaining uncertainties. Reviewers have to build confidence in the understanding developed by the operator. For that purpose, reviewers must develop appropriate knowledge to understand:

- the processes on which rest the performances of the four main components of the disposal system (waste forms, canister and overpacks, Engineered Barrier System (EBS) and geosphere);
- the processes resulting from potential internal and external perturbations of the DGD (during operational phase and after closure). In particular, potential interactions between the four main repository components (waste/host-rock; waste/EBS interactions; EBS/host-rock interactions), perturbations due to construction and operation of the disposal are of major concern (see SITEX D3.1);
- The monitoring issue. Monitoring should define the reference state of the system (normal/expected evolution) and methods have to be designed in order to detect deviations from this reference state. During construction phase monitoring should be performed as for civil engineering/mining objects. During operational phase it should confirm the expected evolution of DGD and be used to update the safety case.

5.3 ASSESSMENT OF EXTENT, INTENSITY AND IMPACT OF PROCESSES

In order to demonstrate the long-term and operational safety of the repository, operators have to assess the spatial extent and the intensity of the processes resulting from the internal and external perturbation of the DGD and the potential radiological impact that would results from these evolutions. This assessment is mainly supported by modelling activities.

The review extent and intensity of these processes relies first on the assessment of the two previous issues (data quality and description of processes). On the basis of this understanding, the numerical models, the development of scenarios and the methodology followed to manage the uncertainties are key parts of the review.

SITEX identifies following scientific and technical knowledge needed for reviewing:

- the relevance of features, events and processes (FEPs) and scenarios of DGD evolution. The definition of design basis and beyond design basis scenarios remains a key concern;
- the influence of the level of abstraction and simplification (of mechanical, hydrological, thermal and chemical processes) on the description of the processes and the way to couple the processes is of key importance; this coupling is of crucial importance during the transient phase (several thousand years) where the different processes interact and the system evolve drastically to reach a more stabilized configuration at long term;
- the management of uncertainties (e.g. lack of knowledge, upscaling, mathematical representation of processes included, abstraction/simplification of reality, long-term extrapolation etc.)

5.4 THE OPERATIONAL SAFETY

In terms of methodology of regulatory review, the existing methods already used for various nuclear facilities remains valid and serve as basis for reviewing safety of the operation of geological disposal. But some specific hazards or situations need to be addressed without any substantial feedback experience from the operation of existing nuclear facilities (management of concomitant activities –construction and emplacement of waste canisters-, management of fire in undergrounds, handling of radioactive waste canisters in "mining" conditions…). Parameters associated to the characterization of the considered hazards (fire, flood…) needs to take into account the peculiarities of such a facility. Finally, the identification of Limits, Controls and Conditions for the operational phase remains a challenge, since influence of operating conditions on the long term safety has to be considered;

The table in Appendix presents in detail the above scientific and technical knowledge needed for reviewing the safety case as defined in SITEX D3.1.

6 Development of the Strategic Research Agenda (SRA)

It is proposed to develop a SITEX **Strategic research agenda** (SRA) along the following considerations :

- The identification of scientific areas where expertise function should implement its own R&D activities. Implementation of research is in particular justified when there is a need for investigating specific safety issues that deserve an independent view from the reviewer to perform a contradictory review and check assumptions taken by the implementer with respect to safety. It may concern the analysis of uncertainties and sensitivity of processes to containment capabilities, or issues that are not considered (or not sufficiently) by the implementer, and require a particular attention;
- The identification of issues of common interest and priorities according to the two situations mentioned above;
- The identification of available human skills, experimental installations and computer tools as well as funding provided by national research program owners;
- The identification of potential cooperation with WMOs on the basis of the SRA developed by IGD-TP, paying attention to the governance of joint programmes and use of results, in order to maintain independence of reviewers from the development of the safety case;
- The identification of expectations from the civil society by auditing organisations capable to provide scientific concerns in relation with the protection of the human and the environment; such concerns may influence the orientation of R&D program.

The SRA should be a living document that should be updated during the course of development.

6.1 DEALING WITH HETEROGENEITY OF CONCERNS WITHIN SITEX

R&D activities performed by TSOs and regulatory bodies in the framework of national RWM programmes are of various level of maturity depending on the progress of the national disposal programmes. For this reason, it appears quite difficult to draw full common lessons in terms of key safety priorities and in perspectives for cooperation. Two main situations may be considered: on the one hand that related to processes where the scientific community already made progress and where additional efforts concern specific ongoing development designs in selected sites (for more advanced programmes) - **specific issues**, on the other hand that related to **generic scientific topics** that concern most programmes (more related to the assessment methodology). As far as the DGD programme matures, the knowledge pool increases and uncertainties all together decrease (see following Figure 1).

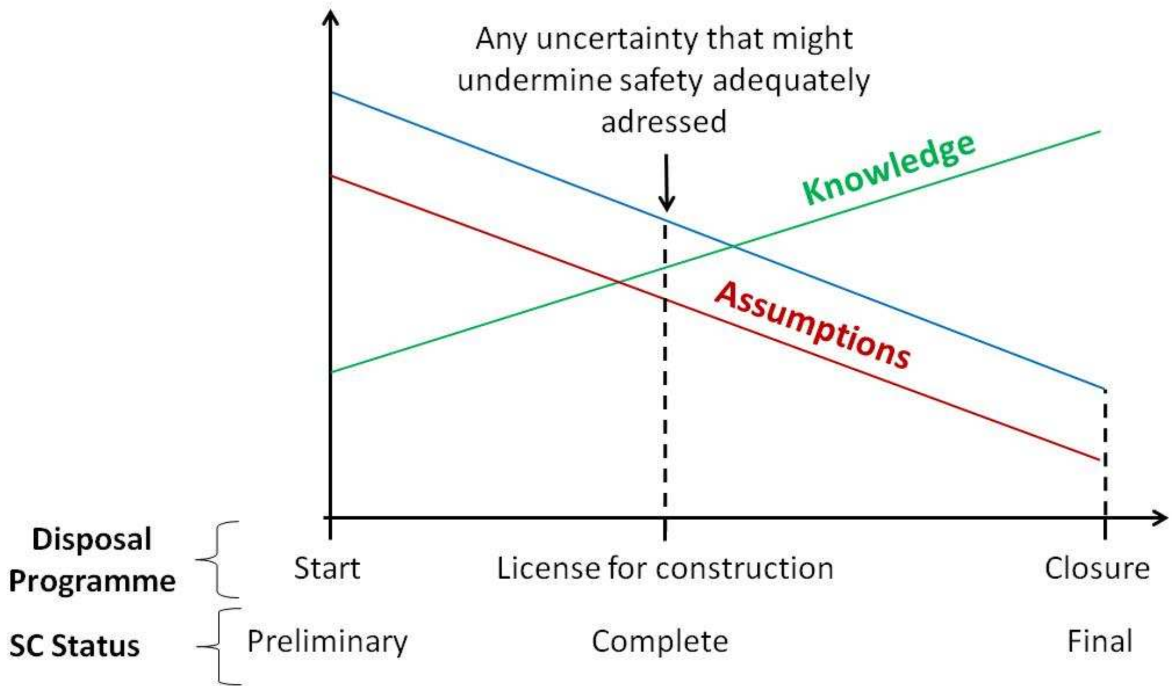

Figure 1 Knowledge pool increase following the disposal programme development (F.Lemy, F. Bernier, Euradwaste, 2013)

Following topics are examples of generic concerns of interest for most programmes :

- Modelling coupled processes during transient phase (interactions that lead to strong evolutions) that specify the conditions for long term evolution,

- Upscaling methods: from lab scale to site,
- Defining basis and beyond design basis scenarios,
- Definition of reference state and monitoring methods to check deviations.

Following topics are examples of more concept specific concerns:

- Waste matrix and source term: bitumen, glass fracturing, gas release, IRF
- Container: corrosion, µ-organisms, radiolysis
- Engineered components: geochemical interactions, behaviour of concrete, performance of seals, role of interfaces…
- Host rock: methods to detect heterogeneities

A possible way for deriving joint scientific activities could be to address two main categories of scientific issues: on the one hand those related to processes where the scientific community already made progress and where additional efforts concern specific ongoing development designs in selected sites (for more advanced programmes), on the other hand those related to generic scientific topics that concern any kind of programmes (more related to the assessment methodology). In general, collaborative programmes do remain of interest on some higher level scientific topics related to components and materials (behaviour of concrete, performance of seals…) or cross-cutting issues and integrated modelling (role of interfaces, coupling of processes for example, transient phase…).

6.2 EXISTING TECHNICAL AND SCIENTIFIC TOOLS FOR IMPLEMENTING THE SRA

SITEX partners own various experimental installations (surface and underground research laboratories) and computational tools aiming at testing extent and intensity of processes and the influence of those processes on safety functions. This set of resources, in combination with associated manpower provided by SITEX, constitutes high level capabilities to implement the future SITEX SRA. It represents a potential pool for exchanges and sharing within SITEX. The two following tables list the set of available installations and codes used by SITEX partners and were compiled on the basis of available information from SITEX D3.2.

6.2.1 Inventory of experimental installations

The following table summarises the scientific installations, available for SITEX beneficiaries. The identified installations are laboratories, mainly designed for radiochemistry, and underground research laboratories. Some of these installations are not owned by SITEX partners but used in the framework of bilateral or international cooperative research programs.

Table 3. Summary of the scientific installations available for SITEX beneficiaries for potential R&D actions

Beneficiary	Labs	Coop/ Subcontracting	URL/ Cooperation in URL	Monitoring (which kind)
BELV FANC	No	IRSN	No, coop in Mont Terri and Tournemire	
CNSC	CANMET-MMSL (radiochemistry, chemistry)	IRSN, universities	No, coop with IRSN	Radionuclides in soil and water
UJV Rez, a.s.	UJV (radiochemistry, migration properties, buffer+backfilil properties, package properties	Universities, research institutions	No, coop in GTS and Josef gallery	GW properties Radionuclides in soil, water and air
IRSN	LAME (physical, radiological, and chemical characterizations of soils, rocks, and waters)	Specialists in Geomechanics	Yes, Tournemire Cooperation in Mt. Terri	Geomechanical properties GW properties System parameter evolution (T, seatide,etc.) Radionuclide monitoring (Rn)
GRS	Geoscientific lab (geochemical and geotechnical issues)	Universities, research centres	Yes (salt mine). Cooperation in Mt. Terri, Bure, GTS	Environmental monitoring (soil, water, air)
LEI	Installation for heat transfer	No	No	Currently not
NRG/ELI	Hot Cell Lab and actinide lab (NRG)	Yes (TNO, Uni Utrecht, GRS)	No, coop with HADES	Cooperation with foreign URLs; in situ demonstration of innovative monitoring techniques
DECOM	No	Yes (GUDS, TechUni)	No	Cooperation (VUJE): Radionuclides in

				soil and air

6.2.2 Inventory of modelling capacities

The following table summarises modelling tools, available for SITEX beneficiaries. The modelling tools are used namely for radiation protection activities, inventory calculations, heat transfer, geochemistry, geomechanics, migration of radionuclides and for dose calculations. Safety assessment category generally refers to migration of radionuclides or combination of process level modelling at large scale.

Table 4 Summary of the modelling capacities available for SITEX beneficiaries to cover specific R&D issues

Beneficiary	**RadProtection/ Inventory**	**Heat transfer**	**Geochemistry**	**Geomechanics**	**Transport, migration**	**Safety assessment**
BELV FANC	RadProtection: MCNPX		PHREEQC		HYDRUS 1D, HYDRUS 2D STANDARD	MELODIE (IRSN), batch calc., sensitivity analyses (own code)
CNSC		COMSOL		COMSOL	MODFLOW, CORMIX	
UJV Rez	Inventory: SCALE, ORIGEN 2.2	TOUGH2	PHREEQC, GWB, TOUGHREACT		TOUGH2, FEFLOW	GOLDSIM, PAGODA, Amber, RESRAD
IRSN	RadProtection: SYMBIOSE, AQUAREJ, FOCON 96, ISIS (fire)		PHREEQC, HYTEC	CASTEM, LAGAMIN	DIPHOM, nSIGHTS (hydraulic tests)	MELODIE
GRS		TOUGH2	PHREEQC	FLAC3D	TOUGH2, MARNIE, FLAC3D, Spring	MARNIE

Beneficiary	RadProtection/ Inventory	Heat transfer	Geochemistry	Geomechanics	Transport, migration	Safety assessment
LEI	Inventory: MCNPX, SCALE RadProtection: MCNPX, Visiplan, Microshield, MicroSkyshine, SCALE	ANSYS/ FLUENT		COMSOL	AMBER, DUST, GENII, GWSCREEN, GoldSim, Petrasim (TOUHG2), COMSOL, Compulink, CHAN3D	AMBER, DUST, GENII, GWSCREEN, GOLDSIM, COMPULINK, CHAN3D
NRG	Inventory: DANESS RadProtection: MCNPX, Visiplan, Microshield, MicroSkyshine, SCALE	TASTE	TOUGHA2, TOUGHREACT ORCHESTRA	EMOS (compaction)	EMOS, REGIS II.1, ORCHESTRA	EMOS, LOPOS, PORFLOW, ORCHESTRA
DECOM	ORIGEN, Scalem Helios (cooperation)				MODFLOW, HYDRUS (VUJE)	GOLDSIM, AMBER

It can be noted that several scientific activities and topics are well covered such as geochemical and geo-mechanical laboratory experiments, use of computational codes for transport modelling and safety assessment etc. On the contrary, some of concept/site specific issues would need to be either developed and sometimes the necessary resources are missing. Where appropriate, some installations owned or operated in priority by implementers, for example in sedimentary rocks – Mol, Mont Terri, Bure etc, can be shared through multi-partners programs, allowing variety of approaches and interpretation of results, that allow to preserve independence of organisations involved.

7 Tentative for identification of potential common scientific issues between IGD-TP SRA and SITEX

At this time, SITEX has not derived formally a SRA stricto sensu but collected and organised scientific topics where expertise function must develop skills and interact with the implementers in order to discuss the relevance of process understanding and of safety assessment. On this basis, a preliminary comparison between these scientific key topics identified by SITEX and the Strategic Research Agenda of the IGD-TP has been carried out in order to browse a first view of commonalities that could eventually lead to future cooperation (see **Erreur ! Source du renvoi introuvable.**). The key scientific topics for SITEX are specified in detail in Appendix 1.

IGD-TP's Strategic Research Agenda (SRA) [2], is dedicated to identifying the main RD&D issues that need a coordinated effort over the next years in order to allow the implementation of a first geological disposal in 2025. IGD-TP identified RD&D issues for which enhanced co-operation within the IGD-TP is considered desirable and practically achievable.
The RD&D issues considered by IGD-TP individual member organisations are, to some extent, dependent on the host rock options pursued and the specific disposal concepts developed. The issues generally fall in one of the three main categories:

- Demonstration of long-term safety.
- Development and demonstration of disposal techniques and components.
- Site characterisation and confirmation of site suitability

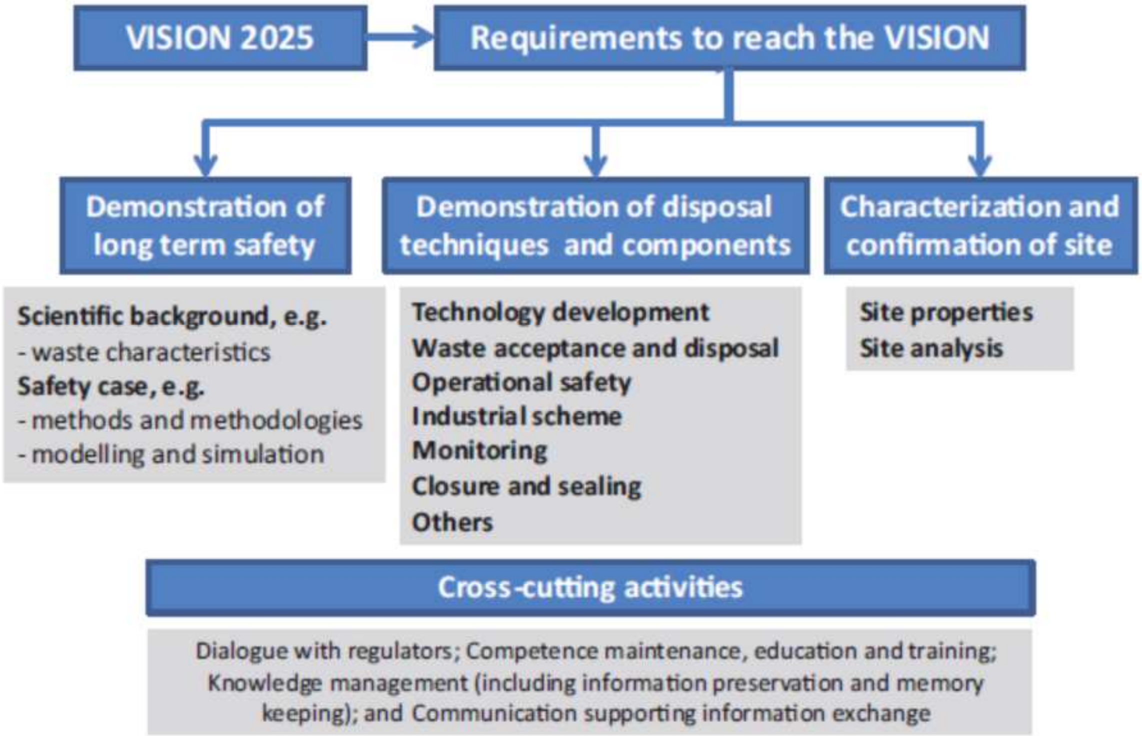

Figure 3: Issues to be considered (grey boxes) during the SRA development and how these can be categorised (blue boxes; [6])

Seven main thematic areas that were defined as Key Topics for IGD-TP.

Table 1: Link between proposed R&D actions, identified within SITEX, and SRA Key Topics.

SRA Key Topic	SRA Topic	SITEX key scientific topics (Appendix 1)
Key Topic 1 Safety case		
	Topic 1 Increase confidence in, test and further refinement of the tools	C1, C2
	Topic 2 Improve safety case communication	Not identified as scientific issues but SITEX WP5 emphasises on modes of interactions with stakeholders and developments are further identified in SITEX D6.2
	Topic 3 Increase confidence in and further refinement of methods to make sensitivity and uncertainty analyses	C3
Key topic 2 Waste form and their behaviour		
H	Topic 1 Improved data for the IRF for spent uranium fuel and improved understanding of its dissolution behaviour in relation to licensing repositories for operation by 2025	A1, B1
H	Topic 2 Improved data and understanding of the release of radionuclides and chemical species from various long-lived ILW	A1, B1, B2, B3, B4, B5, B6, B7, B8
M	Topic 3 Improved data and understanding of the behaviour of MOX fuel – the rapid release fraction and dissolution behaviour under repository conditions	rather considered at this stage as survey activity
M	Topic 4 Further development of burn-up credit methodology and its application for fuels with higher enrichment that allow higher burn-up	A1, B1
L	Topic 5 Improved data and understanding of performance of vitrified high level waste	A1, B1, B2, B3, B4, B5, B6, B7, B8
Key Topic 3a Technical feasibility and long-term performance of repository components. Importance for licensing, description and timing of work (a) – technical feasibility		
	Topic 1. Demonstrations of full-scale operations of HLW disposal containers – including industrial-scale fabrication, encapsulation, container handling and emplacement are required.	not in the scope

	Topic 2. The industrial scale operations for buffer and backfill need to be demonstrated including the entire production and emplacement chain in the repository.	B3
	Topic 3. Construction of main underground facilities: Confirmation of rock properties for final detailed design is required.	A1, A2
	Topic 4. Repository layout design including operational safety studies, see Key Topic 5, and reversibility/ retrievability are needed.	D1
	Topic 5. Pilot demonstrations of repository operations are required.	not in the scope
	Topic 6. Full-scale demonstrations of plugging and sealing including construction and installation technologies for plugs and seals such that all the established performance targets and requirements are met and comply with the safety strategy of the disposal concept are required.	A2, B3, C1 but not with purpose of demonstration
	Topic 7. Knowledge compilation on non-destructive testing (NDT) and related requirements on repository components is required.	not considered
	Topic 8. Knowledge preservation related to retrievability is required.	D1
Key Topic 3b Technical feasibility and long-term performance of repository components. Importance for licensing, description and timing of work- long-term performance		
	Topic 9. Improved understanding of the impact of geochemical evolution on the long-term performance of bentonite buffer in specific disposal concepts developed for crystalline host rocks.	B3, B4, B5, B8 C1, C2, C3
	Topic 10. Description of seals and plugs systems and modelling of their long-term behaviour with assessment of the consequences on long-term safety	B3, B4, B5, B8 C1, C2, C3
	Topic 11. Understanding of the evolution of cement-based seals is required.	B3, B5, B8 C1, C2, C3
	Topic 12. The interaction of cement-based sealing and construction materials with clay-based buffer and seals is also of importance.	B3, B5, B6, B8 C1, C2, C3
	Topic 13. Continued development of low pH concretes is needed to allow them to replace conventional cements and concretes in some application	B3, B6
	Topic 14. Laboratory and modelling work on salt backfill to study its long-term behaviour	B3

	(consolidation, healing, interaction with the surrounding rock, influence of fluids, permeability and porosity). This Topic is specific to salt host rock environments.	
	Topic 15. Investigation of the effects of the iron-bentonite interaction and elevated temperatures (above 100°C) on bentonite buffer material evolution.	B3
	Topic 16. Sharing of knowledge on container materials behaviour is required.	B2, B3
	Topic 17. The emplacement methodology of bentonite directly around waste containers and thereby the influence on thermal effects needs to be optimised.	B2, B3, B5
Key Topic 4: Development strategy of the repository		
	Topic 1. Improved methodologies for developing strategies and approaches for adaptation and optimisation – in order to proceed to the construction of a geological repository, license applications will need to specify how any adaptation and optimisation in design, construction and operations would be managed during the lifetime of the project.	More connected with WP2 (changes in requirements and possible changes in design...) C1
▪ **Key Topic 5: Safety of construction and operations**		
	Topic 1. Improved methodology, approaches and documentation on safety of construction and operations.	D1
	Topic 2. Strategies to evaluate the impacts of construction and operational issues on the disposal system – developing strategies and evaluating the impact on long-term safety, design, complexity and cost of geological repositories for specific operational issues.	B7
▪ **Key Topic 6: Monitoring**		
	Topic 1. Monitoring strategies and programmes for performance confirmation of the repository.	A1, C2 (verification of models and extent of processes), C4
	Topic 2. Availability of monitoring technologies and techniques.	C4
	Topic 3. Monitoring of the environmental reference state.	A1, C2, C4

	Topic 4. Monitoring of engineered barrier systems (EBS) during operations – determination of parameters for monitoring the EBS and the development of appropriate monitoring techniques and sensors.).	A1, C2, C4
	Topic 5. Post-closure monitoring	A1, C2, C4
▪ **Key Topic 7: Governance and stakeholder involvement**		
	Topic 1. Governance of decision-making processes – experience in geological disposal siting programmes world-wide has shown that where the public and other stakeholders have been involved in the decision-making process, decisions with high levels of political acceptance have been achieved, which therefore have an increased likelihood of being implemented.	Issues addressed in SITEX D6.2 as outcomes of WP5
	Topic 2. Use of RD&D results to have open and transparent dialogue with stakeholders and how such results can be reviewed – improved methods, tools and guidance so that the relevant scientific, technical and engineering RD&D results are communicated effectively are required.	Issues addressed in SITEX D6.2 as outcomes of WP5
	Topic 3. Involvement of stakeholders – Development of a repository will be an active presence in a local community during the license application period and even more so when construction and operations commence.	Issues addressed in SITEX D6.2 as outcomes of WP5

This first comparison allows opening dialogue with IGD-TP in order to identify possible joint programming activities in the framework of EC H2020. The development of a SRA for SITEX will consolidate this dialogue.

8 Interaction of SITEX SRA with WMOs and civil society

A special session with SITEX was organised during the IGD-TP Exchange Forum 4, held in Prague, October 29-30, 2013. The participants discussed the possible interactions between IGD-TP and SITEX, preserving the independence of both parties. Following questions were addressed:

1. **Interaction with civil society**
   SITEX was questioned about the role of TSOs in interacting with public. SITEX considered that TSOs can potentially act in complement to WMOs where public

expects an independent view on its scientific and safety concerns and expectations, allowing to enlarge its understanding and knowledge of geological disposal.

2. **Collaborative research and exchange**
   It was agreed that collaborative research could be possible on fundamental issues that deserve international community involvement. But the results should be used independently for the purpose of the safety case building and the safety case review. Beside research cooperation, other topics related to strategic issues on safety approach and governance open possibility for potential cooperation, e.g. reversibility/retrievability, passive safety, long term safety, stability of geological system, impact on future generations, Partitioning & Transmutation etc.

3. **Governance for joint research**
   SITEX and IGD-TP agreed about the importance to elaborate a transparent and approved governance of joint research between WMOs and TSOs. The rules of governance will be developed in the framework of the current 2013 EURATOM call in a coordinated action between organisations from IGD-TP and SITEX.

The SENEC workshop (October 2013, 15 - 18) raised different expectations of civil society actors regarding R&D:

- It is generally expected by the public that the experts should make explicit what is known and what is unknown on a scientific basis, quantifying risks and describing uncertainties. R&D is expected to cover the most problematic areas where additional scientific knowledge is required;
- Definition of SITEX SRA should consider civil society expectations.

9 Identification of modes and opportunities for implementing and communicating SITEX SRA

Ways for implementing and communicating SITEX SRA are of various types: within SITEX network, with ETSON or other TSOs, with WMOs, with European Union, with civil society.

The European Technical Safety Organisation Network (**ETSON**) develops a working group on radioactive waste and this group should be a preferred contact party for interaction with SITEX research.

Interaction with European Union is desirable in order to develop modes of involvement of TSOs, regulators and civil society in the R&D joint programming as defined by **EU H2020** program.

Various modes of collaboration with external entities are further developed in the SITEX D6.2 deliverable that frames the modes of operation and possible opportunities for the future SITEX network.

10 Conclusions

SITEX developed a common view on the scientific and technical knowledge needed by the expertise function for reviewing the safety case. SITEX identified available resources/installations/codes that are already used in order to develop scientific skills of experts where needed. This cartography will be further used to identify potential for cooperation and sharing of resources amongst SITEX.

A SITEX **Strategic Research Agenda** (SRA) will be further developed that will outline the research and development activities, that are currently performed or should be further undertaken, needed to gain independent understanding of key safety topics and issues. The SRA should be framed considering the concerns from experts that justify running scientific research programs or activities but also concerns arising from the civil society. Civil society confirmed its interest in contributing to the definition of the SITEX SRA.

A key issue is the way of implementing part of the SRA in the international context of EURATOM joint programming, in particular with WMOs without any prejudice of respective missions and roles in the decision making process. Maintaining the independence of SITEX with respect to WMOs is a major point.

11 References

[1] IAEA Safety Standards, Disposal of Radioactive Waste, Specific Safety Requirements No. SSR-5, IAEA, Vienna 2011.

[2] IGD-TP (2012): Strategic Research Agenda (SRA). ISBN 978-91-979786-0-6.

12 Appendix: Needs for knowledge (outcome of D3.1)

Regarding long term safety,the needs for knowledge are classified based on three main categories:

- the quality of the data on which rest the safety demonstration;
- the understanding of the complex processes which may potentially influence the long term safety of the DGD. Situations possibly occurring during the operational phase as well as after closure are considered;

- the assessment of the future evolution (in spatial extent and intensity) of these potential processes, as well as the assessment of their impact on the DGD safety.

Each axis is described in the following three subsections. For each subsection, a set of knowledge (considered as necessary for performing the review) is identified. In the follow up of SITEX, these needs for knowledge will be case by case analysed and derived into research activities where needed.

12.1 QUALITY OF INPUT DATA

A1 The adequacy and relevance of methods available for the evaluation of data necessary for long-term and operational safety demonstrations.

Particular points of attention (not exhaustive list):

- Method to characterize the source term;
- Method to characterize DGD thermal development;
- Method to characterize container corrosion rates;
- Method to characterize the geo-mechanical properties of the host-rock (advanced coupled (T)HM behaviour);
- Method to characterize diffusion properties of the near-field materials and the host-rock;
- Method to identify transport properties of the host rock (faults and joints);
- Method for description of geological properties of the site;
- Method to evaluate the sorption capacity of the near-field materials and the host-rock;
- Method to evaluate the permeability of near-field materials and the host-rock.

A2 Representativeness of the data evaluated at small scale (in time and space) with respect to in situ repository conditions and future evolution.

Particular points of attention (not exhaustive list):

- Representativeness of rock properties (mineralogy and petrology, porosity, pore connectivity, fracturing, mechanical properties);
- Representativeness of hydraulic performance of seals and concrete liners;
- Representativeness of the geological structures in 3D dimensions (e.g. seismic methods);
- Representativeness of barriers transport properties (sorption, diffusion data, permeability).

12.2 UNDERSTANDING OF COMPLEX PROCESSES

B1 Understanding in the processes on which rest the performances of the waste form.

Particular points of attention (not exhaustive list):

- SNF disposal: characterization of the process responsible for the Instant Released Fraction (IRF) due to ^{129}I and ^{36}Cl;

- Graphite bearing wastes (e.g. RBMK, UNGG reactor type): characterization of processes responsible for the ^{14}C and ^{36}Cl release from waste forms;
- Vitrified waste: influence of the initial fracturing state of glass on its dissolution rate (and thus the radionuclide release rate);
- The influence of the pH evolution on dissolution rate of the vitrified waste packages (e.g. high pH from the concrete environment);
- Influence of dissolutions rates for radionuclide release from SNF;
- The influence of glass leaching on the radionuclide release rate;
- Gas issue (in case of bituminised waste presence).

Needs for knowledge:

B2 Understanding in the processes on which rest the performances of the waste container and its overpack.

Particular points of attention (not exhaustive list):

- The influence of the thermal dissipated power on the container and overpack properties;
- The assessment of corrosion mechanisms and rates (e.g. generalised or pitting corrosion) in reference conditions;
- The dimensioning of the container and overpack with respect to the different loads experienced under repository conditions (due to the host-rock behaviour and to the thermo-mechanical effects);
- The influence of corrosion layer on the extent of corrosion;
- Influence of microbial activity on corrosion rates.

Needs for knowledge:

B3 Understanding in the processes on which rest the performances of the engineered barriers surrounding the waste packages.

Particular points of attention (not exhaustive list):

- Processes affecting the geo-mechanical properties of the EBS (swelling capacity of bentonite materials, change of the chemical composition of bentonite materials…);
- Process affecting the hydraulic properties of the EBS (EBS permeability…);
- Processes of buffer erosion (causing loss of the performance);
- Processes on which rest the retention/sorption capacity of the EBS;
- Long term evolution of buffer and sealing materials.

Needs for knowledge:

B4 Understanding in the processes on which rest the performances of the Geosphere.

Particular points of attention (not exhaustive list):

- Long term stability of the geosphere (including seismic, orogenic properties);
- Processes affecting the mechanical properties of the geosphere and its healing (for clay rock and rock salt);

- Mechanisms of creation and propagation of natural heterogeneities in multilayer sedimentary system, leading to a “differential fracturing” between limestone and clayey layers at the whole system scale
- Influence of the mineralogical composition of the host rock on its sorption capacity;
- The migration of radionuclides in the host-rock at ambient temperature and considering temperature gradient representative of those that may occur in the near-field of the foreseen waste disposal system;
- Identification of fracture wetting surface in fractured rocks in order to determine the extent of radionuclide migration;
- Evaluation of indicators on the confinement capacity (i.e. diffusion dominated) at long-term, and its consistency with the DGD concept:
    - Clay type DGD: verification that the concentration of solutes (such as Cl) shows a classical diffusion profile, whichproves that diffusion prevailed up to present day (i.e. before DGD implementation); identification of effective porosity, i.e. the porosity available for radionuclide migration
    - Granitic type DGD: identification of pore connectivity in the crystalline rock massives; identification of effective porosity, i.e. the porosity available for radionuclide migration

12.2.1Processes resulting from internal and external perturbations

Needs for knowledge:

B5 Understanding in the internal perturbations of the disposal system resulting from the waste/host-rock and waste/EBS interactions.

Particular points of attention (not exhaustive list):

- Effects from waste forms:
    - The introduction of a large quantity of new chemical component will perturb the in situ conditions and therefore the final geochemical conditions may not be the same as before the perturbation, even after the system returns to equilibrium.
    - The compatibility between bitumen waste and the surrounding concrete and host-rock (with respect to their potential swelling).
    - Generation of gases (H_2, O_2) upon radiolysis pore water, organic-based waste (e.g. bitumen).
    - Radiation effects on materials.
- Effects of gas release from waste packages and from the corrosion or radiolysis of engineered barriers:
    - The study of the pressure, the formation of either microcracks or macrocracks and the integrity of the geosphere
    - The mechanisms of gas generation and migration and their effects on the mechanical (M) and hydrological (H) stability of the geosphere.
- Effects of temperature on cementitious materials:
    - Chemical evolution (solid and pore solution)
    - Microstructure evolution

- Composite effective diffusion coefficient evolutions

Needs for knowledge:

B6 Understanding in the internal perturbations of the disposal system resulting from the EBS/host-rock interactions.

Particular points of attention (not exhaustive list):

- Effects due to the corrosion phenomenon:
  - The corrosion behaviour of steel-based material in an anaerobic environment of deep repository.
  - The clay materials evolution due to iron-clay interactions (characterisation and modelling).
  - Effect of interaction of bentonite/steel on corrosion layer development and influence on the corrosion rate.
  - Anaerobic corrosion of iron metals is in addition connected with gas generation that can be detrimental to other components of a repository.
- Effects due to alkaline perturbation:
  - The clay materials evolution due to cement-clay interactions by characterisation and modelling.
  - Mineral transformations of bentonite in the alkaline front environment (it relates mainly to composition of penetrating alkaline waters, pH, single minerals transformation trend).

Needs for knowledge:

B7 Understanding in the internal perturbations of the disposal system resulting from operational transients.

Particular points of attention (not exhaustive list):

- Effect of the oxidizing and desaturation transient process;
- Effects resulting from the presence of micro-organisms;
- Influence of defects, caused by handling, on canister corrosion;
- EDZ formation and extent.

Needs for knowledge:

B8 Understanding in the potential external perturbations of the disposal system.

Particular points of attention (not exhaustive list):

- General geological condition change (potential marine transgression, future permafrost/glaciations, site erosion, site seismicity, site uplift/subsidence);
- The changes of the properties of the natural and engineered barriers (through the changes in groundwater flow regime, chemical conditions) are strongly related to the condition changes which are expected in the future;
- Potential future human intrusion and activities (gas storage and extraction, geothermal energy, resources exploration etc.): the point is to possibly better know the actual resources but also to link this point with the scenario development

strategy for assessing perturbations due to intrusions inside or close to the disposal facility.

12.3 ASSESSMENT OF EXTENT, INTENSITY AND IMPACT OF PROCESSES

Needs for knowledge:

C1 The methodologies followed by the operators for the assessment calculations.

Particular points of attention (not exhaustive list):

- Features, events and processes that are potentially important for the safety of the disposal system should also be identified thus there is a priority suggested on the development of updated FEP databases. E.g. (not comprehensive list):
  - Scenario caused by earthquake leading to the immediate failure of various numbers of the canisters in the time of mean lifetime of canisters.
  - Scenario caused by denudation or erosion leading to the substantial shortening of radionuclide pathways to the environment.
  - Scenario caused by the formation of preferential pathways in part of buffer in boreholes with immediate failed canisters due to earthquake.
  - Intrusion scenario leading to the failure of one canister and buffer immediately after the end of institutional control of the repository (300 years).
  - Climate change scenario during post-closure period, taking into account evolution of the possible biosphere behaviour.
- Safety functions of all system components should be developed for scenario development.
- FEP screening and scenario development should be supported by experimental demonstration and natural analogue observations.

Needs for knowledge:

C2 The extent and intensity of processes resulting from internal and external perturbations of the repository on human and the environment (including dose).

Particular points of attention (not exhaustive list):

- Relevance of underlying conceptual (phenomenological) models used for the performance assessment:
  - Source term model for the radionuclide release from waste packages and spent fuel. This modelling is of particular concern as it has a deep impact on the long term safety of radioactive waste disposal. As an illustration, the modelling of the spent fuel Instant Release Fraction (IRF) is an important point of attention (see “Data quality” section).
  - The modelling RN migration and sorption, account for the range of relevant geochemical processes.
- Investigate the influence of the level of abstraction and simplification (of mechanical, hydrological, thermal and chemical processes) on the results of the assessment calculations; so as the robustness of the data transfer from one system component to the other.

- Verification and validation of the models, both conceptual and mathematical ones. This point is particularly important as the assessment of the extent and the intensity of processes, as well as their influence on the long-term safety, is principally based on modelling activities. Moreover, the justificationof models during the transient phase (several thousand years) and on long time scales (such as those considered for DGD) is a key aspect of confidence.

Needs for knowledge:
C3 Management of uncertainties

Particular points of attention (not exhaustive list):

- The challenges linked to the management of uncertainties concern several issues:
  - The identification of lack of knowledge (5.2), and link with upscaling process and long-term extrapolation in time
  - The influence of the device and measurements used to obtain input data (see section 5.1).
  - The technics for taking into account the uncertainties into the processes and the models
  - the bias linked to abstraction/simplification of the reality leading to conceptual models.
  - Influence of Mathematical representation of processes included.
  - Applied software and its verification and validation; confirmation of its suitability.

C4 Definition of the reference state of the system (normal/expected evolution) and monitoring methods in order to detect deviations

Particular points of attention (not exhaustive list):

- During construction phase: monitoring like for civil engineering/mining objects.
- During operational phase: to confirm short term evolution and update the safety case; To detect deviations from the expected domain of behaviour: what process to measure? Which components? Which parameter? What is the specified (safe) domain of functioning (the reference state) ?...
- During post-closure phase: until the end of institutional control.

12.4 ASSESSMENT OF HAZARDS DURING OPERATIONAL PHASE

In parallel to the work developed by reviewers to increase knowledge and implement review methods of long term safety, the assessment of operational phase safety is an increasing challenge as far as disposal programmes progress. As example, the IAEA GEOSAF project on international harmonization of approaches in the evaluation of the safety case for a geological disposal launched in 2010 a pilot study on fire hazard and the GEOSAF 2 project was subsequently initiated in 2012 on the integration of operational phase and post-closure phase into the safety case.

In terms of methodology of regulatory review, existing methods already used for various nuclear facilities remains valid and serve as basis for reviewing safety of the operation of geological disposal. But some specific risks or situations need to be addressed without any substantial feedback experience from the operation of existing nuclear facilities (management of concomitant activities, management of fire…). Parameters associated to the characterization of the considered risks (fire, flood…) needs to take into account the peculiarities of such a facility. Finally, the identification of Limits, Controls and Conditions for the operational phase remains a challenge, since it has to integrate the dimension of long term safety: the numerous links between pre- and post-closure arguments of the safety case call for a methodology to verify continuously that the operator is always on the right track to achieving its target, namely the conditions of the repository at the time of closure which form the basis of the demonstration that the facility is sure in the long term.

These four findings lead to the unveiling of five consequences for the preparation of the regulatory review :

1. The analysis of the design, the maintenance, the coherence between the provisions adopted and the considered hazards (especially those that are specific to a geological disposal) should be deepened. This underlines the questions related to the technologies used in the facility, the architecture, the components' robustness and easy maintenance, as well as a deep understanding of the mechanisms associated to the ageing of the abovementioned components.
2. The analysis of the scenarios used by the licensee, especially those that are envelope, should be carried out with a good understanding of the peculiar characteristics of a geological disposal.
3. Risks associated to activities running in parallel over extensive periods of time should be considered as essential.
4. The analysis of the adequacy of a monitoring and surveillance programme during the operational phase, which would consider several objectives, should be performed as well.
5. As stated above, a deeper knowledge of the various situations and parameters that influence the "initial state" of the closed repository (namely the characterization of the set of parameters that control the post-closure safety assessment) should be sought as well.

Needs for knowledge:

D1 A methodology to review the hazards possibly occurring in an underground nuclear facility and scientific basis associated to development of conventional/nuclear hazardous processes in underground

- fire hazard
    - characterization of fires in underground spaces
    - thermal response of ILW emplacement cells on temperature rise aggressions
    - quantification of effects of fire on specific target in confined environment
    - integration of different confined environment in IRSN's simulation tools
- handling hazard

  - characterization of situations of stopping the transfer of canisters and emplacement
  - consequences of these situation on the components relevant for safety and on the general level of risks in the facility
- hazard due to activities performed in parallel (co-activity)
  - methods (including in other industries) for organizing safely activities performed in parallel
  - definition of situations (such as evacuation in the case of a fire in the underground area) that should be taken into account in the analysis of these risks