Deliverable 10.17: Synthesis report of WP UMAN outcomes from a civil society point of view

Work Package 10 UMAN

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Disclaimer

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What is the UMAN project about?

Decisions associated with Radioactive Waste Management (RWM) programmes are made in the presence of irreducible and reducible uncertainties. Responsibilities and role of each stakeholder, the nature of the RW disposal programme and the stage of its implementation influence the preferences of each category of actors in approaching uncertainty management. EURAD WP UMAN carries out a strategic study about the management of these uncertainties. This study is based on extended exchanges of the experience accumulated in the national RWM programmes by a broad range of stakeholders representing WMOs, TSOs, REs and civil society, as well as on a review of knowledge generated by past and on-going R&D projects, and findings of international organisations (such as IAEA, NEA, etc.).[1]

UMAN discusses the classification schemes and approaches as applied to the management of uncertainties and identifies possible actions to be considered in their treatment. Their relevance for safety associated with site and geosphere, human aspects, spent fuel, waste inventory, spent fuel and near-field, as perceived by each type of the above stakeholders, and the approaches used by these stakeholders to manage these uncertainties are explored via questionnaires, workshops and seminars, with the aim to reach either a common understanding on how uncertainties relate to risk and safety and how to deal with them along the RWM programme implementation, or, when agreement is not achieved, a mutual understanding of each individual view. As result of these activities, UMAN identifies uncertainties assessed as highly significant for safety and associated R&D issues that should be further investigated.

This Work Package (WP) of EURAD includes the following tasks:

- Task 1 - Coordination, interactions with Knowledge Management (KM) WP & integration
- Task 2 - Strategies, approaches, and tools
- Task 3 - Characterisation and significance of uncertainties for different categories of actors
- Task 4 - Uncertainty management options and preferences of different actors across the various programme phases
- Task 5 - Interactions between all categories of actors including Civil Society

Interactions between the different tasks and types of actors including civil society are central to this WP. These interactions take place notably through workshops (Task 4) and seminars (Task 5) where the significance of identified uncertainties (Task 3), possible strategies and options to manage them (Tasks 2 and 4) are discussed.

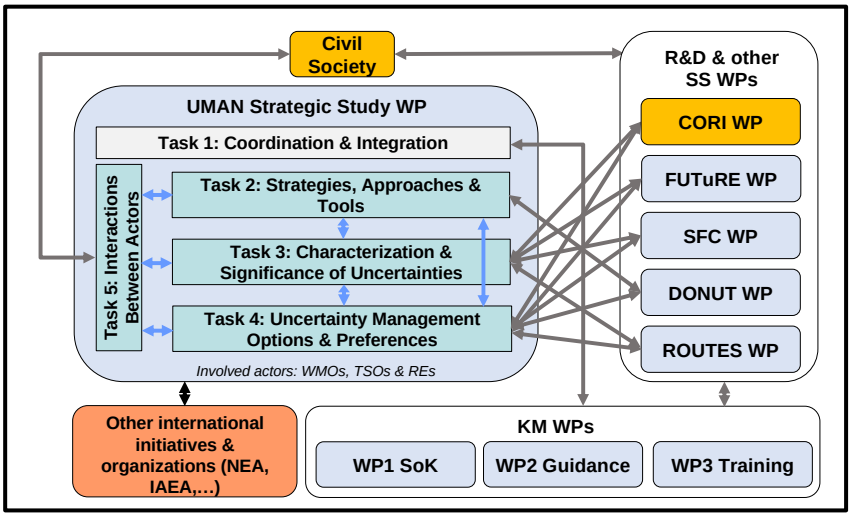

Figure 1 - UMAN WP structure and interactions

[1] More details on the EURAD website: https://www.ejp-eurad.eu/

Executive Summary

This report provides a synthesis of the work carried in UMAN Subtask 5.2 – Input of civil society experts – in the frame of UMAN Task n°5 – Interactions between all categories of actors, and its main outcomes from a civil society point of view. The views of civil society on WP UMAN results were collected and developed in depth through five seminars (four of them have already taken place with an additional one held in December 2023):

- Seminar 1: What does uncertainty management mean for different types of actors and how is it related to risk, safety, and the safety case? (October 2020)
- Seminar 2: Management of uncertainties related to site and geosphere characteristics. (October 2021)
- Seminar 3: Management of uncertainties related to human aspects. (June 2022)
- Seminar 4: Methods that can be used for discussing and organising pluralistic assessments of uncertainties throughout a disposal programme (December 2022)
- Seminar 5: Pluralistic assessment of near-field uncertainties. (December 2023).

The extracted results from each seminar are presented here and follow four main themes:

- Transparency and public participation in uncertainty management.
- Shared culture for safety and security.
- Ethical principles.
- Rolling stewardship.

This report synthetises the outcomes of the different tasks of the WP UMAN from the civil society point of view and gives recommendations. The first annex of this document reflects the civil society group's views on management of radioactive waste and spent fuel within the frame of UMAN, presenting the complete outcomes of the UMAN civil society questionnaire and the analysis of the answers.

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Acronyms

CCNR: Canadian Coalition for Nuclear Responsibility

CS: Civil society

CSI: Civil society involvement

DGR: Deep geological repository

EIA: Environmental impact assessment

EU: European Union

EURAD: European Joint Programme on Radioactive Waste Management

ENSREG: European Nuclear Safety Regulators Group

FEP: Feature, event and process

FSC: Forum of Stakeholder Confidence of NEA

GD: Geological disposal

HLW: High level radioactive waste

IAEA: International Atomic Energy Agency

ICS: Interaction with civil society

IGSC: Integration Group for the Safety Case (IGSC) of NEA

ILW: Intermediate level radioactive waste

INSAG: International Nuclear Safety Advisory Group

IRSN: Institut de radioprotection et de sûreté nucléaire (the French Institute for radioprotection and nuclear safety)

JOPRAD: Joint Programme on Radioactive Waste Disposal

LLW: Low level radioactive waste

LTS: Long-term stewardship

MODATS: MOnitoring equipment and DAta Treatment for Safe repository operation and staged closure

MKG: Miljöorganisationernas kärnavfallsgranskning (the Swedish NGO Office for Nuclear Waste Review)

NEA: Nuclear Energy Agency

NGO: Non-governmental organization

NIMBY: Not in my backyard

NPP: Nuclear power plant

PEP: Pathway evaluation process

PSR: Periodic safety review

RD&D: Research, development & demonstration

RE: Research entity

RW: Radioactive waste

RWM: Radioactive waste management

SEA: Strategic environmental assessment

SITEX: Sustainable network for Independent Technical EXpertise on radioactive waste management

SITEX-II: Sustainable network for Independent Technical EXpertise on radioactive waste management – Implementation and Interaction

SITEX. Network: https://www.sitex.network/

T&PP: Transparency and public participation

TEC: Treaty on European Union

TFEU: Treaty on Functioning of the European Union

TSO: Technical safety organisation

UMAN: Uncertainty Management Multi-Actor Network

VLLW: Very low-level radioactive waste

WMO: Waste management organisation

1. Introduction

1.1 Objective of Task 5, definition of uncertainty and main hypothesis in UMAN

Management of uncertainties is a cross-cutting issue within the different research themes identified in the work programme of EURAD. It is why a project such as UMAN was implemented. The UMAN project started its work on uncertainties from a basic definition: *"An uncertainty is a situation in which something is not known, or something that is not known or certain"* (Cambridge dictionary). An uncertainty can be **« epistemic »** i.e., relating to knowledge or to the degree of its validation (e.g., lack of knowledge about site characteristics). In this case, it can be reduced (reducible uncertainties). Or it can be **« aleatory »,** i.e., related to random variability (e.g., uncertainty over the time of occurrence – long term uncertainty or magnitude of rare events). In this case, it cannot be reduced (irreducible uncertainties).

Uncertainty is different from risk, that can be defined as "*a quantity expressing hazard, danger or chance of harmful or injurious consequences associated with exposures or potential exposures* (Source: IAEA Safety Glossary 2018). Risk is related to a scenario or sequence of events and can be interpreted as the measure of significance of an uncertainty. **The significance of uncertainties needs to be assessed.**

On this basis, the following assumptions guided the work carried out in UMAN and especially in UMAN Task 5:

- The involvement of stakeholders is essential at all stages of a radioactive waste management (RWM) programme.
- Decisions related to radioactive waste management and geological disposal (GD) have to be made in the presence of uncertainties.
- Even in the post-closure phase, some uncertainties will inevitably remain, but it should be demonstrated that these uncertainties are managed in a way that they do not undermine safety arguments.
- Dealing with uncertainties associated to disposal facilities is particularly challenging due to the long timescales.

Based on these assumptions, Task 5 developed the following objectives:

1 - Develop a **common understanding** or at least to share different viewpoints among the different categories of actors on uncertainty management[2] and how it relates to risk & safety, whether and why a safety case is robust vis-à-vis uncertainties.

2 - Share knowledge and **discuss challenging issues on uncertainty management among a broader group of actors.**

3 - Identify **methods for organizing a regular and pluralistic[3] dialogue** on uncertainties during the development and review of the safety case.

4 – Provide **recommendations for future EURAD activities.**

[2] In the UMAN perspective, uncertainty management is a key element of the safety case. It is an iterative process associated with the stepwise implementation of the disposal programme. As some uncertainties have the potential to jeopardize safety, they need to be identified and assessed; several options might be available to reduce, avoid or mitigate these uncertainties. The strategies defined to do so are called uncertainty management.

[3] In the context of UMAN Task 5, Pluralistic means diversity of actors and an interdisciplinary perspective (embedding technical and socio-technical issues)

1.2 Methodology of Task 5

To fulfil these objectives, Task 5 implemented a methodology based on the organisation and animation of a set of pluralistic seminars. The aim was to discuss UMAN (interim) results with a broader scope of actors including Civil Society (CS) actors (CS experts[4] and members of CS larger group[5]), representatives of regulators[6] and international organisations (IGSC[7], FSC[8]). The set of seminars was elaborated as an integrative process, each seminar constituting one step of the pluralistic analysis of UMAN results. The final goal was to identify methodologies enabling to organize a regular dialogue around uncertainties between experts and Civil Society all along the geological disposal implementation (including pre-disposal phase and post-closure phase). The topics of the different seminars were:

- **Seminar 1: What does uncertainty management mean for different types of actors? How is it related to risk, safety, and the safety case?** (October 2020) Seminar 1 addressed the meaning for different actors of uncertainty management and its relationships with risk, safety, and the safety case. It discussed the results of the different UMAN tasks (Task 2.1 and Task 3.1).
- **Seminar 2**: **Focused on site and geosphere: Preferences of actors, evolutions of uncertainties throughout different phases and how interactions with Civil Society could contribute to manage these types of uncertainties?** (October 2021) Following seminar 1 which provided a global perspective on uncertainties and their management, seminar 2 examined the aspect of uncertainties addressed in UMAN, namely "Site and Geosphere related uncertainties". The aim was to identify and discuss the views of different types of actors on the following topics based on concrete cases: Preferences regarding possible uncertainty management options, Possible evolutions of uncertainties throughout different phases of a disposal programme and how the interactions with civil society could contribute to manage these uncertainties?
- **Seminar 3: Focused on uncertainties related to human aspects: Preferences of actors, evolutions of uncertainties throughout different phases and how could interactions with Civil Society contribute to manage these types of uncertainties?** (June 2022) seminar 3 focused on the uncertainties related to human aspects. Human uncertainties are defined on a very large basis, i.e., the uncertainties related to human activities during the different phases of a geological disposal programme. The topic was considered too large to enable fruitful discussions, it was therefore necessary to select key topics to be further analysed. The aim of seminar 3 was to discuss the views of different types of actors on the following topics based on concrete cases: Public acceptance, Schedule to be considered for implementing the different phases of the disposal programme, New Knowledge and adequacy of safety related activities for the implementation of safety provisions (with a focus on the construction phase)

[4] The CS experts are experts with technical and socio-technical background or/and experience on the involvement of CS in scientific and technical issues. They are involved in EURAD activities through NTW (international association), translating scientific/technical results for exchanging with a larger group of CS representatives (NGOs, representatives of local communities)

[5] The composition of the CS larger group is detailed in EURAD deliverable D1.13 (Dewoghélaëre et al., 2020a): https://www.ejp-eurad.eu/sites/default/files/2020-11/EURAD%20-%20D1.13_ListofCSgroupmembers_EURAD.pdf

[6] The representatives of regulatory authorities are part of the UMAN end user group: FANC from Belgium, Environment Agency from United Kingdom, Safety of Nuclear Waste Management (BASE) from Germany, State Office of Nuclear Safety from Czech Republic

[7] The Integration Group for the Safety Case (IGSC) is the main technical advisory body to the Radioactive Waste Management Committee (RWMC) on the deep geological disposal, particularly for long-lived and high-level radioactive waste. It was established in 2000 in recognition of the need to foster full integration of all aspects of the safety case. https://www.oecd-nea.org/jcms/pl_29043/integration-group-for-the-safety-case-igsc

[8] The Forum on Stakeholder Confidence (FSC) was established by the NEA Radioactive Waste Management Committee (RWMC) in 2000 and serves as a platform for understanding stakeholder dialogue and discussing methods to develop shared confidence, informed consent and approval of radioactive waste (RW) management solutions: https://www.oecd-nea.org/jcms/pl_26865/forum-on-stakeholder-confidence-fsc

- **Seminar 4**: **Methods that can be used for discussing and organising pluralistic assessments of uncertainties throughout a disposal programme** (December 2022) Seminar 4 focused on methods to enable fruitful interactions between institutional/technical experts and civil society in the long term. Seminar 4 gave the opportunity to discuss the lessons learnt during the 3 previous seminars and Task 4 workshops on **how to manage uncertainties in a pluralistic way and in a long-term perspective**. One of the objectives was to identify the potential needs for strategic research on methods to achieve this goal.

With the implementation of the second wave of EURAD-1, an additional seminar is planned in the frame of Task 5. It will be focused on near-field uncertainties:

- **Seminar 5:** Will focus on near-field uncertainties: opportunity to test the methodologies emerging from Seminar 4 (planned for December 2023) The main objectives of Seminar 5 are to discuss the UMAN results related to the near-field uncertainties; To test the identified methodologies to explore uncertainties in a pluralistic way and especially the PEP game.

The seminars were prepared by a pluralistic team involving representatives of each EURAD college (WMOs, TSOs, REs) and CS experts involved in UMAN. The team prepared presentations:

- On the work performed in UMAN (views of WMOs, TSOs and REs on the identification, characterisation, potential significance, and management of uncertainties). When appropriate, elements coming from other sources (IAEA, national programmes, etc.) were added to feed into the discussions.
- On the CS views and analysis. The analysis was performed by the CS experts involved in UMAN based on their review of the UMAN work and on the comments from the CS larger group[9].

These presentations constituted the basis for starting the discussion. To deepen the discussions, working groups sessions were organised. Participants were invited to discuss concrete cases (use of the Pathway Evaluation Process or PEP approach[10]): the concrete cases are a way to illustrate the issues linked to the uncertainties under discussion, enabling all actors to enter the discussion on the same footing. After the working group session, a final session was dedicated to reporting and identification of potential needs of research.

Prior to CS experts entering the dialogue with the other EURAD colleges in the seminars, a broader understanding of the CS group members' experience and thoughts on uncertainties in RWM needed to be developed. Therefore, the UMAN CS expert group developed the **UMAN CS questionnaire** (Dewoghélaëre et al., 2020b)[11] in the frame of seminar 1 preparation. All CS group members were asked what important uncertainties they see in each phase of the RW backend management, also in comparison to results from the UMAN-questionnaire in which WMOs, TSOs and REs were asked about their views (Grambow 2023). 15 CS group members answered the UMAN CS questionnaire. Among those, eleven are members of the CS larger group and four of the CS expert group. Approximately 50% of both the CS larger group and the CS expert group answered. Answers from ten countries were received: Belgium, Bulgaria, Czech Republic, Finland, Hungary, Netherlands, Norway, Sweden, Slovakia, UK. Four answers came from women, eleven from men.

[9] The comments from the CS larger group were collected during annual ICS workshops. During the UMAN sessions of these workshops, the UMAN results were presented and discussed. The UMAN session of ICS workshop n°1 was held online on 6 and 18 May 2020. The UMAN session of ICS workshop n°2 was held online on 26 March 2021. The UMAN session of ICS workshop n°3 was held online on 16 March 2022.

[10] The PEP is a tool of dialogue (designed as a serious game) developed under the frame of the SITEX-II project and SITEX.network that enable multi-actors' discussions in the field of radioactive waste management. EURAD Lunch and Learn Session on PEP methodology: https://www.ejp-eurad.eu/news/recording-ll-pluralistic-tool-dialogue-rwm-pathway-evaluation-process-pep

[11] In Appendix A are described the detailed objectives, the way the questionnaire was elaborated and distributed and the detailed results.

About 680 uncertainties were identified over all phases (from the concept to the post-closure phase), they were clustered as follows:

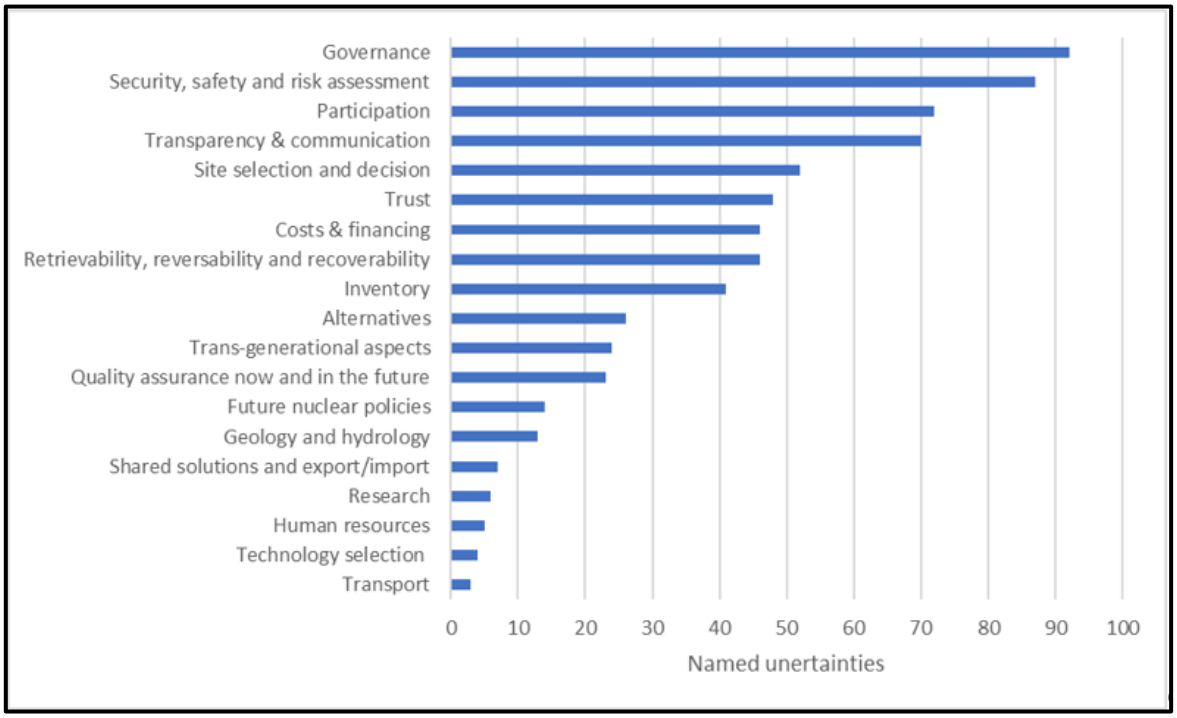

Figure 2 - Clusters of named uncertainties in the UMAN CS questionnaire, total over all six RWM phases.

As we could not work on all these identified uncertainties, after UMAN Seminar 1 we selected the four topics that gathered the most of answers to investigate in more detail in the frame of the UMAN WP Task 5. This does not mean that the other identified uncertainties are not important. The four topics are interrelated.

1. Transparency and public participation (T&PP) with a focus on dealing with uncertainties.
2. Development of a shared culture for safety and security[12]
3. Guiding ethical principles.
4. Governance with a special focus on intergenerational governance (LTS/RS).

Aspects of these four uncertainty topics were worked on in all UMAN seminars. Results of this work are discussed in detail in the following chapters.

[12] Why we use this term instead of “safety culture” is explained in detail in chapter 3.

2. Transparency and public participation in uncertainty management

In this chapter, a topic of high importance for civil society is discussed: transparency and public participation (T&PP) in the overall management of spent fuel and radioactive waste, with a focus on the management of uncertainties.

2.1 Results extracted from Seminar 1 on the global picture

UMAN Seminar 1 was held on 26-27 October 2020 on the question "What does uncertainty management mean for different types of actors and how it is related to risk, safety and the safety case?" (Röhlig, 2021). In advance of this seminar, two questionnaire surveys were conducted – one for the three EURAD colleges and one for the CS experts in EURAD. Results from both surveys were presented and debated from several viewpoints in the seminar.

In the CS UMAN questionnaire survey, CS experts named uncertainties in a wide range of topics. Before going into detail on uncertainties concerning transparency and public participation, it must be clarified that these comprise two strands of discussion: **Transparency** means that all information and data which are necessary for assessing risks for health and environment are available for the public early enough and detailed enough and, that information on procedures and structures is transparent. Communicating information to the public is a part of a transparency regime, but only when there is also possibility for interaction within a participatory regime. The Nuclear Waste Directive 2011/70/Euratom regulates in Art. 10 that Member States shall ensure that necessary information on RWM is made available to workers and the general public. The Aarhus Convention defines what kind of information has to be made available and how this environmental information has to be made accessible. Transparency on research activities and results related to RWM are in the scope of the Aarhus Convention – this is the primary reason why CS experts are engaging in EURAD.

Participation comprises of all forms of interaction between the public and the organisations and authorities responsible for RWM. Interactions have a wide range, from information events to dialogues between actors and consultations to co-decision procedures. Informing the public about the national RWM programme in a webinar, establishing a committee for continuous dialogue with stakeholders in a possible siting community, guaranteeing the right to veto for siting candidates, making a public hearing in an EIA procedure, engaging with CS experts in a research project – all these activities are participatory methods[13] and should be conducted in a transparent way. The Nuclear Waste Directive 2011/70/Euratom requires in Art. 10 Member States to ensure that the public be given the necessary opportunities to participate effectively in the decision-making process regarding spent fuel and radioactive waste management. Public participation in programmes and projects of RWM concerning the environmental licensing are regulated in detail in both SEA and EIA laws on a national, European, and international level, among those the EU SEA and EIA-Directives and the Espoo and Aarhus Conventions. Effective participation is often not regulated sufficiently throughout all steps of the licensing, safety review and monitoring, etc.

Transparency, participation, and access to justice go hand in hand. One is not complete without the other. This is recognised in the Aarhus Convention and in the answers of many CS larger group members to the CS UMAN questionnaire.

Definitions of transparency have been discussed in detail in the ROUTES deliverable D9.17 (Żeleznik et al., 2022). They are consistent with the definitions used in this deliverable and apply equally to the terms developed in the NTW BEPPER Report (Swahn et al., 2015).

[13] See also the ladder of participation by Arnstein, S. (1969.) A ladder of citizen participation. Journal of the American Planning Association, 35(4), 216–224. It shows that there is a wide range of interactions that can be subsumed under "participation"; the ladder can be used as one basis for developing effective participation in RWM

The results of the CS UMAN questionnaire can be found in detail in Appendix A. When summarising **results of the CS UMAN questionnaire concerning transparency and public participation**, it becomes obvious that adequate transparency and public participation regimes for all steps of RWM have not yet been established in all Member States.

It is essential to see that **transparency in managing uncertainties is closely linked to uncertainties about transparency and participation**. It is not sufficient to be transparent about a technical uncertainty if you have not built trust by using a high-quality T&PP regime throughout the whole RWM process.

For environmental licensing, participation procedures are available, but are not used by all Member States (many countries did not conduct a SEA for their national RWM programme[14]). **Providing information on uncertainties and lack of knowledge in the frame of EIA and SEA procedures on RWM programmes and projects should be improved**, i.e., with guidance for providing better quality information on uncertainties for the public. This would be a helpful result of the EURAD project.

CS experts named a wide range of uncertainties concerning T&PP in the CS UMAN questionnaire, among them: Who will be allowed to participate, who is seen as affected by RWM, how will the participation in different steps be conducted, will there be resources made available, also for independent expertise? How will decisions be made, will there be the right to veto and who will get it? These questions have high importance and need to be resolved in a timely way.

Given there is no operating HLW repository yet, public acceptance will remain a major challenge for any DGR. While it is not in the scope of EURAD to research how public acceptance can be reached or how dialogue in local communities can be established, it is in the scope of EURAD to **open up the EURAD research activities for dialogue with CS, to establish together fruitful ways for interactions** between all actors in a research programme and to develop not only mutual understanding but also take into regard questions of CS in the research questions and communicate results to CS.

Different countries have different transparency and participation regimes. Especially difficult is the situation in Eastern European countries[15]. Focus should also be put on missing access to information from private companies engaged in RWM as they do not fall under the Aarhus Convention. A mutual understanding needs to be built given that a lack of transparency might well result in a consequential loss of trust.

Learnings from discussion in UMAN Seminar 1

In Seminar 1, three main topics were discussed:

1. Meaning of uncertainty management and types of uncertainty,
2. Evolution of uncertainties, and
3. Interactions with Civil Society

In this seminar, the whole range of uncertainties identified by the EURAD actors was presented and discussed. Uncertainties concerning T&PP were among them:

Some EURAD actors define missing public acceptance of a DGR as uncertainty. This was also mentioned in Seminar 1. As our colleague Gilles Hériard-Dubreuil who sadly passed away much too early used to say about CS participants in the EURAD project: “We are not here to improve societal acceptance.” Societal and political uncertainties like changes in the political context or changes in

[14] See for instance, EC evaluation report: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52019SC0436

[15] Examples of issues related to transparency were given several times during the UMAN seminars. On this topic, see also: Hooghe, M., Quintelier, E. Political participation in European countries: The effect of authoritarian rule, corruption, lack of good governance and economic downturn. *Comparative European Politics* **12**, 209–232 (2014). https://doi.org/10.1057/cep.2013.3

societal priorities are linked to socio-technical but also technical uncertainties. They do impact on technical solutions. But **public acceptance as such is more a question of democracy.** Good quality T&PP regimes in which uncertainties are openly discussed, together with safety approaches dealing adequately with recent and future uncertainties will be key to reach public acceptance of any DGR[16]. It is also important to be aware CS experts are participating in EURAD to help gain a mutual understanding of all stakeholder's views and establish methods of fruitful interaction.

During the debates in UMAN Seminar 1 it became clear that different views exist about the length of time necessary to provide T&PP in RWM. The view that societal uncertainties reduce with time as the point of facility closure nears cannot be shared by CS experts; the same is true for technical uncertainties – some might be reduced over time, but new ones might arise. Therefore, **CS experts find it necessary to involve civil society in all phases of RWM, and also in the post-closure long-term perspective**. Discussing how such long-term involvement of CS could be installed became one of our working focusses. Questions of intergenerational governance and management methods like long-term or rolling stewardship are in the focus of CS experts, especially so concerning the management of uncertainties: We should not burden future generations with our nuclear waste, but we have the responsibility to enable them to adequately deal with risks and uncertainties that might change in the future (see chapter 5 of this deliverable for more discussion of this topic).

2.2 Results extracted from Seminar 2 on site and geosphere

UMAN Seminar 2 was held on 4, 5 and 11 October 2021 on management of uncertainties related to site and geosphere characteristics (Rocher, 2021). In this seminar, three different scenarios were discussed, focusing on changes that have not been anticipated in the planning and licensing of a DGR:

- Fault detection & reactivation
- Climate evolution with a focus on future glaciations
- Site`s natural resources

One of the focus of discussions was the question **how a regular dialogue with CS could contribute to manage such types of uncertainties**.

Common to these scenarios are that as new research results become visible, they could not have been envisaged before the time of planning or licensing. The studied uncertainties belonged to the categories known unknowns and unknown unknowns with some interpretations of the scenarios included as ignored knowns.

The workshop debates resulted in the following answers to the question as to, if and how interaction with CS can contribute to managing uncertainties in the three scenarios:

Dialogue with CS is seen as necessary and even essential for managing all the scenarios. **If there is regular dialogue between actors and CS, uncertainty issues need not be a surprise.** But if no regular basis for dialogue has been established, if there are no regular points in time for interaction, it might be difficult to enter a fruitful dialogue if a situation needs immediate attention. During the operation period of a DGR, **Periodic Safety Reviews** (PSR) could be a point in time where new scientific and technical knowledge could be assessed and debated with CS[17], and where possible, problematic developments can be discussed. Typically, PSRs are done in 10-year intervals. However, in UMAN Seminar 2 it became clear that it is not known if all countries plan to have PSRs over the whole operational phase of a DGR. And, as it is the case with PSR for NPPs, most countries do not have mechanisms for interaction with CS at each PSR.

[16] See also chapter 4.1 in this deliverable.
[17] According to general findings of the Aarhus Convention Compliance Committee for the 7th Meeting of Parties of the Convention in 2021https://unece.org/sites/default/files/2021-10/ECE.MP_.PP_.2021.45_ac.pdf, par. 63-64, Periodic Safety Reviews are good opportunities to reassess the safety.

It is necessary that **engagement and dialogue with CS is a long-term and enduring.** It should not be interrupted for long time periods, otherwise interactions and trust-building would need to start from scratch as no structure for dialogue would be available if problems occur. In UMAN Seminar 4, the aspect of institutionalisation of a structure for a pertaining dialogue with CS has been taken up again – see chapter 2.4 of this deliverable.

What has been established as **important elements of a dialogue with CS**? Trust building is especially important in managing uncertainties, when RWM actors do not know an answer, they have to say so instead of claiming that everything is under control, otherwise trust will be destroyed.

Communication about safety ("it is safe") might not be the best way to win trust, **communication on risks** and changes in risks is preferable from a CS point of view. Uncertainties and changes in knowledge over time need to be openly communicated and translated into information about risks to health and the environment. This is not only true for research projects, but also more generally concerning communication with the public on wider RWM issues. Preparing risk reports in addition to safety reports and discussing them with an interested public might be an example for improving communication.

Competence building of CS and education: At some point in time a community will be asked to take a decision as to whether to host a DGR. To take such a decision in ignorance is a derogation of responsibilities owed both to itself and to its future generations. Any community asked to take a decision on siting is effectively acting as a proxy for the generations who will follow them. From a social perspective this poses a range of ethical questions but foremost is the level of risk (however small) future generations will have to shoulder. Education can and should play a key part in trust and confidence building. At the time a community is required to take a decision, an educated community is more likely to make an informed decision.

Commonplace technology, e.g., the Internet can provide a good educational platform to increase both awareness of siting and explain risks as they are known to exist. Additionally, as data gathering activities increase from underground research laboratories, opportunities such as allowing for data visualisation by way of 3D and 4D modelling allowing users to understand how a repository will evolve over time. The EURAD MODATS work package is, when a format for metadata is agreed, uniquely positioned to leverage such opportunities. Initially as to how a generic repository will evolve and where inventories are known, with designs approved as "Digital Twin" models. e.g., in a 4D scenario users would be able to slide a time bar to discover how their proposed repository is expected to evolve over user selected timeframes, users could also discover what reducible uncertainties currently exist and how it is proposed to mitigate them and also to be aware of what irreducible uncertainties persist.

Other technologies such as IRSN's Open Radiation Project[18] set up in response to the Fukushima disaster can also be used to both involve data collection by citizens (citizen science) and with a good take up give granularity to background radiation exposure. Indeed, such projects could be rolled out to encompass communities where all nuclear licensed sites are located. Currently in the UK, negotiations are taking place with the West Cumbria Community Partnerships to involve interested schools to participate in the Open radiation data collection.

2.3 Results extracted from Seminar 3 on human aspects

UMAN Seminar 3 was held on 14 and 15 June 2022 and discussed uncertainties related to human aspects (Dumont, 2022). These four topics have been selected from a list of ten for further investigation by UMAN subtasks:

- Public acceptance of the repository at potentially suitable or projected locations.
- Schedule to be considered for implementing the different phases of the disposal programme.
- New knowledge.

[18] See the Open Radiation website: https://www.openradiation.org/en

- Adequacy of safety-related activities (in siting, design, construction, operation, and closure) for the implementation of safety provisions.

For these four uncertainty topics, presentations were held and working groups discussed in detail with the help of concrete cases. These cases also included reflections on security aspects due to the ongoing war in Ukraine.

When focusing on T&PP, it became clear that aspects which have already been identified as important in the earlier seminars will also help in managing the concrete cases discussed in the working group. These aspects concerning T&PP are:

- **A project needs to be acceptable before public acceptance can be expected**. The public acceptance is way to measure the quality of the implementing process in regard to societal concerns (transparency regarding research and monitoring results, democratic process at all phases, independence and plurality of expertise, etc.)
- **Public non-acceptance can be a corrective to unsound safety measures**. Linked to previous statement, the public non-acceptance could be considered as a complementary safety layer to the existing safety system. The societal function could complement the expertise function.
- **The involvement of Civil Society needs to start early in the process**. Involving CS in research projects is a good way to take into account this recommendation, as it is a place when issues that have not been solved yet can be discussed in a transparent way. There is still room for taking into consideration CS concerns and suggestions.
- Fair communication, continuous dialogue and transparent decision-making are required. The involvement of CS should not be considered only at the beginning of the process or during the site selection process. It requires a process enabling regular meetings all along the process.
- Building and keeping trust is necessary. Trust is a result of a fruitful multi-stakeholder's dialogue, more than a way to to achieve public acceptance. It necessitates to ensure conditions of a fruitful dialogue between the different actors.
- An independent expert body should be a participant. One of the conditions for building and keeping trust is notably to have an expertise function that is trusted by all the actors. In addition to the recognition of its scientific competencies, the expert body should be recognized as independent from any interest that could delegitimize its expertise.
- Transparency is also needed on security aspects, even if some aspects cannot be publicly disclosed.
- The public consists of many diverse groups which need to be addressed specifically. It should be envision to have different interactions process with CS at different levels (local, national, international), with different types of audience (CS following the RWM issues and larger audience that have no or little experience with these issues). These different types of interactions are complementary.

2.4 Results extracted from Seminar 4 on pluralistic methodologies

UMAN Seminar 4 was held on 14-15 December 2022 on the question "How to manage uncertainties in a pluralistic way and in a long-term perspective?" (Dewoghelaere, 2024). Seminar 4 put a focus on combining our four main uncertainty topics with results from the joint development of methods in UMAN.

The importance of establishing a transparent and public participatory regime that enables dialogue on uncertainty management in all phases of RWM was strongly recalled.

We discussed -amongst others – in detail:

- The double wing model as an effective way for participation of CS in a RWM research project.
- Use of the PEP game and other use cases and scenarios for enabling fruitful interaction between the actors in RWM.

Four scenarios were discussed in Seminar 4 dealing with uncertainties about performance of seals, new results on radionuclide transport modelling, deviation of monitoring data from expectation, and the termination of the institutional monitoring phase by the government and therefore the abandonment of the DGR.

What is meant by **"double wing model"**? This model has been developed in the former research projects SITEX-II and JOPRAD for inclusion of CS in research activities. The following figure shows how it works as an example in the EURAD project: A group of civil society experts works together with the other EURAD colleges on a regular basis. These experts are compensated for their work. A larger group of CS members gives input and feedback at several points in time (ICS-workshops, questionnaires etc.); this group is only partly compensated.

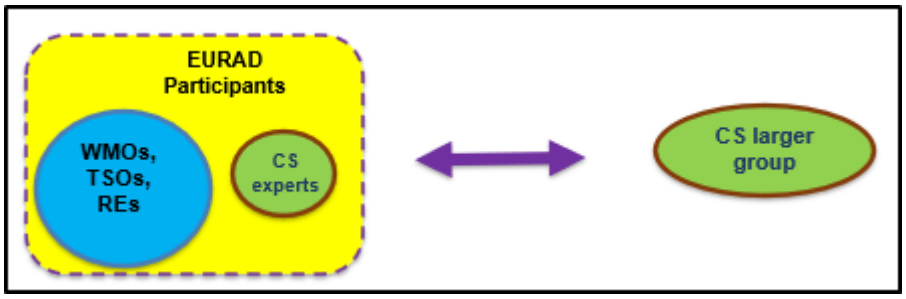

Figure 3 - Double wing model for inclusion of Civil Society in the EURAD project

The participants of Seminar 4 discussed scenarios in small groups and investigated if such a double wing model could help solve the above-mentioned scenarios. During these discussions it became (once again) clear that managing difficult situations in the near and or far future will prove **helpful if participation structures with the public are already established and can be used to deal with upcoming issues in a structured way**. Such structures could **build upon the double wing model** tested in research. **National and local committees/advisory boards** could be established in each country with the involvement of CS experts that can help communicate with the broader public when needed. Such committees need to have resources to contract expertise and enable members of the public to form their opinions. CS experts working in such committees can reach out to a larger group of interested public on a regular basis, enabling fruitful dialogue between all actors. **Good practice examples**[19] for such committees are already available such as the Danish contact forum for nuclear waste. Also, the Swedish NGO, MKG, is a good practice example – it is not a committee composed of different actors but a special NGO- providing expertise in national debates. Due to budget cuts MKG unfortunately is now at risk. This example shows that it is not only necessary to establish such structures to enable dialogue in an institutionalised way over a longer period of time (several decades at least), but also to make them independent and equipped with enough resources.

Nine conditions for a fruitful dialogue have been developed by CS experts in Task 8.3. based on interviews of a selected panel of EURAD members (Geisler-Roblin & Lavelle, 2022):

- Fruitful interactions necessitate legitimate processes in which all actors can dialog on the same footing.
- Fruitful interactions require that a community can conduct a variety of inquiries (scientific, moral, social).
- Fruitful interactions depend on the capacity of all actors to encompass others' views and to enlarge their initial perspective.
- Fruitful interactions require from an actor that they take into account the different dimensions of themselves.
- Fruitful interactions require pluralistic expertise and therefore cannot be reduced to a sole "scientific process".
- Fruitful interactions include exchanges on the meaning of the existence of repository in the life of people.

[19] More detailed examples are available in Zeleznik N., Swahn J., Daniška M., Haverkamp J., Hooge N.H., de Butler M, Wales C., (2022): Implementation of ROUTES action plan second phase. Final version as of 22/08/2023 of deliverable D9.17 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593D9.17, available on EURAD website: https://www.ejp-eurad.eu/publications/eurad-deliverable-d917-routes-implementation-routes-ics-action-plan-second-phase

- Fruitful interactions must take into account the deep impact of a geological disposal on the meaning people give to their life in a territory.
- Fruitful interactions are necessary to address the complexity of the issues (technical and non-technical) linked with geological disposal.
- Fruitful interactions cannot be meaningfully achieved without an intergenerational perspective, given the extreme timescales.

Pluralistic, multi-actor approaches in RWM support the inclusion of actors and topics to establish collaborative processes and co-create a shared knowledge.

Fruitful pluralistic interactions between different actors are a tool of effective participation and therefore can contribute to effective decision-making in RWM. But it needs to be kept in mind that pluralistic interactions are no substitute for participation or decision-making.

Furthermore, in UMAN Seminar 4 it was discussed if the use of the **PEP game** could help in solving the above-mentioned scenarios. The PEP[20] is a tool of dialogue (designed as a serious game) developed under the frame of the SITEX-II project (2015-2017) and SITEX network that enable multi-actors' discussions in the field of radioactive waste management. The objective is to identify issues all along the pathways that would really matter for different categories of actors, which do not have the same vision of what should be the pathway and what should be the safe situation for the long term. A PEP session put into discussion different strategies which facilitated a safe situation for the long term to be reached. Such a serious game can help enable fruitful dialogue in a structured form, bringing all the relevant group of actors to one table. But the possibilities to support dialogue can be best used in the planning phase when preparing for a crisis. But if a crisis has already occurred, the situation can no longer be solved by playing the game, other mechanisms need to be used.

What also became obvious in UMAN Seminar 4, that there is still no **mutual understanding of the definition of "the public" and "civil society".** But it is important to see how diverse "the public" and "CS" are. CS experts in EURAD cannot represent civil society. Entering a dialogue with CS experts will need other preconditions than with members of the general public. For members of siting communities other issues might be at stake than for "the interested public" in general.

We suggest the following definition of CS for EURAD:

Civil Societies are highly heterogenous and diverse. The definition of the public in the Aarhus Convention, Article 2, 2(4-5) is helpful: "One or more natural or legal persons, and, in accordance with national legislation or practice, their associations, organisations or groups." The public concerned is defined as: "The public affected or likely to be affected by, or having an interest in, the environmental decision-making; for the purposes of this definition, NGOs promoting environmental protection and meeting any requirements under national law shall be deemed to have an interest."

CS actors engaging in environmental topics have different knowledge of RWM and nuclear topics in general, and they have different political standpoints on nuclear. They work on local, regional, national, European and/or global level, are part of organisations or acting on their own. They have different amounts of resources for their work.

CS groups in EURAD have expertise in nuclear topics including RW, only some of them are paid, others engage on a voluntary basis.

[20] Here is a link presenting the PEP during a EURAD webinar held on September 28, 2022: https://www.youtube.com/watch?v=c00AGwEZVPA&list=PLahXOQn-bremN911IEn0w8yAzQyuUR3ky&index=17

3. Shared culture for safety and security

What do we mean when we talk about safety culture? The term **"safety culture"** was first introduced in INSAG's Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident, published by the IAEA in 1986. The IAEA has traditionally defined safety culture as "the assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance".

The IAEA developed the concept in several aspects. In its leaflet on the topic[21], IAEA uses the term **"safety and security culture"**. By making security issues more visible in the term, the importance of overlapping activities to avoid accidents and safeguard violations becomes clear. And IAEA shifted the meaning also towards the term **"culture for safety"**.

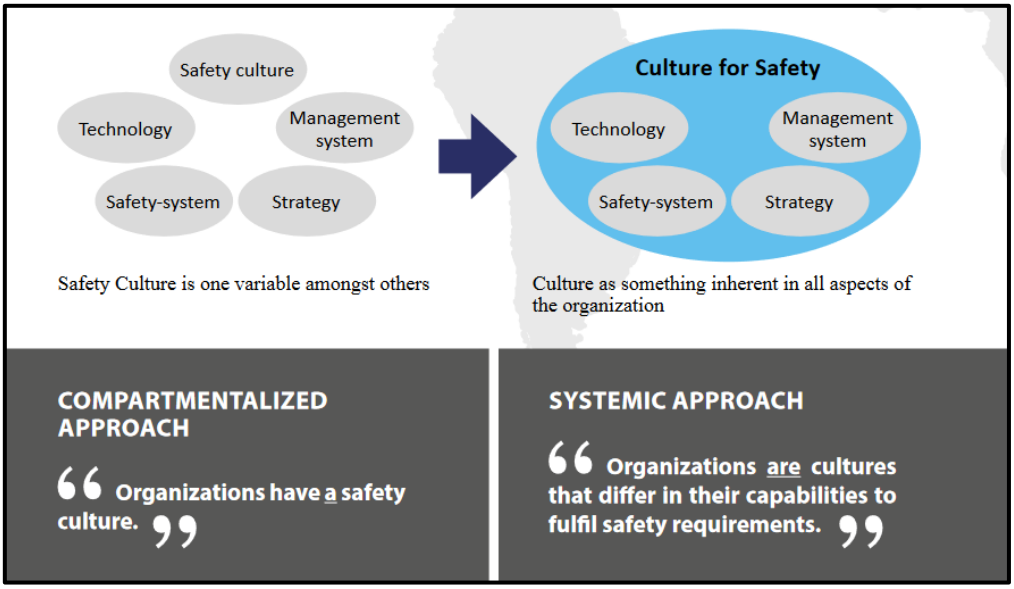

Figure 4 - From Safety Culture to Culture for Safety (IAEA)[22]

For civil society, safety culture is a very promising concept to sustain trustworthy interactions between all categories of actors in the context of RWM.

Safety culture is addressing nuclear actors involved in nuclear safety at institutional and individual levels but it also needs to encompass CS actors. How this could look in detail needs to be developed in the perspective of the Aarhus Convention.

In SITEX II, the term "**shared safety culture"** was developed. It refers to sharing elements of corporate safety culture and societal safety culture (see also figure 3 in chapter 5.3). This concept can also be called an **"enlarged safety culture".**

In UMAN Task 5, we started with a broad definition of safety culture and developed it further in the Seminars and ICS Workshops.

3.1 Results extracted from Seminar 1 on global picture

The above presented definitions of culture for safety and shared safety culture are connected to all topics of relevance for nuclear safety and security. Nevertheless, in this chapter we focus on **uncertainties that are related to the political and scientific culture and to security**; the latter is in our opinion a sector often neglected when talking about culture for safety.

[21] https://www.iaea.org/topics/safety-and-security-culture
[22] https://www.iaea.org/sites/default/files/culture_for_safety_leaflet.pdf

In the UMAN CS questionnaire, the following uncertainties related to political and scientific culture for safety were named by CS members:

- Independence of regulatory authorities, and who is controlling the controllers?
- Enabling independent expertise and enough resources for NGO work.
- A stable and trustworthy legal system
- A stable and trustworthy political system, decisions need to be reliable, i.e., if phase-out of nuclear energy is an objective, then inventories for disposal can be fixed and necessary capacities in DGRs can be assessed accordingly.
- Corruption and fraud need to be exposed with consequential legal remedies,
- Political influence should not override scientific facts.
- Commercial or "private status" of RWM operators might be problematic, especially concerning transparency.
- Human errors and human behaviour must be taken into account, including terror and war (security)
- Reversibility of decisions (is discussed in chapter 5 of this deliverable)

In the working groups of UMAN Seminar 1, three questions had to be answered: Which uncertainties are most important for the different colleges and CS? What are commonalities and differences between the actors? How to mitigate these differences?

We analysed if uncertainties defined by the CS members from the above list were also in the focus of the other three colleges.

TSO's regard changes in the political context, changes in the societal priorities and in ethical views as non-technical issues. They may lead to a change in the national programme or even to an absence of decision for a long time (link with reversibility). In our view, this split between technical issues (including uncertainties) and non-technical issues is misleading, because **DGRs are socio-technical systems** with a strong policy component. Any change on the "socio"-level is in connection with the "technical"-level and vice versa.

Societal and political uncertainties are often assigned to the programme phase of RWM. This is too narrow. **Political change can also lead to unexpected changes in safety and security regimes during all phases of the RWM** – i.e., if the budget is cut, or if a regulator is disempowered, this will lead to unpredictable changes in the operation and closure phase, and also in the post-closure phase. The impression that we live in times when a societal disruption can endanger a DGR programme seems to be more widespread.

The topic of fraud was mentioned once in the debates, when discussing if paying for communities to host a site is **bribing** or **compensating** for what is in effect a "national service"? Either way, economic interests have not *per se* the same goals as safety and security regimes; a shared culture for safety and security needs to reflect on the possible consequences of selecting what might not be the site best for long term safety but the (only) site that is willing to host a DGR when being compensated. But even if safety and security is duly considered, local communities might need to be compensated (e.g., property values will drop).

Societal uncertainties were brought into the debate by all three colleges focusing on **acceptance** of a DGR by the society, on communication issues etc. Therefore, it was stressed that such uncertainties will reduce over time. We discuss these issues in chapter 3.3 of this deliverable.

The security topic was brought up in the debates by the **hazard of unintentional human intrusion** into a DGR. Actors have different views on the significance of this uncertainty and the way to manage it. Most see the isolation of nuclear waste as the management strategy, others were more in favor of knowledge and memory keeping to at least keep out unintentional intruders.

Uncertainty management and safety optimisation needs to be a living process during RWM. A quote from the discussion formulated: "*When we look back, there is generally something that we should have done differently*." This is an important part of culture for safety – to reflect on failures and in general **establish learning structures and organisations** to avoid making future mistakes.

The topic of **independence of experts and expertise** was discussed. It became clear that no common definition of independence existed currently among seminar participants. Some participants defined e.g., WMO as provider of independent expertise, but others questioned this as WMO often are private companies having business interests. Generally speaking, expert opinions should constitute qualified scientific works by recognised competent natural persons or organisations in the field, in which the opinion is delivered, and are also independent, because they are impartial and have no prior business or personal relationship with the commissioners of the opinions. A helpful approach of independence is to have the possibility of a second expert opinion, or to shift the definition to **"plurality of expertise"**, without giving up on the demand for independence, at least for the second expert opinions**.** Nonetheless, all actors have their specific responsibilities, perspectives, and roles. Not everyone is an expert in a scientific or technical discipline, you do not automatically become an expert if you take part in expert circles. But expertise can also come from social science entry points, and from long-term work initiatives. CS has a right to be "subjective" – this was formulated in a working group. What does it mean? On the one hand, there is "objective" science and technology on RWM topics (mostly without including social science), and on the other hand there are "subjective" approaches. It is a problematic discourse to use these terms against each other, and to assume an overall objectivity of science and technology.

To allow NGOs to build up expertise and to take part in a socio-technical dialogue, **resources** are needed, including to be able to pay for experts.

One role of CS is to challenge the RWM system, this might also include **whistleblowing** as part of a shared culture for safety and security. There is a need for protection of whistleblowers.

For the safety case, boundary conditions are needed. What happens with **uncertainties that are not within the boundaries of the safety case?** This is especially the case for the political uncertainties. It is the responsibility of civil society to keep them in focus and use the **CS control function** to bring them into scientific and technical discourses where appropriate. Participative structures like the Danish contact forum for radioactive waste help to establish a place where these uncertainties can be worked on.

Participants did not agree if a **ranking of uncertainties** is important**.** Suggestions were to rank them based on their importance for safety, by considering their correlations. But the importance of safety is not a fixed rank or number. This is especially true when considering political uncertainties, i.e., they might become very important for nuclear safety or security in a short period of time. The start of the Russian war against Ukraine was such a change with direct consequences for nuclear security and safety. Cultural flexibility is needed.

3.2 Results extracted from Seminar 2 on site and geosphere

During the UMAN Seminar 2 on management of uncertainties related to site and geosphere characteristics several aspects were discussed which are of relevant to a shared culture for safety and security. The debates were held around three scenarios concerning the activity of faults, future glaciations, and the site's natural resources. All scenarios focused on changes that have not been anticipated in the planning and licensing phase of a DGR.

Concerning a shared culture for safety and security, several topics came up in the discussion that should be highlighted further.

In addition to the issues already discussed in chapter 3.1, a focus on Seminar 2 discussions lay on scenario-based necessities for **adaptation of governance, reversibility of decisions and having alternative options**. For example: One of the scenarios used in Seminar 2 was on the possible presence of natural resources at the site of the DGR that future generations might want to mine, either during the operation phase or after; and additionally on possible emergence of new natural resources. This might occur before or after the memory of the DGR is lost. Such scenarios could lead to human intrusion and potentially the breaking up of the barriers while drilling. As one way to avoid such a scenario, site selection with exclusion of known natural resources is helpful, but the risk of the other

scenario, that new resources emerge, cannot be reduced. Furthermore, banning the use of the area and keeping memory of the site will help to reduce the uncertainty and associated risk.

In a culture for safety and security, dealing with these topics requires not only flexibility but preparation for alternative options in case of necessary changes. One problem could be, there is no budget available for major future changes. In Seminar 2, discussions showed two opinions: A budget needs to be kept for future generations, or is the responsibility of our generation(s) only to create no undue effort for retrieval? (Passive Safety). It will be important to think early concerning change management: we should have an early dialogue on the criteria to retrieve and on the reasons for reassessment.

The continuity of organisations was also questioned. What will happen if an organisation ceases to exist, and if nobody can take over? i.e., if a national archive is lost.

Memory keeping needs to be defined and expanded to include a **memory function** to remind future generations what to do if research results come up that prove the safety assumptions for the DGR wrong. Safety assessments might only take place as long as there is a license valid, but what comes after?

3.3 Results extracted from Seminar 3 on human aspects

UMAN Seminar 3 was held on 14 and 15 June 2022, which discussed uncertainties related to human aspects (Dumont, 2022). Of the four topics that were selected, the adequacy of safety-related activities in siting, design, construction, operation, and closure for the implementation of safety provisions, and public acceptance of the repository at potentially suitable or projected locations, were perhaps the most relevant regarding a shared safety culture. The seminar focused on, what the key uncertainties were for the considered type of actor, for the topic in question, what their impact on safety were, what the available options to manage the uncertainties could be, the pros and cons of each option, and what the best options to manage them would be. The cases included in the discussions also contained reflections on security aspects due to the ongoing war in Ukraine.

As a starting point, the relevance of public acceptance regarding EURAD and UMAN was touched upon and it was stressed that EURAD recognises and supports Civil Society Involvement (CSI) in regard to safety, supported by the Aarhus Convention, and that the UMAN perspective on CSI regarding safety follows this line. Both EURAD and UMAN include safety-related research on public acceptance of a DGR as part of CSI in their goal definitions. However, the question was also asked, if public acceptance as part of CSI is inherently related to safety, should it then be viewed as an uncertainty or as an uncertainty management strategy? It cannot be both. The premise for answering this question is that acceptance or non-acceptance are the ultimate manifestations of the views of the public on any DGR. Regarding the public itself, there is no higher instance. Furthermore, public acceptance or non-acceptance do not only have to be related to safety. Other motives - political, financial, etc. - can also play a role. In an open, democratic society, public acceptance of any DGR is a goal in itself. Public acceptance can, in a deliberative process, be framed by a strong implementation of the Aarhus Convention which confirms the robustness of safety culture as an integral part of uncertainty management solutions. Conversely, public non-acceptance can be a corrective to insufficient safety measures. Thus, public acceptance and non-acceptance can change over time, especially if safety measures are perceived as better or proven wrong. Finally, even if it is seen only as a means to succeed with final disposal of the RW – which could be the case by some of the WMOs, TSOs and REs – one could argue that the achievement of public acceptance is one of the main reasons for the EURAD 3+1 dialogue.

Also, the respective statuses of **acceptance** and **acceptability** must be clarified. Here, the main issue is whether public acceptance is preceded by public acceptability, which would then become a necessary prerequisite for public acceptance and whether public acceptability can replace public acceptance (*for more on this issue, see 4.3*).

Regarding the uncertainties related to the adequacy of safety-related activities for the implementation of safety provisions, it was acknowledged that socio-technical aspects are at the root of this type of uncertainty with an enlarged safety-culture being a precondition for ensuring the continuity of the safety-related activities (see below: management options). In this context, the term "safety culture" was traced back to INSAG's Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident, which gives the following definition: *"Safety culture is that assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance"* (IAEA, 1991). This means that safety becomes a question of more than just the application of technology and although application of best available technology is necessary, it is not in itself a sufficient condition for reaching the best possible safety practices.

This notion of safety culture addresses the first circle of actors involved in nuclear safety: governments, regulators, operators, researchers, and designers at institutional and individual levels and also involves legal, technical, financial, organisational, individual, ethical and social aspects. This is illustrated by the following Figure.

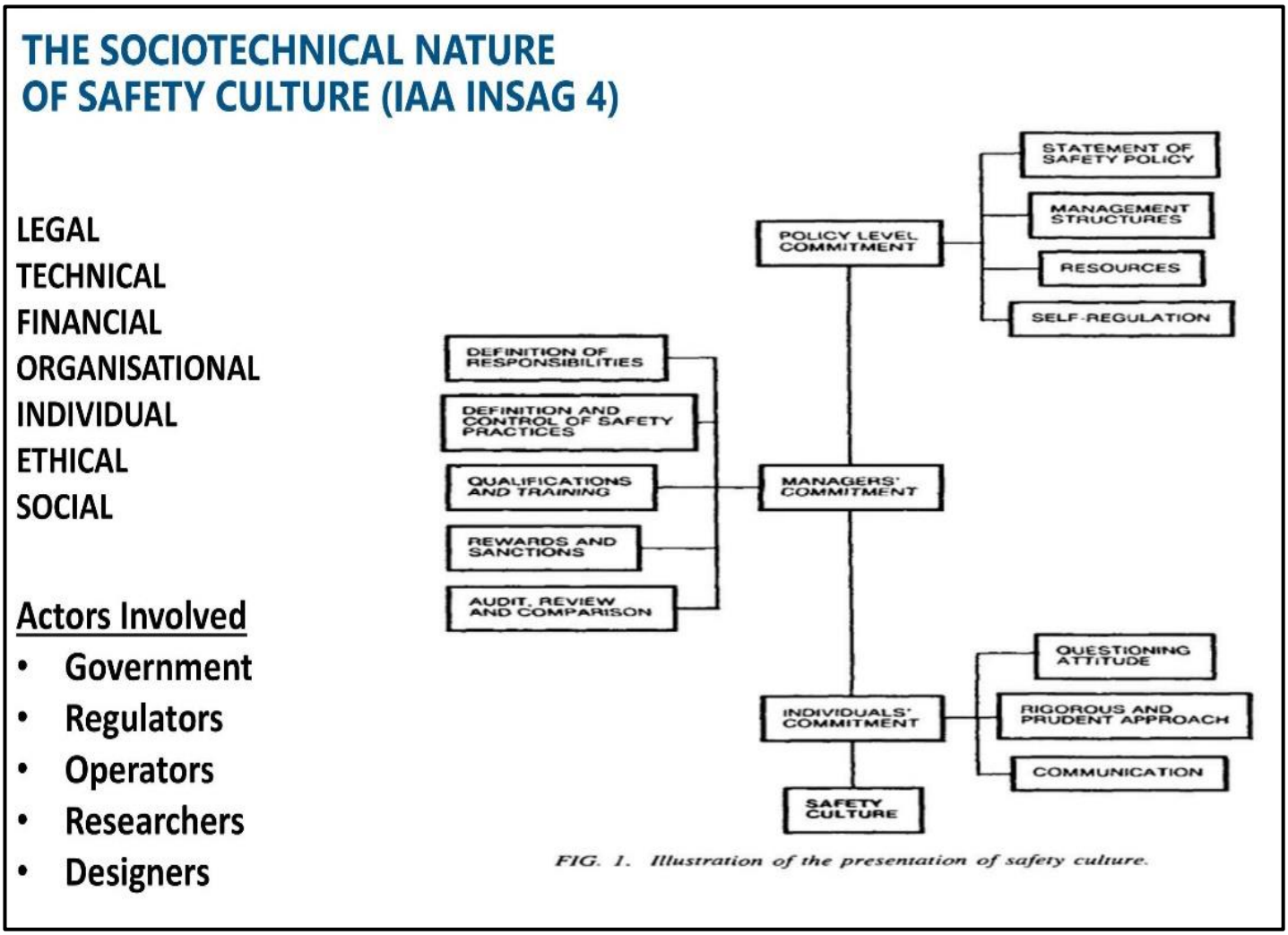

Figure 5 - The sociotechnical nature of safety culture (Hériard-Dubreuil, 2022).

A discussion based on a hypothetical case on **security issues** linked to a national emergency emerged on, among others, whether uncertainty on security needs to be represented and assessed in the safety

case, what kind of rules should be implemented to manage this type of uncertainty and whether a dialogue with CS could contribute to managing the situation and if so, how? Some pointed out that, based on the experiences in Ukraine, it is evident how little power international organisations like the IAEA and other international bodies have. In terms of facility design, possibly some rethinking could be done e.g., minimising the surface concentration of waste and or distributing waste to several locations. Updated safety and security rules could be envisaged, but if they are not complied with, they will not have much impact. It was mentioned that perhaps the Geneva convention should be reviewed to include all nuclear facilities and not only NPPs and that safety concerning current facilities should also include assessment of barriers for nuclear attacks. Perhaps some sort of stress test should be added as proposed by NTW to the ENSREG[23]. Management of current information is important as well. In conclusion, it could be said that this is a complex issue and that all kinds of external threats need to be taken into account in the safety case, including in the FEP list, although not everybody agreed on how and to what extent. Basically, because of the potentially catastrophic impacts of a serious emergency, especially in a war situation, these are issues for the whole of society, for which reason CS should be included in the dialogue.

3.4 Results extracted from Seminar 4 on pluralistic methodologies

In Seminar 4, the pluralistic methods that were developed throughout the UMAN work package, were tested in debating scenarios.

What is of special interest for the shared culture for safety and security is the possibly all of the methodologies can be used to increase safety and security in a shared cultural system where CS and other RWM actors have a regular dialogue.

The pluralistic methods are discussed in chapter 2.4 above.

[23] It was proposal of NTW to the EC, DG Energy and ENSREG: The need for a stress test on safety related issues during nuclear security events, including acts of war. Paris/Brussels, 19 May 2022, see https://www.nuclear-transparency-watch.eu/non-classe/open-letter-from-ntw-eeb-calling-for-reviewed-stress-tests-after-the-attacks-on-ukrainian-npp.html

4. Ethical principles

4.1 Results extracted from Seminar 1 on global picture

The main focus of CS in regard to the application of ethical principles during Seminar 1 was on possible evolutions of uncertainties in a political and societal context, which could also constitute a conceptual challenge (Röhlig, 2021)[24]. Here, the lack of public information and transparency was identified by CS representatives as a cause of uncertainty and also a management issue, because they could hamper effective RWM. The reason is that T&PP in the governance on decision-making in RWM should not only be perceived as an aim in itself, but also as a way to improve safety. T&PP are essential elements of environment-related decision-making pursuant to the Aarhus Convention, the Espoo Convention on Environmental Impact Assessment in a Transboundary Context, the Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment, and the Directive 2014/52/EU on the assessment of the effects of certain public and private projects on the environment. Also, CS representatives called for a broadening of the scope of EURAD in general, considering that transparency of uncertainties is strongly linked to uncertainties of transparency - one cannot exist without the other. It is not enough to be transparent about a technical uncertainty if you have not built trust by using a transparency and participation model of high-quality throughout the whole RWM process[25]. It soon became obvious that it is not only important to assure transparency on and participation in all steps of RWM but also in the underlying and guiding principles that should be the ethical basis of managing RWM and the related uncertainties.

The main principle for the CS members to be applied during this process was identified as **the precautionary principle**. The precautionary principle is a **legal** as well as an **ethical** principle and is considered one of the pillars of European environmental law. Its origin is among others Principle 15 of the Rio Declaration that defines it the following way: *"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."*

This means that if there is a strong suspicion that a certain activity may have environmentally harmful consequences, it is better to act before it is too late than wait until full scientific evidence is available that unequivocally demonstrates a causal connection between the activity in question and its possible impacts. Systematically, the precautionary principle is a sub-category of the prevention principle, which says that is easier to respond to environmentally harmful activities before rather than after they occur, by preventing them.

The precautionary principle generally justifies action or inaction to prevent damage and avoid potential risks (in dubio pro natura). In **European law**, the principle is consolidated in Article 191 (ex Article 174, Treaty on European Union, TEC) in the Treaty on Functioning of the European Union (TFEU). One of its implications is that the European Commission has the right to establish the level of protection of the environment and human, animal and plant health that it deems appropriate (European Commission, 2000)[26]. Although the principle concerns risk management, this does not mean that all risks must be reduced to zero. Where action is deemed necessary, measures based on the precautionary principle should be proportional to the selected level of protection, non-discriminatory in their application, consistent with measures already taken, based on an assessment of the potential benefits and costs of

[24] Furthermore, this description of the CS inputs to Seminar 1 is mainly based on Hériard-Dubreuil et al., 2020

[25] It was also pointed out that when communicating on uncertainties, the term "risk" instead of "safety" might be the better choice.

[26] Commission guidelines on how to apply the precautionary principle: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Al32042

action or lack thereof and subject to review in the light of new scientific data. However, the problem is that RWM, legally speaking, constitutes an exception in this regard: the Euratom Treaty, which is the foundation of European nuclear law, is not subject to the application of the precautionary principle or other environmental principles. Euratom suspends Article 191, paragraphs 1 and 2, in the TFEU. Obviously, this has an effect on how RW is managed in the EU.

Nonetheless, regarding RWM, the precautionary principle could be relevant for policy, framework and program establishment, site evaluation, selection and characterisation, and facility construction, operation, closure and post-closure. Not least, it could help determine the choice between short term and long term, and reversible and irreversible options, e.g., between interim storage and disposal, deep geological repositories, and deep borehole technology, etc. And because it is an environmental principle, it takes precedence of economic calculations of costs and benefits by putting environmental considerations first (Dewoghélaëre et al., 2020a).

4.2 Results extracted from Seminar 2 on site and geosphere

In Seminar 2, the focus was on the possible evolution and safety significance of uncertainties related to three site and geosphere related topics - i.e., fault detection and reactivation, climate evolution with a focus on future glaciations and their effects, and the natural resources of a site - as well as possible options to represent these uncertainties in a safety assessment and, where needed, to reduce, avoid or mitigate them (Rocher, 2021).The ethical principles identified as relevant in this regard relate both to content and process concerning RWM decision-making. Their objective would be to facilitate a modus operandi to be applied at all stages of RWM by virtue of an integrated approach, including an integrated framing of the perspective of increasing complexity over time based on – to the widest degree – a full picture of the issues at hand. In this context, the application of ethical principles should help broaden the scope of the view. Also, in the perspective of CS, the perception that the UMAN research community tends to look at uncertainty categories as isolated, non-connected questions, which resort to specific linear separated strategies, is seen as a problem.

Application of **ethical principles related to the process of the RWM decision-making** is not specific to any one step of GD. This GD structure has to be described as clearly and fully as possible, including answering the following three preliminary questions: *Who* has moral and legal standing, i.e., who are the decision-makers and to what degree? *Which* considerations will be allowed as a basis for decision-making (legal, technical and ethical)? *What* is the role of the CS in the decision-making process? At some point in time, a decision in the RWM process has to be made, which means that a legal, technical and ethical basis for the decision has to be defined. In regard to uncertainties in the knowledge base, a classification system – i.e., known knowns, known unknown, unknown/ignored knowns and unknown unknowns, etc. – is relevant, but irrespective of the composition of the knowns and unknowns, the decision-making process will continue.

The most suitable ethical system to be applied in this process is **deontological ethics**, which is a normative theory, in which acts are judged morally without including their consequences in the judgement criteria. What matters are their motives. Its advantage is that it provides the opportunity to consider core (non-derivative) rights, such as human rights, civil rights and property rights. Also, non-human rights might have a standing in the decision-making. More specifically, the so-called *rule deontology* that focuses on the universal applications of moral principles or a code of ethics to every situation, judging general courses of actions as either prohibited, permissible or prescribed. These rights are not weighted against each other but should be perceived as complementary (Werner, 2006; Hofmann-Ridinger, 2006).

It follows from deontological ethics that individual and collective acts are only permissible, when they are approved by those whose rights and interests are at risk. Obviously, consent cannot be obtained

from all the affected parties in every situation, nor is it possible to get a full consensus. But it must be assumed that people who normally would be unwilling to accept a particular risk would be inclined to submit to a decision-making process, which is embedded in a fair and democratic structure, respecting the integrity of individual rights. Thus, deontological ethics delivers the best and most convincing ethical arguments for implementation of the Aarhus Convention and public access to information, participation, resources and justice during the course of the RWM process[27].

Regarding **principles applied to the content of the RWM decision-making**, among others the following two safety-related guiding principles could be applied, depending on the quality and certainty of the information that is available: *The Bayesian criterion*, which is basically optimistic and is considered the universal type of action orientation. It says that you have to maximise the expected value of the consequences of an act. The expected value is the subjective value of the consequences of an act measured by the subjective or objective probability that it occurs. Here. *objective risk* is defined as a risk that is measurable and quantifiable to a certain extent (a certain resistance of material, permeability of host rock, etc.), and *subjective risk* as something one cannot calculate (human intrusion, political blow up, sudden lack of funding, war, terrorism, etc.).

The second model is the *Minimax criterion* that applies to uncertainty but not to risk situations. It says that where there are no probability calculations for future incidents, a scenario should be selected, whose worst possible consequences are better than the worst possible consequences of all other possible scenarios.

Both principles are part of **consequentialist ethics**, i.e., ethics that judge actions only by their consequences. With regard to RWM, these ethics have some weak points. Notably: In consequentialist risk assessment, there is *no distinction between decision-makers and the people affected by the decisions*. Over very long periods of time, which is characteristic of the decay of the RW, this is problematic, because one or a few generations of decision-makers make decisions affecting a very large number of generations. Another weakness is the question of *autonomy*: People are responsible for their lives and this responsibility cannot be taken away by other people. One of the consequences of this autonomy is the prohibition of paternalism: Even if I am absolutely convinced that a certain measure has more advantages than disadvantages for a person or a group of persons, it cannot be implemented if this person or group of persons oppose it. In particular, prohibition of paternalism is relevant in regard to NIMBY phenomena. *Disregard of criteria such as equity and fairness*: In an ethical analysis it makes a big difference, if a group of persons accept a higher level of risk themselves in order to gain advantages, or the risk is put on them by another group of persons in order for them to gain these advantages. Or in other words: How big a risk should a certain type of industry be allowed to inflict on the surrounding communities to benefit from it itself? In conclusion, the consequentialist criteria for decision-making can only be applied, when they are combined with an interpersonal and coherent evaluation parameter. Dissimilar criteria for moral judgment are not compatible with such a parameter (Hooge 2021a).

4.3 Results extracted from Seminar 3 on human aspects

The focus of seminar 3 - interactions between all categories of actors, including CS, on uncertainty management options throughout the different phases of DGR implementation as well as on governance and interactions between stakeholders, with discussions based on concrete examples of uncertainties related to human aspects (Dumont, 2022) – constitutes in a CS perspective perhaps one of the broadest subjects of any of the UMAN seminars. Thus, a wider set of ethical principles should be applied during

[27] Another example is that deontological ethics provides the opportunity of a *municipality veto* against hosting a final repository for RW, as it has been seen in Sweden and France.

these interactions. The broadest of all the ethical principles to guide the interactions between the stakeholders in RWM is the **responsibility principle**, in which a sense of responsibility plays a central role. First and foremost, it is based on a will by those who possess the causal capability to carry out an act in order to behave unselfishly in regard to a valuable object and this responsibility is prima facie not reciprocal. As a consequence, to take responsibility implies moral accountability. For a stakeholder in the RWM decision-making process, this responsibility becomes acute, when such an account is included in the possible impacts of a course of action[28]. Those who are carriers of responsibility and held responsible are free and autonomous entities that are also legal subjects. As legal subjects, they can either be physical (persons) or moral persons (institution for instance) . In the latter case they are non-human entities with rights and obligations provided by law, which enable them to carry out the duties required within the safety culture (e.g., NGOs. companies, corporations, municipalities, government agencies, intergovernmental organisations, etc., that have a legal name and certain rights, protections, privileges, responsibilities, and liabilities and consequently can enter into contracts, sue and be sued, i.e., have capacity to transfer rights and obligations). Juridical personhood allows one or more physical persons to act as a single entity for legal purposes. In order to be a moral agent in this respect, a physical person also has to be a moral person, i.e., furnished with the aforementioned basic rights and obligations. Furthermore, the responsibility principle has an affinity with **virtue ethics** - a type of ethics that focuses on virtues, i.e., traits of character, which can be extended to a "functionalist" account of which traits that are required in what situations. Each function requires different mixes of institutions and practices that need different kind of virtues for its ideal development[29]. Development, maintenance and reinforcement of virtues presuppose integration into a moral tradition, which allows for a narrative order of a single life (or in the case of moral, non-physical persons: of a single continuity, which regard to RWM has to be very long-term) and which depends for its existence on standards of excellence in certain practices. In each case, the moral agents must be able to look backwards and forward to see how their existence make a difference[30]. The moral principle of responsibility is supplemented by a **legal principle of ultimate responsibility** in RWM. A prominent example of this is found in Council Directive 2011/70/EURATOM of 19 July 2011 establishing a Community Framework for the responsible and safe management of spent fuel and radioactive waste, where EU member states bear ultimate responsibility for the safety of spent fuel and RWM (Preamble, Recitals 23 and 25, and Articles 4(1,2), 5(1) and 11), whereas a license holder has overall responsibility for any activity or facility related to the management of spent fuel or RW as specified in a license (Article 3(6)). This responsibility cannot be delegated (Article 7(1)). The concept of responsibility is even a determining criterion in the definition of a license, which means "any legal document granted under the jurisdiction of a member state to carry out any activity related to the management of spent fuel or radioactive waste, or to confer responsibility for siting, design, construction, commissioning, operation, decommissioning or closure of a spent fuel management facility or of a radioactive waste management facility" (Article 3(5)).

Relevant to the interaction between the different categories of actors in RWM is not least whether public acceptance as part of CSI related to safety should be viewed as an uncertainty or an uncertainty management strategy, i.e., as a responsible act, because it cannot be both. The distinction between **acceptance** and **acceptability** can be viewed in the same perspective: If public acceptance is preceded

[28] Arguably, the responsibility principle is particularly important in *technology ethics*, because of the way that technology application impacts the world (Jonas, 1979/2003, pp. 153-245; Andrén 2012)

[29] Virtue ethics is based on a notion of "what is good". What is perceived as good is not subjective but based on an objective order of things. Good is when something serves its purpose. That means that "the good" first and foremost in based on knowledge and rationality. And that in a situation, when a moral agent does not know everything about all things (which is usually the case), the agent has to rely on expert opinions. In this context, there is little different between normative and descriptive knowledge. E.g., see: Nida-Rümelin, 2005.

[30] It should be mentioned that there are objections to virtue ethics: When moral agents are judged on their character, their intentions, decisions, and actions become less important (although their character to a large extent can be defined as the sum of these intentions, decisions, and actions). For more general information, see Hooge, 2021b.

by public acceptability, which would then become a necessary prerequisite for public acceptance and even replace it, it would shift the focus from those who bear the consequences of the RWM activities – i.e., the public – to the activities themselves and it could be argued that this is a sort of paternalism (who decides acceptability?). On the other hand, it could also refer to a theoretical framework based on valid ethical approaches. In conclusion, as part of an uncertainty management strategy, public acceptance can, in a deliberative process be framed by a strong implementation of the Aarhus Convention, confirm sound safety solutions. Conversely, public non-acceptance can be a corrective to unsound safety measures and a proportionate response to non-acceptability. Notions such as "the public", "acceptance" and "public acceptance" in regard to RWM are to a certain degree context-specific notions which could signify different things dependent on e.g., the perspectives of the actors who need it to start or continue activities or those who will bear the consequences of these activities (Hooge, 2022).

As in other cases and contexts, the responsibility principle could here be combined with recourse to a general **precautionary principle** indicating that suspicion of an activity's negative environmental impacts justifies actions that aim at limiting or preventing the activity in question before final scientific evidence of its possible danger is provided.

4.4 Results extracted from Seminar 4 on pluralistic methodologies

The basis of pluralistic and multi-actor approach, which was the focus of Seminar 4, is the co-creation and sharing of knowledge among different types of actors with complementary expertise, thereby establishing collaborative processes, which involve a diversity of actors in order to address complex issues. The methods used in these processes must support inclusion of actors and topics in the short and long term and enable them to enter fruitful dialogue in all phases of RWM[31]. This presupposes as a minimum, compliance with the Aarhus Convention and other relevant European and international law.

All this gives priority to the importance of an appropriate process to be in place, in this case based on ethical principles related to **deontological ethics**, i.e., a normative theory, in which acts are judged morally without including their consequences in the judgement criteria, and more specifically **rule deontology** (*for more on this, see 4.2*). However, considering the projects that are included in the process focus on real problems for which end-users need solutions, these solutions must be applied in practice and cover real needs. Ethical principles related to the process of decision-making must be supplemented by ethical principles related to the content of the decision-making in RWM. In this case first and foremost integration of the results of pluralistic discussions in a safety case review and other procedures linked to final disposal of RW (licensing processes, etc.). Here, arguably, the **responsibility principle** (*for more on this, see 4.3*) – which relates both to content and process - could play a leading role, supplemented by the **precautionary principle** (*for more on this, see 4.1*) (Hooge et al., 2022).

[31] Fruitful pluralistic dialogues and interactions are means of effective participation and contribute to effective decision-making in RWM. For more on this subject, see Geisler-Roblin & Lavelle, 2022.

5. Rolling stewardship

5.1 Results extracted from Seminar 1 on global picture

As previously mentioned, one of the focuses of CS during Seminar 1 was on possible evolutions of uncertainties in a political and societal context. Concerns were raised particularly with respect to the investigation of RWM programme alternatives in order to address uncertainties in the process itself and in regard to the possibility of retrievability, recoverability and related knowledge transfer. Furthermore, the precautionary principle as guidance for decision-making (cf. 4.1) and the idea for rolling stewardship for RWM were advocated.

In the view of CS representatives, reversibility, recoverability, and approaches of rolling stewardship are potential means to manage uncertainties and here long implementation times were considered an asset. However, evolution over time might require a flexible interpretation of safety standards. More attention should be paid to managing "unknowns knowns" (or "ignored knowns"), e.g., by means of establishing appropriate management systems and developing a safety culture. Also, given there are ways and methods of addressing technical uncertainties, other uncertainties require more attention. CS representatives stressed the most important uncertainty is the societal understanding of the system and that technical and political uncertainties are related and therefore should not be separated. They see their involvement in an open dialogue on these and other matters as a contribution to safety. Although the different actors take different views on uncertainty management, it appears that there were shared views with WMOs, TSOs, REs about uncertainties on knowledge management, on storage and transfer of data over generations, as a part of societal uncertainties (Röhlig, 2021)[32].

Rolling stewardship can manifest itself in more than one version[33] The one that CS representatives mostly referred to, was attributed to Gordon Edwards, who is the president of the Canadian Coalition for Nuclear Responsibility (CCNR) (Edwards, 2013; CCNR, undated). Broadly speaking, it signifies an **intergenerational management concept requiring monitoring and maintenance of RW for an indefinite period of time**, with responsibility being passed on from one generation to the next, preserving the possibility of retrieval, recharacterisation and repackaging of the waste. It also requires a mechanism for reinstructing the next generation, which provides detailed information on the nature of the wastes and the associated hazards and ensures that the next generation is fully aware of the need to spend time and money on the RW and if necessary, to see that corrective action is taken in a timely way. This process could last until a final safe solution is found which would no longer require constant care and memory.

More specifically, it provides a **framework for a chain of management decisions** that can be changed over time, empowering each generation with greater information on stewardship tools and practices. Instead of focusing on an infinite, unpredictable future, it touches on practical problems that can be solved in the short term with some guarantee of success. Moreover, it includes institutional control mechanisms that are meant to address among others legal, technical, financial, administrative, and R&D issues (Dewoghélaëre et al., 2020b).

Thus, the pathway to rolling stewardship that was primarily emphasised, were concerns over the recoverability of RW in **the post-closure phase** of a DGR and it was discussed for how long this possibility should exist, if not permanently. The UMAN CS Questionnaire results clearly demonstrated

[32] Furthermore, the description of the CS inputs to Seminar 1 is mainly based on Hériard-Dubreuil et al., 2020.

[33] Rolling stewardship was first mentioned in 1995 in a study by the U.S. National Research Council. At that time, it had a more limited scope than today, planning for stewardship only one generation ahead. The study recommended rolling stewardship as an option for addressing contaminated sites that pose significant clean-up problems and where no ample technological solutions are available. See: National Environmental Policy Institute (NEPI), 1999, p. 10.

that CS larger group members see many uncertainties connected to the post-closure phase[34]. Furthermore, the question was asked; whether the possibility of full retrievability and recoverability would be one of the determining criteria for choosing the type of disposal method. Thus, a characterisation of the needs for retrievability options and the corresponding criteria in order to make it possible to plan for keeping these options open as long as possible would be needed. In this regard, uncertainties on trans-generational aspects, including information transfer from generation to generation, the risk of memory and data loss, warning over time, the time perspective of surveillance (when can it be stopped?) and responsibilities, and after the responsible bodies have disappeared, would constitute a problem. In conclusion, the CS representatives wanted the rolling stewardship ideas to be researched.

5.2 Results extracted from Seminar 2 on site and geosphere

As mentioned, Seminar 2 focused on the possible evolution and safety significance of uncertainties related to site, geosphere related topics as well as possible options to represent these uncertainties in a safety assessment and, where needed, to reduce, avoid or mitigate them (Rocher, M. 2021). According to the CS representatives, effective inclusion of CS should be seen in an intergenerational perspective, not least because implementation of a DGR is far from being a classical industrial delivery. Rather, it is an experimental process of development involving unavoidable uncertainties that will be dealt with over time, incorporating at each stage new social, political, economic, and technical information. Hence, the objective of a risk analysis of a final disposal concept for RW must be able to address the challenges from long-lived RW and produce a well-planned and science-based strategy for RWM in the long term (efficiency within a multitude of timeframes, but particularly in the long term). Furthermore, any complex problem within RWM, even when it is analysed as a supposedly isolated phenomenon, must be assessed in the context of the six phases defined in EURAD as constituting the RWM process - i.e., policy, framework and programme establishment, site evaluation and site selection, site characterisation, facility construction, facility operation and closure and post-closure - even though not all phases turn out to be relevant in a given context and some are more relevant than others. A stepwise, transparent, and flexible decision-making process is needed to manage uncertainties in a way which is satisfactory to all stakeholders. The dialogue with the stakeholders is a continuous exchange that includes regulators and society in a long-term engagement and decision-making on uncertainties based on, among others, multi-layer discussions with local and national stakeholders.

In order to ensure necessary information can be used by future generations, it would make sense to develop a **preliminary framework for rolling stewardship** as a way to address uncertainties of T&PP, with complementary issues such as the perspective of increasing complexity of uncertainties over time, uncertainties on knowledge and information management for an indeterminate period of time, promoting the contribution of CS members into the UMAN picture and setting ethical principles on how to identify and deal with uncertainties. Today we do not know which resources will be needed in the future, but can nonetheless provide ample information to enable future generations to maintain their options - e.g., by reserving a budget, preserving retrievability, keeping memory of knowledge, etc.

Consequently, ensuring a rolling stewardship **programme by** engaging CS in the long-term implementation of the DGR, is a key asset in the perspective of dealing with uncertainties. This has to be grounded on the Aarhus Convention, creating an effective practical capacity of each successive generation to access the necessary information and to participate in decision-making as a key priority. An effective participation of CS along successive generations requires maintaining, in the long term, good governance (including regulators' independence) and high standards of safety, security and risk assessments (Hériard-Dubreuil, 2021).

[34] It was also pointed out that when EURAD started, 6 phases were defined, among them no. 5 – the post-closure phase. However, during 2020, this phase disappeared from the EURAD list of phases (Introductory Course on 2020-09-14). This was perceived as a problem by the CS representatives, considering that almost all uncertainties in regard to RWM will have an unpredictable impact on future generations. Therefore, ensuring recoverability and keeping the memory of the repository alive during the post-closure phase could be important.

Due to the long timeframe of RWM, **future ethics** are relevant to decision-making, both in regard to process and content: Future ethics is an ethical system concerned with the transactions and relationship between successive generations. These do not only impact relationships between overlapping generations of different ages, such as grandparents, parents, and children, but also the relationships between the generations that live at different times, including future generations, whose numbers, quality of life and existence very much depend on the decisions and policies of current generations (Attfield, 2006). Regarding question of **justice between the generations**, at least four interrelated questions are relevant: Do current generations have obligations towards future generations, and if so, what are the arguments for these obligations, how far do they reach, and what is their content (Ott, 2007)? The most convincing argument for a future oriented responsibility for the RW can be found in the so-called *intergenerational egalitarianism*, which is not an absolute, but relative standard. It says that future generations should not be put in a worse position than current generations. This argument presupposes a universal equality principle, which implies that it is possible to justify equal rights for all currently living persons. A precondition for this recognition is on the object-side that they possess characteristics – e.g., autonomy – that qualify them as moral partners, and on the subject-side a universal moral perspective. If such an argument applies to current generations, it also, in principle, applies to future generations, because the qualifying properties in such an extension do not have to be altered (Leist, 2005). Intergenerational egalitarianism is supported by risk ethical reflections on the symmetry of and distance in time and space, as it is generally accepted that moral agents who are able to affect people, who are located far away in space, have a responsibility for these people. This point of view is recognised in all types of universal ethics: What applies to people far removed in space, also applies to people far removed in time, because it is just as arbitrary to discriminate on the basis of time as to discriminate on the basis of space. Thus, currently existing persons have obligations towards future existing persons, irrespective how far in the future they might exist. The fact that people who are distant in space can be identified, but not people distant in time, is irrelevant in this context. This not only applies to RWM, but is relevant, e.g., to the consequences of human induced global warming as well as other types of long-term environmental damage.

With regard to the **environmental principles** to be applied in the RWM decision-making process (ethical, but also legal), they should be the same as all other EU environmental policy rests on, i. e., the principles of precaution, prevention and rectifying pollution at source, and on the polluter pays principle[35]. These could be supplemented by IAEA's and NEA's ethical principles for RWM from 1995 and The Bure Ethics Group's basic principles of RWM from 2012. Furthermore, it was stressed that the precautionary principle could provide guidance in RWM decision-making in all its phases, not least in the long-term (*for more on this principle, see 4.1*) (Hooge, 2021a).

5.3 Results extracted from Seminar 3 on human aspects

In the CS perspective on Seminar 3 on human aspects, particularly an **enlarged safety culture**[36] is perceived to support long-term intergenerational multistakeholder governance of GD, which also offers a variety of arguments for rolling stewardship as a suitable management solution. Regarding uncertainties related to the adequacy of safety-related activities for the implementation of safety provisions, it is recognised that not only technical, but also socio-technical issues are at the root of this type of uncertainty.

[35] TFEU Articles 11 and 191 to 193. In practical terms, this means preserving, protecting, and improving the quality of the environment at a high level, protecting human health, a prudent and rational utilisation of natural resources and combating climate change. In implementing such measures, among others the available scientific and technical data and the potential benefits and costs of action or lack of action must be taken into account.

[36] Here, the term safety culture refers to INSAG's Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident, published by the IAEA in 1986: "Safety culture is that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance."

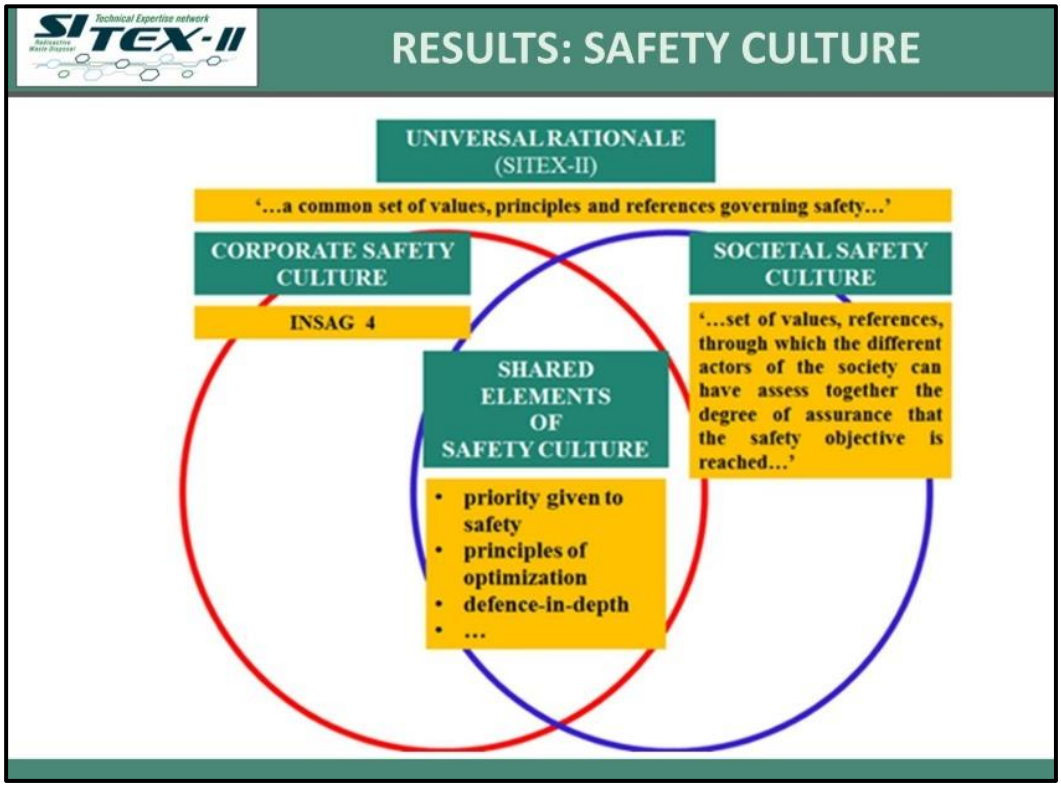

Figure 6 - An enlarged safety culture (SITEX II)[37].

Conditions and means for a very long-term intergenerational governance are that CS must take part in the decision-making process right from the start and that ample time is made available to consider and discuss the issues in depth before coming to a considered view. Here, transparency is a key factor - i.e., transparency of information, in decision-making processes, transparent reporting of participants' views, etc. This is illustrated by the figure above. Furthermore, public support can be generated through **trust** and trust is generated through meaningful public engagement. In this regard, trust should not only be considered as a condition for the acceptance of a particular technical solution, but as a general condition for managing high complexity issues. In conclusion, the notion of safety culture can help sustain trustworthy interactions among the concerned categories of actors in the context of long-term RWM processes involving uncertainties. There is also a need for flexibility in order to make room to consider progress and errors necessitating reorientation during the process. Hence, further research is needed to update the notion of the safety culture concept to the specificities of RWM in order to be able to encompass the very long-term dimension of the RWM processes. This should include CS at international, national, and local level, during the development of the safety case in a rolling stewardship perspective and also in the perspective of the Aarhus Convention.

Regarding **uncertainty on scheduling**, it is agreed that any given schedule is the result of a mixture of technical constraints and strategies of the various actors, with sometimes conflicting interests, leading to irreducible uncertainties. Here, postponing decisions can be a condition for improving safety (*cf. the comments on application of the precautionary principle in 4.1*) by taking appropriate time to manage unexpected events or uncertainties. Differences of views between several authorities involved in the decision might disclose problematic aspects of safety (e.g., the Swedish context and the copper corrosion issue), but for that to happen, an appropriate plan B should be in place.

[37] The EU project SITEX II (task leader: FANC) was dedicated to an enlarged safety culture to support very long-term interactions with society (Hériard-Dubreuil, 2022).

Concerning the emergence of **new knowledge** - i.e., knowledge that has emerged by new research and monitoring, is new only for certain actors, including actors that would benefit from having it (unknown knowns) or known but not taken into account (ignored knowns), is generated through RD&D activities, technology development, etc. (Dumont, 2022) – it is inherent to a safety analysis of any long-term process. In a CS perspective, it does not undermine the credibility of the safety review, on the contrary it contributes to reinforce it. Hence, the question is: The extent to which new knowledge can be given due attention in a rolling stewardship model in order to reinforce safety of the implemented solutions of the disposal programme. For this to happen, a structure linked to rolling stewardship has to be implemented to produce new knowledge and consider its relevance for a DGR - especially in the far future. Possibly periodic safety reviews and renewal of the licenses could be used as points in time to introduce and discuss new knowledge in a democratically oriented, participatory manner. Resources to produce new knowledge have to be ensured, which might be a task for research policies, and transparency of the monitoring results would be a key aspect in order to create conditions for new knowledge to fully contribute to reinforce safety. Proper scheduling of periodic safety reviews, open to public review associated with EIAs would also be necessary if crucial new knowledge emerges.

5.4 Results extracted from Seminar 4 on pluralistic methodologies

Regarding the management of uncertainties from a pluralistic and long-term perspectives from a CS perspective is to acknowledge that the basis of rolling stewardship is **Long-Term Stewardship (LTS)**, a theoretical as well as a practical and legal term, originating from U.S. national law, but also embedded in European law[38]. Because rolling stewardship can be identified as a sub-category of LTS, it does not always make sense to distinguish between the two notions. As mentioned in 5.1, rolling stewardship signifies an intergenerational management concept requiring monitoring and maintenance of RW for an, in principle, an indefinite period of time, with responsibility being passed on from one generation to the next, preserving the possibility of retrieval, recharacterisation and repackaging. It also requires a mechanism for reinstructing the next generation, providing detailed information on the RW and the associated hazards, and ensures that the next generation is fully aware of the need to spend time and money on the RW and, if necessary, to see that corrective action is taken in a timely way. This process could last until a final safe solution is found which would no longer require constant care and memory.

During Seminar 4, the following six pillars were listed as crucial for the structure of rolling stewardship: (i) In spite of the long time-horizon, **continuous knowledge management**, including memory keeping. (ii) Unbroken possibility of **reversibility** of all crucial decisions in RWM in all phases of the disposal process, including post-closure of a DGR in the strong version of rolling stewardship (iii). Unbroken possibility of **retrievability** and **recoverability** of the RW, including during post-closure of a DGR in the disposal process in the strong version of rolling stewardship. (iv) Continuous access to resources for rolling stewardship, including for all stakeholders and CS. (v) Both long-term **partnership** between all stakeholders and long-term **public participation** have to start early and be kept in the post-closure phase. (vi) Assignment of long-term and final **responsibility** for the RW (Hooge et al., 2022).

Furthermore, the arguments for and against LTS/rolling stewardship were weighted against each other. The **main arguments for**: A strong emphasis on safety (and security) under all conditions as the primary goal of RWM and final disposal of RW, which should not be diminished, offset or compromised. Hence, LTS/rolling stewardship is the best manifestation of the precautionary principle. Also, an

[38] LTS is defined as the physical and institutional controls, and other mechanisms needed to ensure protection of people and the environment at sites where plans have been developed to complete clean-up after site closure (e.g., landfill closures, remedial actions, removal actions, and facility stabilisation). This includes land-use controls, monitoring, maintenance, and information management. LTS applies to sites and properties where long-term management of contaminated environmental media is necessary to protect human health and the environment over time. Homepage, U.S. Department of Energy: Long-Term Stewardship (LTS) — DOE Directives, Guidance, and Delegations

intergenerational management concept dealing with uncertainty, LTS/rolling stewardship sets out to define an “intergenerational common good” in order to address the uncertainties triggered by the extremely long time-horizons of the issues it deals with. In doing that, it represents a strong manifestation of both the responsibility principle and intergenerational justice. The **main arguments against**: Its perceived lack of practicality because it is doubtful whether it can be sustained for tens or hundreds of thousands of years. Due to its high economic costs, it could also be argued that it puts undue and disproportional burdens on future generations, thus violating the polluter pays principle, unless sufficient resources are made available from the outset by the generations that produce the RW. LTS/rolling stewardship also raises some fundamental questions regarding the long-standing discussion on whether obligations to future generations exist and if so, how far they go, whether a comparative, egalitarian or absolute standard should be applied, and how risks and uncertainties should be dealt with.

6. Key messages and recommendations

This chapter concludes key messages for the four topics and gives recommendations on uncertainty management for several groups of actors.

6.1 Key messages on transparency and public participation in uncertainty management

The UMAN questionnaire showed that for CS experts it is uncertain if there will be effective and good quality T&PP in RWM including DGR development. The existing regimes do not always enable good quality in T&PP in all phases[39]. Moreover, major differences between European states exist. **It is key that T&PP regimes be established from the concept phase to the post-closure phase.**

The need for regular appointments between the RWM actors and CS has clearly been established. To guarantee continuous good quality T&PP regime over all phases, we recommend establishing national advisory boards or committees including CS experts that accompany the process and establish interaction with the larger, interested public (double wing model). Furthermore, we recommend 10-year PSRs with public participation.

Uncertainty management needs to be made a part of these T&PP regimes.

Participation of the public comprises a broad spectrum of activities: Receiving information, interactive debates among all stakeholders, and participation in the decision-making have to be elements of a T&PP regime. Decisions have to be made in the presence of uncertainties. Dealing with uncertainties associated with disposal facilities is particularly challenging due to the long timescales (at least several generations). Therefore, **uncertainties have to be discussed openly in all steps of participation**.

Participation of CS in research projects like EURAD contributes to involve the interested public in an early stage as is required in the Aarhus Convention. As a method the double wing model has proved successful: an inner core of CS experts is deeply involved in the research project and communicate information and results with a larger CS mirror group. **Large research projects in the field of RWM should establish double wing models for inclusion of CS**.

Methods such as the **serious game PEP** have proven to be valuable for fruitful dialogue among all stakeholders. The PEP should be promoted in RWM research, education, and policy.

Good quality pluralistic interactions between different stakeholders are necessary for **fruitful dialogue**. Methods like the PEP game and discussing use cases and scenarios under diverse perspectives can help to establish trust. In EURAD, a list of preconditions for fruitful dialogues has been created that should be spread among all RWM actors. But to keep trust it is – amongst others – important to recognise that pluralistic interactions are no substitute for participation, especially participation in decision-making.

CS experts should have a role in **developing cases and scenarios** for dialog on how to manage uncertainties. This should also lead to re-assessment of the FEP lists.

6.2 Key messages on a shared culture for safety and security

The term “safety culture”, formerly restricted to the work inside a nuclear organisation, is no longer broad enough. It should not only be changed to include security in scope, but also be shifted to a more systemic approach (culture for safety) and to open up to actors outside the narrow frame of RWM. Civil society is

[39] A definition of the GD implementation phases is available in the Roadmap guide of EURAD, 2021 p5: file:///Users/julien/Downloads/EURAD%20Updated%20Roadmap%20Guide_%20Issue%202.pdf

part of such an enlarged culture for safety and should be part of the decision-making processes. Therefore, we recommend using the concept of **"shared culture for safety and security".**

For CS experts it is of importance to bring to the debate **uncertainties related to political systems and culture.** Political uncertainties are not identical with societal uncertainties. Uncertainties in political culture refer, for example, to changes in the nuclear legal system that are not science-based but subject to political changes, political influence especially on regulators, corruption and fraud, etc.

Working with **uncertainties is a good entry point** for establishing a shared culture for safety and security.

Independence of regulators and other RWM actors is a request that is confronted with vague definitions of independence; especially when questioning to what degree scientists can act independently of any type of influence from outside forces. Generally, expert opinions should constitute qualified scientific works by recognised competent natural persons or organisations in the field in which the opinion is delivered, that are also independent, because they are impartial and have no prior business or personal relationship with the commissioners of the opinions. An alternative could be to enable and provide **"pluralistic expertise"**, without giving up on the demand for independence, at least for the second expert opinions**.** Under all circumstances, expert opinions should be published together with a disclosure of information on who financed the work in question and of the goals of the expert organisation.

Having two or more expert opinions on an issue could help form an opinion and increase trust. Civil society organisations need resources to be able to fund such opinions.

The Russian war on Ukraine shows (again) that **security issues** need to be put into focus, also for RWM facilities. It has to be part of safety governance to make sure that war and terrorism either cannot damage a DGR, or at least develop a plan for minimising impacts of such malevolent acts. In the shared culture for safety and security this needs also to be reflected by preparing for intended an unintended human intrusion in a DGR.

6.3 Key messages on ethical principles

From a CS perspective, ethical principles must guide the process as well as the content of the RWM decision-making. Application of **ethical principles related to the process of the RWM decision-making**, is not specific to any one step of the GD. The most suitable ethical system to be applied in this process is **deontological ethics**, which is a normative theory, in which acts are judged morally without including their consequences in the judgement criteria. Here, individual and collective acts are only permissible when they are approved by those whose rights and interests are at risk. Consent cannot be obtained from all the affected parties in every situation, nor is it possible to get a full consensus. But it must be assumed that people who normally would be unwilling to accept a particular risk would be inclined to submit to a decision-making process which is embedded in a fair and democratic structure, respecting the integrity of individual rights. Thus, deontological ethics delivers the best and most convincing ethical arguments for implementation of the Aarhus Convention and public access to information, participation, resources, and justice during the course of the RWM process.

The main principle to be applied in regard to **the content of RWM decision-making** is **the precautionary principle**, a **legal** as well as an **ethical** principle that is considered one of the pillars of European environmental law. It signifies that if there is a strong suspicion that a certain activity may have environmentally harmful consequences, it is better to act before it is too late than wait until full scientific evidence is available that unequivocally demonstrates a causal connection between the activity in question and its possible impacts. Systematically, the precautionary principle is a sub-category of the prevention principle, which says that is easier to respond to environmentally harmful activities before rather than after they occur, by preventing them. The precautionary principle is supplemented by the **responsibility principle**, that relates both to the process and the content of the decision-making and constitutes the broadest of all the ethical principles to guide the interactions between the stakeholders in RWM. First and foremost, it is based on a will by those who possess the causal capability to carry out

an act in order to behave unselfishly in regard to a valuable object and this responsibility is prima facie not reciprocal. Consequently, to take responsibility implies moral accountability. For a stakeholder in the RWM decision-making process, this responsibility becomes acute when such an account is included in the possible impacts of a course of action.

6.4 Key messages on rolling stewardship

During the UMAN seminars, rolling stewardship has been identified as a **subject of interest** in the UMAN agenda in regard to, in particular, the following questions: What levels of uncertainty could be acceptable in the long-term and very long-term from a CS perspective and how should they be managed? And more specifically: When comparing current on-going RWM to GD, what would be the most important differences regarding the types of uncertainty and risks entailed by each of these options? And last, but not least: How could rolling stewardship involving CS be implemented?

From the CS perspective, it is evident that rolling stewardship is not a controversial or "alternative" notion, but a dynamic concept that could manifest itself in different versions (not a "one size fits all") and whose pros and cons should be **discussed openly** and without prejudice. The concept also has a close affinity with LTS, which has already been implemented in U.S. national and European law. Thus, research on not only rolling stewardship, but also on LTS, should be promoted and integrated into UMAN and the EURAD project generally.

When comparing current on-going RWM to GD, the most striking difference is that the former, due to timescales is a well-known entity which has existed for more than half a century, whereas the latter is still an unproven technology which has not yet stood the test of time. There is also a consensus that there has to be a structure in place for both options – economically, socially and in regard to knowledge - which hands over management of uncertainties and risks from generation to generation. Equally, in regard to the precautionary principle, there is an indication that regulation of RWM has not much credibility if the precautionary principle is not integrated at all levels of RWM decision-making and also that LTS/rolling stewardship could be the best manifestation of this principle, the arguments against LTS/rolling stewardship notwithstanding.

In conclusion, there is little doubt that rolling stewardship addresses one of the core uncertainties in UMAN, namely the extremely long time-perspective of RWM and final disposal of RW, which is likely to make most risk estimates very complex and difficult. Thus, **UMAN and EURAD could be appropriate fora**, in which the viability of rolling stewardship in its capacity as a long-term intergenerational RWM concept could be further explored and evaluated in the perspective of the parameters that have been established.

6.5 Recommendations

Based among others on the above key messages, the following are the recommendations we elaborate for future work on uncertainty management and its involvement with CS. In addition to originating from the content of this Deliverable, they constitute common and general reflections based on our four years of activity in UMAN. The recommendations target different actors for their work not only in research projects but also beyond.

Recommendations on transparency and participation: Transparency and public participation (T&PP) are crucial in RWM. Without them, no final repository will be tolerable or even acceptable for the public. But good quality T&P regimes for such a long-term intergenerational activity like a DGR for high level waste do not exist yet. Existing procedures like environmental impact assessments need to be adapted to become effective, and new procedures need to be established. The following points need to be fulfilled to allow for good quality T&P:

- Develop a continuous T&PP regime over all phases of RWM, not only for the site selection.
- Prepare to engage in the long-term in RWM. RWM authorities should help establish reliable structures for long-term dialogues with all stakeholders including CS on local but also national

level, e.g., by enabling long-term advisory boards with CS participants (both from CS experts and general public).

- Engage in fruitful interactions with CS on a regular basis in technical organisations, establish continuous interaction with CS and hold the dialogue alive in the long-term. This includes adapting communication concepts to reach the young generations, and to establish organisational knowledge transfer of these interactions
- Interaction is important not only with the general public, but especially with the interested public; different ways of interaction will be needed for those two groups of civil society. Especially in research projects, a regular and good quality dialogue with CS experts leads to added value and fulfills legal obligations of the Aarhus Convention at the same time.
- Helpful tools for working together with the interested public in research projects are:
    - the PEP-game, which should be further developed f at national and local level.
    - the double-wing model, should can be expanded to a three-wing dialogue
- Dialogue on uncertainties and their management options can be used as entry points in debates with the public.

Recommendations on a shared culture for safety and security

In a shared culture for safety and security, civil society is a partner like other stakeholders. We recommend broadening up definitions of safety culture to actively include civil society in defining and working for a culture for safety. This encompasses also to include topics of nuclear security which are of high importance for civil society.

A culture for safety and security is based on independence of nuclear regulators and TSOs, and a legal structure that their independence cannot be challenged by political change.

Independent and multi-perspective expertise on RWM issues will help building trust. Good practice examples like the former Swedish MKG NGO-office would help to provide a second opinion that is trusted by CS. But such organisations would need continuous funding.

To develop a good quality shared culture for safety and security, social science research in RWM is needed.

Recommendations on application of ethical principles: Application of ethical principles related to the process of the RWM decision-making, is not specific to any one step in the process. The most suitable ethical system to be applied in this process is deontological ethics, where decisions are only permissible when they are approved by those whose rights and interests are at risk. Thus, the decision-making process should be embedded in a fair and democratic structure, respecting the integrity of individual rights. The main principle to be applied in regard to the content of the decision-making is the precautionary principle, which should be used as much as possible.

Recommendations on rolling stewardship: The viability of rolling stewardship in its capacity as a long-term intergenerational RWM concept should be further explored and funded within UMAN and EURAD and evaluated in the perspective of the parameters that have already been established.

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Appendix A. Preliminary elements for D10.17: Uncertainties in Radioactive Waste Management – Views of the Civil Society's Group

Preliminary elements for D10.17: Uncertainties in Radioactive Waste Management – Views of the Civil Society's Group

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Internal document finalized on November 2020 that was not a deliverable but that helped Task 5.2 team building the content of the deliverable D10.17

Executive Summary

This paper reflects the Civil Society (CS) group's views on management of radioactive waste and spent fuel within the frame of the Uncertainty Management Actor Network (UMAN) in the European Joint Programme on Radioactive Waste Management (EURAD). The CS group means here the CS experts involved in UMAN and the members of the CS larger group, which comprises 22 representatives from 15 countries in Europe, reflecting a variety of characteristics. It takes part in EURAD under the auspices of the Aarhus Convention in order to bring in views of CS and give inputs on nuclear issues based on the work of the group members.

The paper has been prepared in the frame of the preparation of the first UMAN seminar (held remotely on 26-27 October 2020). It is based on discussions within the UMAN CS expert group, analysis of milestone papers of other UMAN subtasks (mainly Task 2.1 and Task 3.1), discussions held during introductory session (held remotely on 5 May 2020) and UMAN dedicated working session (held remotely on 18 May 2020) of the ICS workshop. These discussions involved the CS experts, the CS larger group members and a panel of UMAN beneficiaries. The document also integrates feedbacks from this CS group up to October 2020. Most notably it is based on the UMAN CS questionnaire - a short questionnaire prepared for the members of the CS larger group before the UMAN Working Group Day. In the questionnaire, the CS group members were asked what important uncertainties they see in radioactive waste management in the following six phases identified by IAEA and used in EURAD:

- Phase 0: Policy, framework and program establishment
- Phase 1: Site evaluation and site selection
- Phase 2: Site characterisation
- Phase 3: Facility construction
- Phase 4: Facility operation and closure
- Phase 5: Post closure

About 680 uncertainties were identified by the CS larger group members over all six phases. They were then coded and grouped into clusters and the answers in each cluster evaluated and emerging topics identified. The clusters are: uncertainties on public participation, on transparency and communication, on the future of nuclear policies, on governance, on trust, on alternatives (plan B), on reversibility, retrievability and recoverability, on costs and financing, on human resources, on inventory, on security, safety and risk assessment, on site selection and decision, on technology selection, on geology and hydrology, on transport, on quality assurance now and in the future, on trans-generational aspects, on research, and on shared solutions and export and import.

The overall tenor of the answers was that CS should participate in the discussion of all types of uncertainties. Uncertainties exist during all the phases in question and changes might occur during the entire process. Hence, CS needs to be involved all the way. It is also important that the full range of stakeholders in CS are heard, e.g., local government, community organisations, academics, business, etc. as well as NGOs and the general public. Some CS larger group members thought that the discussion on technical uncertainties is more appropriate only after key concerns regarding participation and transparency (and non-transparency) issues have been resolved in a way that does not allow any lack of trust or any doubts towards the responsible actors.

This document constitutes preliminary elements for the elaboration of the final deliverable of Task 5.2 due in June 2023 at the end of the UMAN project. The elements detailed in this draft constitutes a first step and will be enriched during the project with the elements linked to the three upcoming UMAN seminars. The next steps of the CS expert group will be to integrate results of discussions of the first UMAN seminar (7 members of the CS larger group participated to this seminar) to the document and discuss our results in the upcoming interactions with WMOs, TSOs, REs and the CS group.

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Glossary

BAT: Best Available Technology

CEE: Central and Eastern European Countries

CS: Civil Society

DGR: Deep Geological Repository

EIA: Environmental Impact Assessment

EU: European Union

EURAD: European Joint Programme on Radioactive Waste Management

GD: Geological Disposal

HLW: High Level Radioactive Waste

IAEA: International Atomic Energy Agency

ICS: Interaction with Civil Society

ILW: Intermediate Level Radioactive Waste

LLW: Low Level radioactive Waste

NGO: Non-Governmental Organization

NPP: Nuclear Power Plant

RE: Research Entity

RW: Radioactive Waste

RWM: Radioactive Waste Management

SEA: Strategic Environmental Assessment

T&PP: Transparency and Public Participation

TSO: Technical Support Organisation

UMAN: Uncertainty Management Actor Network

VLLW: Very Low-Level Radioactive Waste

WMO: Waste Management Organisation

1. Introduction

The main objective of the UMAN Work Package is to develop a common understanding among the different categories of actors (WMOs, TSOs, REs and Civil Society) on uncertainty management and how it relates to risk & safety in the management of radioactive waste[40]. In cases where a common understanding is beyond reach, the objective is to achieve mutual understanding on why views on uncertainties and their management are different for different actors. Another objective is the sharing of knowledge/know-how and discussing common methodological/strategical challenging issues on uncertainty management.

The **Civil Society (CS) larger group** engages in UMAN on a voluntary basis. It is composed of local, national and European CS representatives who have a specific interest in NWM. The CS larger group comprises 22 representatives from 15 countries in Europe, reflecting a variety of characteristics (Western and Eastern countries, advanced and less advanced programmes, diversified interests, gender and age). The CS larger group takes part in EURAD under the auspices of the Aarhus Convention in order to bring in views of Civil Society and give inputs on nuclear issues based on the work of the group members (see in detail milestone D1.13.) Two categories of CS participants are involved: on one hand, the CS larger group, on the other, the **CS expert group**. The **UMAN CS expert group** is part of the latter.

The UMAN CS expert group focused in its first 17 months of work on developing an understanding of uncertainties perceived by the CS larger group: what are the notions of the different CS group members of uncertainty, risk and safety? What are in the views of the CS Group on important uncertainties in different phases of the radioactive waste management and how should and could Civil Society participate in dealing with uncertainties?

The CS expert group provides this keynote paper to inform the EURAD team of the results of this work.

2. Methods

What is this keynote paper based on?

First, **the discussions within the UMAN CS expert group itself**: the experts in this group (who are also the authors of this paper[41]) focused on their own experience with uncertainties in NWM and questions and models within the parts of the NGO community engaged in questions of nuclear risk and T&PP issues.

Second, **the UMAN CS expert group discussed the milestone papers of other UMAN subtasks and provided feedback within the framework of the ICS Workshop**; some of this feedback is also included in this keynote paper.

Third, **the UMAN CS questionnaire**: a short questionnaire was prepared for the members of the CS larger group before the UMAN Working Group Day (see below). Many CS group members took the opportunity to reflect on the relevance of uncertainties in NWM from their points of views. This provided us with a lot of interesting material to be evaluated. Details of the UMAN CS questionnaire are discussed in chapter 3.

[40] The definition of the CS expert group of radioactive waste includes spent fuel according to Directive 2011/70/Euratom, recital 20: "The operation of nuclear reactors generates spent fuel. Each Member State remains free to define its fuel cycle policy. The spent fuel can be regarded either as a valuable resource that may be reprocessed or as radioactive waste that is destined for direct disposal. Whatever option is chosen, the disposal of high-level waste, separated at reprocessing, or of spent fuel regarded as waste should be considered."

[41] David Lowry is a former member of the team.

Fourth, **the ICS Workshop No 1 and the UMAN Working Group Day**, held on 5-6 and 18 May 2020, respectively: This workshop was the first meeting of the CS larger group. Due to COVID-19 pandemic, it had to be held as a video conference. The UMAN Working Group Day was also conducted virtually as a zoom meeting over five hours (see the minutes in milestone No. 82). During the UMAN Working Group Day, the UMAN CS expert group organised five sessions. In one of these, the first results from the UMAN CS questionnaire were presented. The other four focused on the four topics represented in chapters 4-8 in this paper. The discussions and feedback from the participants of the ICS Workshop and the UMAN Working Group Day were taken into consideration when writing this keynote paper.

Fifth, **feedback of CS larger group members to the draft of this paper**: in order to ensure transparency also on the different views of the CS larger group members, we sent the draft out for comments.

3. The UMAN CS Questionnaire

3.1 Method

Civil Society's points of views on NWM cannot be represented in its full scope by only 36 CS experts in the EURAD project. Not even the opinions and approaches of all European NGOs engaging in nuclear issues can be fully represented. Moreover, the CS group was not provided with enough resources to research a broad variety of views of CS in Europe in a structured way. Therefore, the UMAN CS expert group decided to give at least all CS group members the opportunity to give a written presentation of their experience and thoughts on uncertainties in NWM. For this purpose, the UMAN CS expert group developed the **UMAN CS questionnaire**. The UMAN CS questionnaire can be found in Appendix A.

In the **first question**, CS group members were asked what important uncertainties they see in each phase of the RW backend management. The following six phases were defined by IAEA and are used in EURAD:

- Phase 0: Policy, framework, and program establishment
- Phase 1: Site evaluation and site selection
- Phase 2: Site characterization
- Phase 3: Facility construction
- Phase 4: Facility operation and closure
- Phase 5: Post closure

In the first ICS Workshop in the UMAN Plenary Session on 6 May 2020, Bernd Grambow presented results of the UMAN-questionnaire – WMOs, TSOs and REs were asked about their views on uncertainties in the different phases of the backend management of HLW. In the **second question** of the UMAN CS questionnaire, CS group members were asked for their feedback on these results.

The **third question** was, which uncertainties should Civil Society primarily participate in the discussion of?

Questionnaire response:

- 15 CS group members answered the UMAN CS questionnaire.
- Among those, eleven are members of the CS larger group and four of the CS expert group.
- Approximately 50% of both the CS larger group and the CS expert group answered.
- Answers from ten countries were received: Belgium, Bulgaria, Czech Republic, Finland, Hungary, Netherlands, Norway, Sweden, Slovakia, UK
- Four answers came from women, eleven from men.

In the first evaluation steps, all answers to the first question were copied in an excel sheet. Answers were split into single arguments if needed. **About 680 uncertainties were identified over all six phases**. The length of the answers varied. Some members of the CS group only gave short, one-word

answers like uncertainties on “participation”, others wrote a few sentences to explain in more detail what uncertainties were important in their opinion and why. Many uncertainties were seen as relevant for some or all phases.

Table 1: Numbers of uncertainties named in each phase:

Total named uncertainties	**679**
Phase 0	137
Phase 1	133
Phase 2	109
Phase 3	94
Phase 4	104
Phase 5	102

In a second evaluation step, **all named uncertainties were coded and grouped into the following clusters**. For quality assurance, three UMAN CS expert group members reviewed the codes based on their scientific different backgrounds and different experiences in the field.

Table 2: Clusters: CS group members see uncertainties on…

Participation
Transparency & Communication
Future of nuclear policies
Governance
Trust
Alternatives
Retrievability, reversibility and recoverability
Costs & financing
Human resources
Inventory
Security, safety and risk assessment
Site selection and decision
Technology selection
Geology and hydrology
Transport
Quality assurance now and in the future
Trans-generational aspects
Research
Shared solutions and export/import

3.2 Results

3.2.1 Quantitative overview of uncertainties

To get an overview of which uncertainties were mentioned how often and in which phases, the following figures were prepared for each cluster and for the six phases.

This provides a first impression of the focus of the members of the CS group focus who answered the UMAN CS questionnaire.

The following figures show the quantitative relation between uncertainty clusters in each phase and in total.

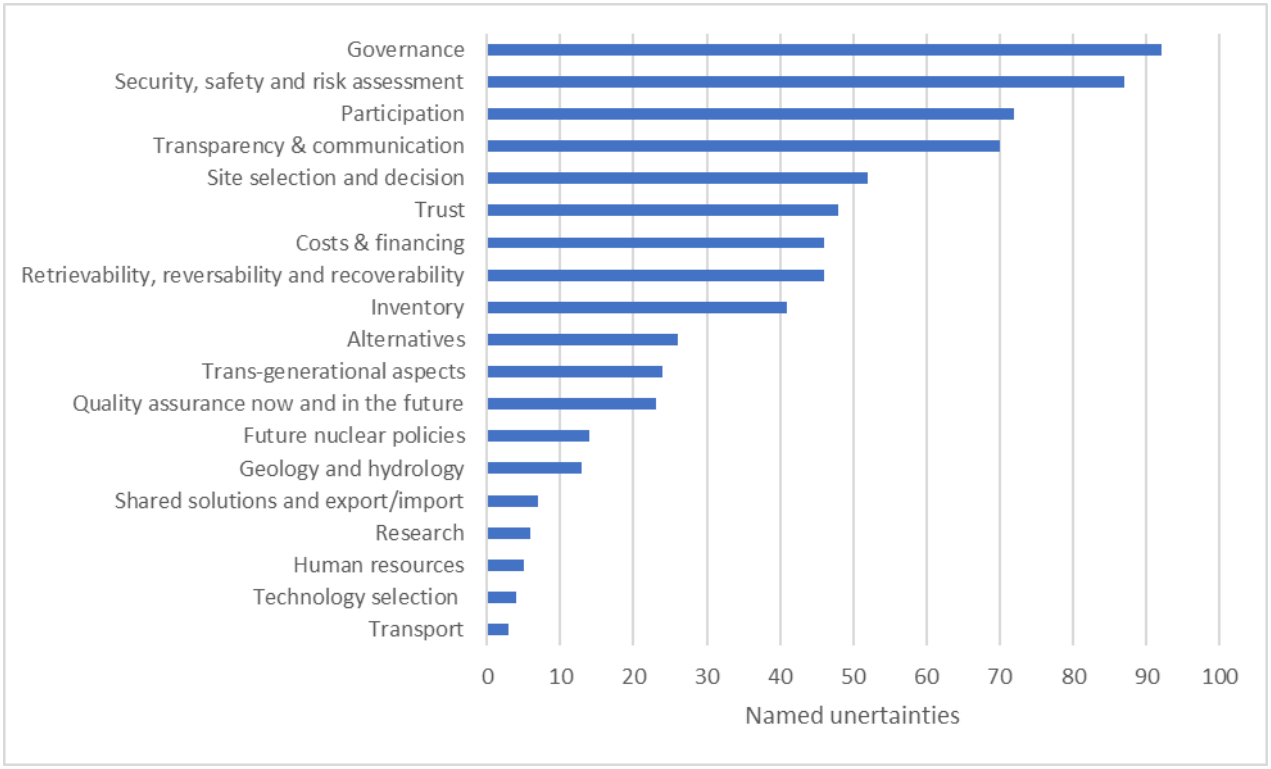

Figure 1: Clusters of named uncertainties, total over all six phases

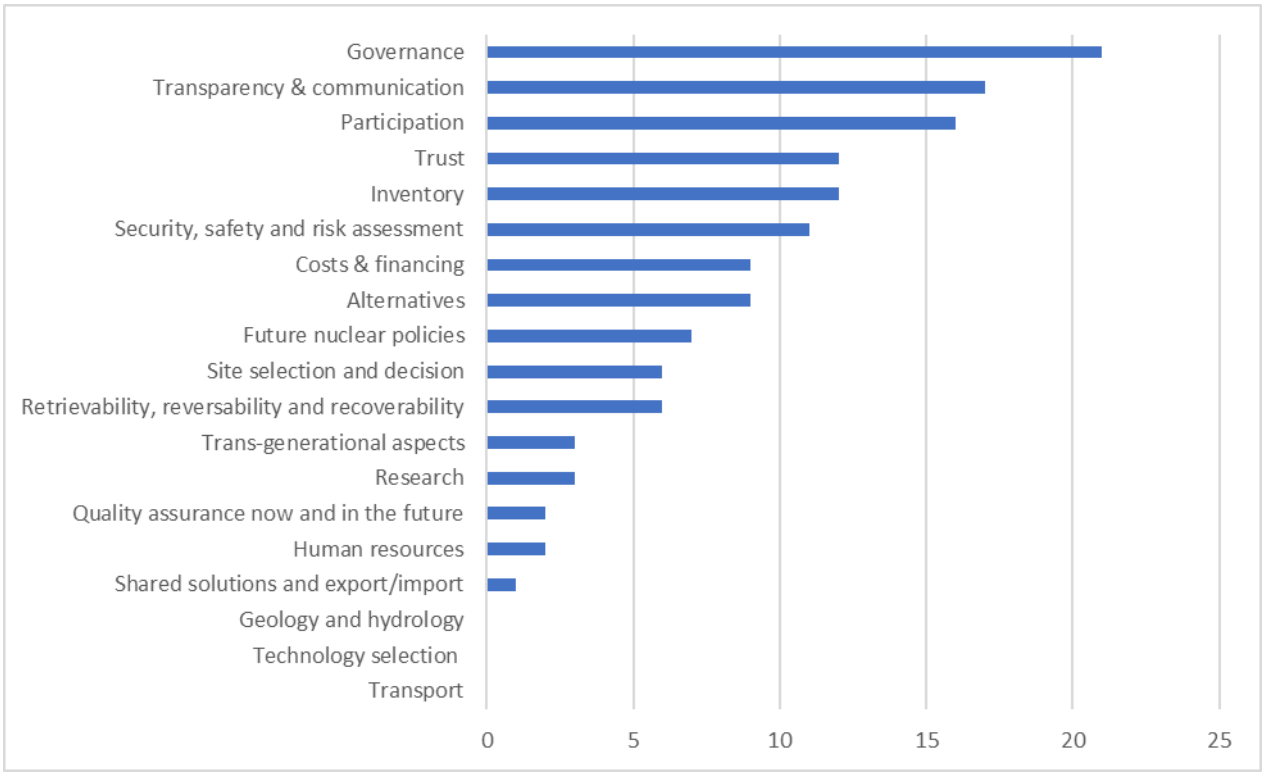

Figure 2: Clusters of named uncertainties in phase 0

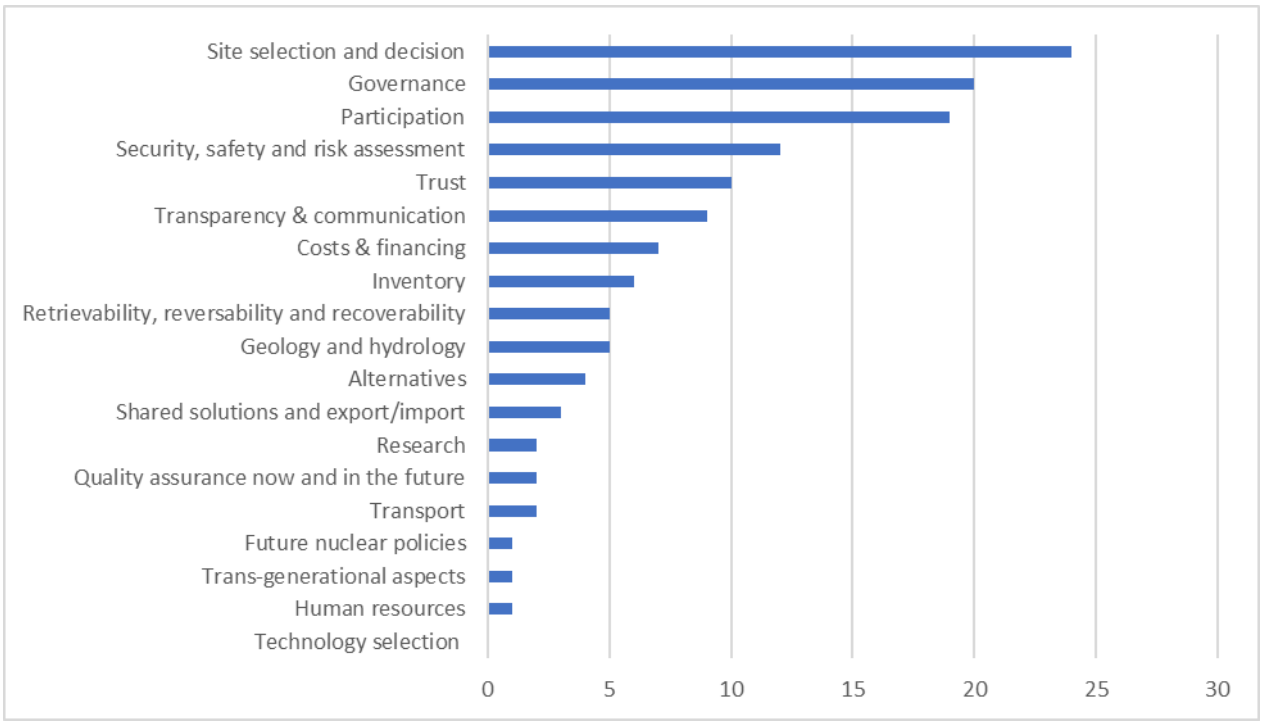

Figure 3: Clusters of named uncertainties in phase 1

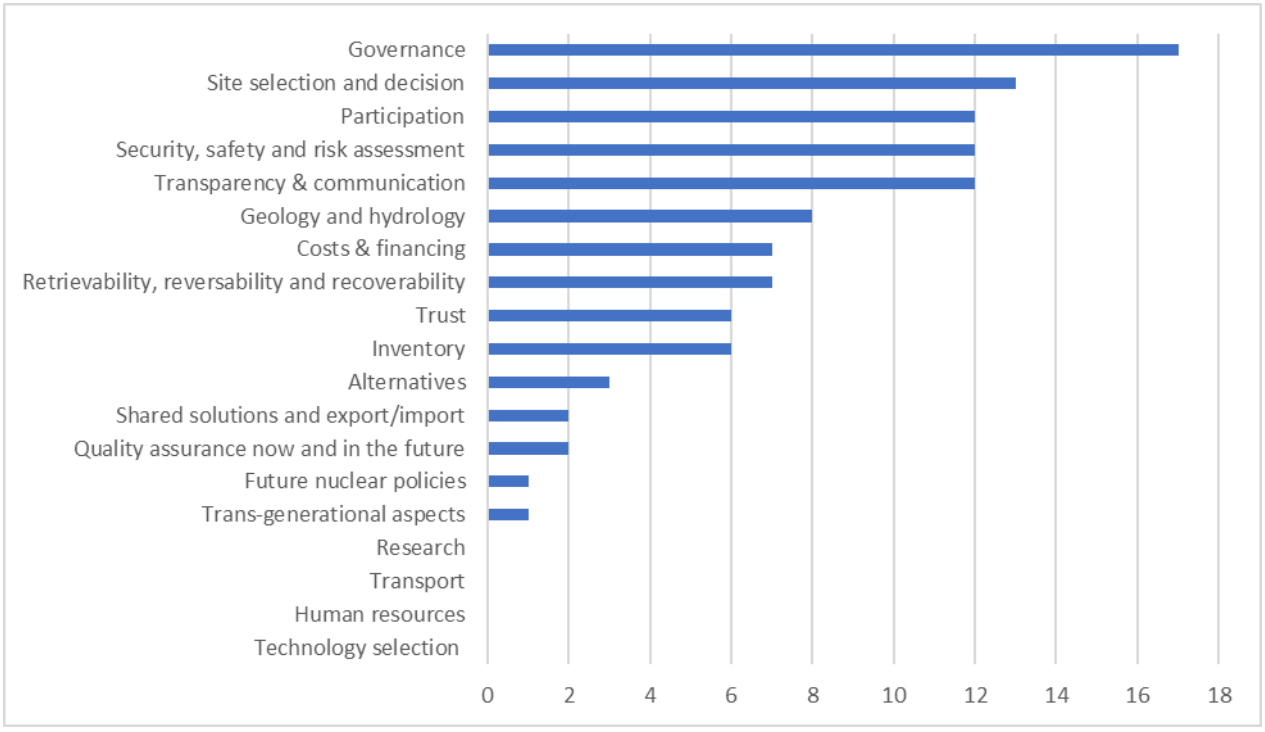

Figure 4: Clusters of named uncertainties in phase 2

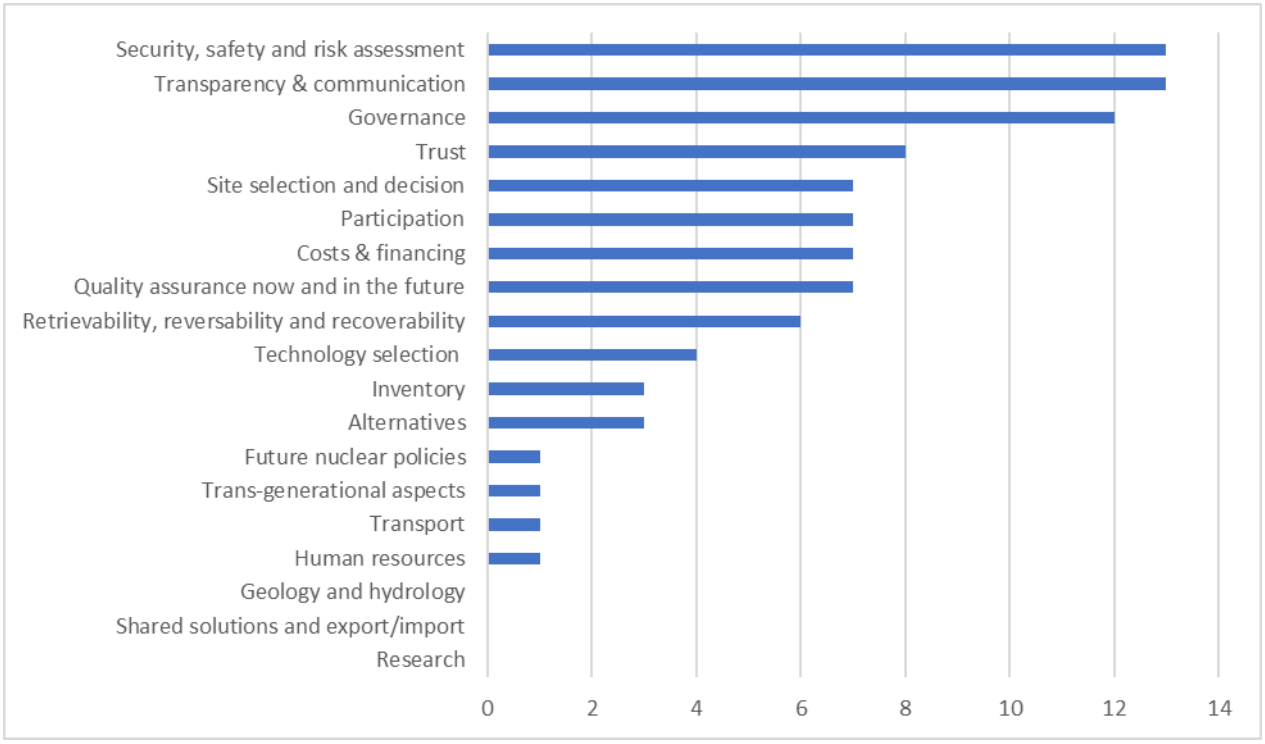

Figure 5: Clusters of named uncertainties in phase 3

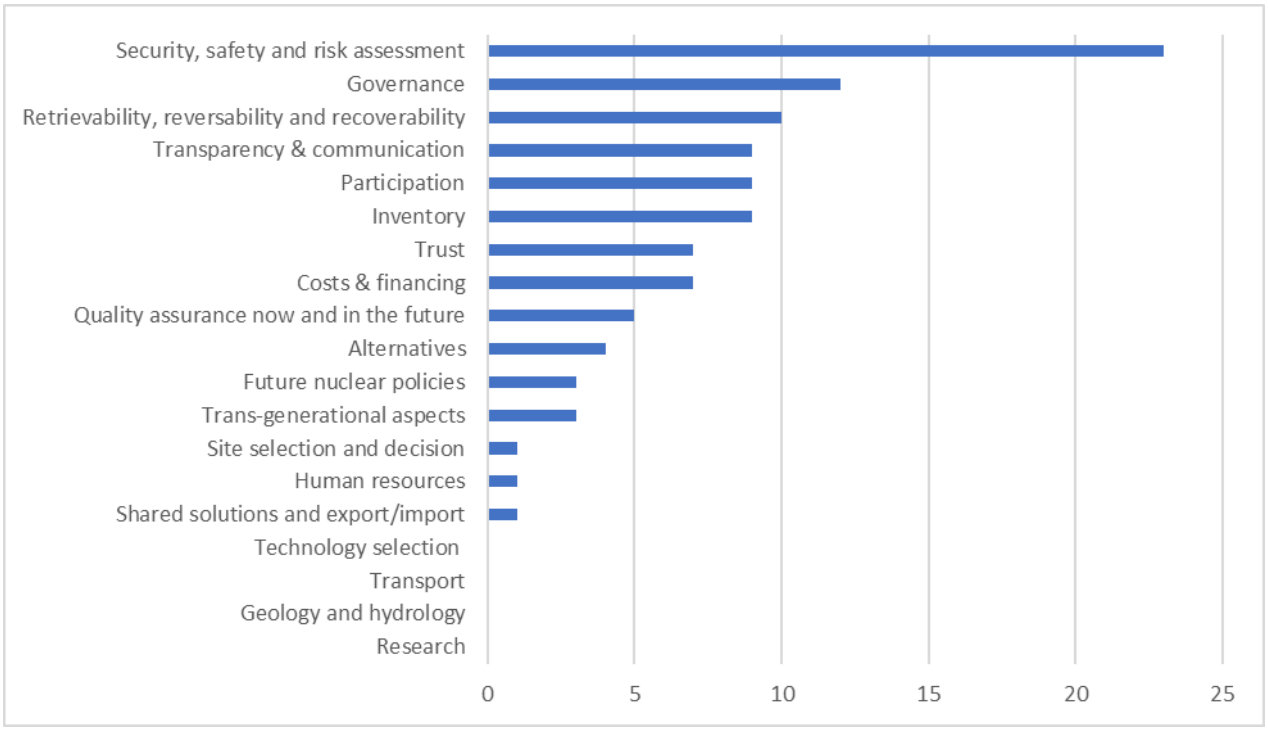

Figure 6: Clusters of named uncertainties in phase 4

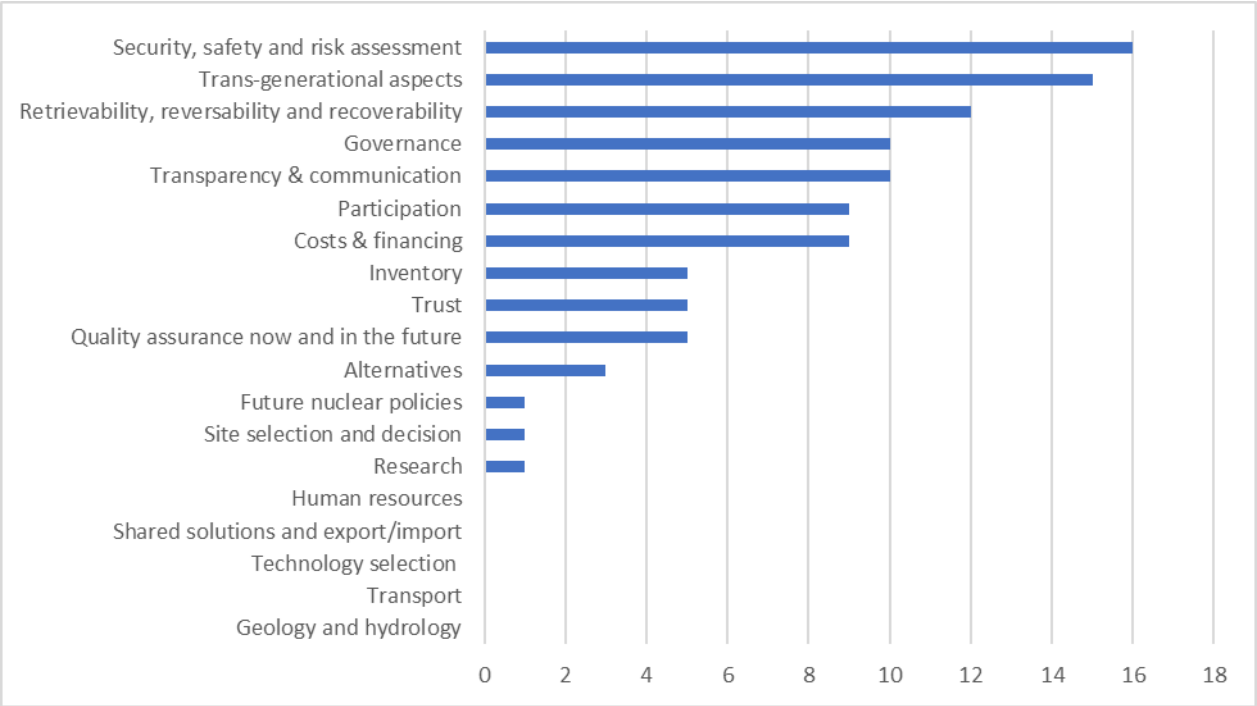

Figure 7: Clusters of named uncertainties in phase 5

Most of the named uncertainties are seen as important for each phase.

Uncertainties on technical aspects and geology/hydrology aspects of possible repository sites were not mentioned very often. But uncertainties on criteria for choosing sites and technologies are an important topic in the answers. For more detailed information, see the following chapters.

3.2.2 Uncertainties named for each phase – detailed discussion of the answers.

In the next step, **the answers in each cluster were evaluated and emerging topics were identified**. CS group members did not always formulate their answers strictly in terms of uncertainties, but sometimes mentioned topics of importance, which were not taken into account but could yet result in uncertainties in the future.

The following chapters begin with a brief introduction to the issue at hand, then summarizes the answers of the CS members and draws a short conclusion.

3.2.1.1 Uncertainties on public participation

Background: Public participation is of key interest for CS in regard to all nuclear-related issues, including NWM. The Aarhus Convention could provide useful insight into the notion of public participation. Here “the public” is defined as one or more natural or legal persons, and, in accordance with national legislation or practice, their associations, organisations or groups. Also “public authorities” - community administrations, environmental authorities, authorities of a foreign state, etc. – fall in certain respects within the ambit of this perception of the public.

Participation of whom?

There is a variety of different actors who should participate in radioactive waste management: authorities and regulators, WMO, TSO, research entities, local communities, NGOs (local, national, international), the interested public, the affected public, the whole public, the Civil Society, foreign bodies, foreign public, EU institutions, international bodies….

It is not clear yet, how the affected public in the host communities will be defined. What will be the **extent of the "affected area"**?

The **future role of the communities where the RW is located now**, is also seen as uncertain.

In many answers, there was a concern about **lack of CS representation**.

Transboundary aspects of participation are even more uncertain. When it is not clear how and what the local population can participate in, it is even more unclear if the foreign public in general or from certain countries can participate.

An uncertainty was formulated that there is **a risk to the process** if some parties decide they do not wish to engage or become hostile to what is proposed. Especially problematic is how to include communities that have already participated or were at least somehow involved in former siting processes, but where these procedures have not been successful or effective and have become a **negative legacy**.

Especially for phase 2, it was mentioned that focus has to be put on social suitability, in the meaning of being aware of (lack of) lack of influence of the local population (especially in **marginal regions**), and measures to counterbalance this. This argument also applies, when radioactive waste is exported to be treated/stored/disposed of in marginal regions of the world. How can people and local communities in foreign countries be included in participation procedures?

How to participate?

Uncertainties result from **not having defined a consent-based process** for how views of different public actors are taken into account. It has to be ensured that participation is not only another word for receiving information.

It was requested that the highest ethical and moral guidelines should direct the process. characterised by the best social standards and environmental principles and laws, including human rights principles, and avoiding conflicts of interest and corruption; the **relevant EU directives, the Aarhus and Espoo Conventions, and other relevant environmental quality standards** should be taken into proper account, meaning that they should be sufficiently implemented and fulfilled. The right to participate in NWM should be established firmly in legal texts. (see more on this question in chapter 6)

In this answer, a lot of topics are addressed: "How will CS be involved? Who will be watchdogs on behalf of the public, apart from the regulator? How can one know that these are not just being included "for show"? To what degree can CS influence the process? To what degree will they be able to participate and exercise influence? On which issues? How? What limits are there? And, how is a constructive exchange made possible, vs "just an exchange"?"

Uncertainties of the **effectiveness of public participation** in NWM were often named. CS members do not only want clarity on who will be allowed to participate and how participation will work, they also want to know whether participation is effective or not, if participation is only "for show", and if results are predetermined or only treated "in a formal way". Another aspect of effectiveness is, when people bring arguments or proposals into the participation procedures, they should be reviewed by an independent expert – as opposed to being reviewed only by government officials and experts engaged by operators of radioactive waste facilities.

Some answers discuss the **role of a "voluntary process",** meaning that sites could be favoured where the community is stepping forward voluntarily for hosting a DGR. There is concern that such a voluntary process is the result of influence of the nuclear industry more than based on suitability criteria. Also, the question of **compensation payments** has to be taken into account. Participation would not be effective if such underlying processes are not visible and if participation does not start before a voluntary decision is made and compensations are promised.

It is uncertain whether the public will be able to participate **from the early beginning**, as it is defined in the Aarhus and ESPOO Conventions. Early stage pursuant to these Conventions means that the public

should be able to participate already when the radioactive waste management program is established, and not only when the decision on the DGR site selection is made. It is no wonder that there are uncertainties regarding the starting point of public participation, considering that in some European countries, public participation is not possible during the preparations for the NWM programs. (See also chapter 6).

Questions were raised, who will be **watchdogs on behalf of the public**, apart from the regulator? First, this implies that the public trusts the regulators (which in some countries is not the case for all of the CS), and secondly, additional watchdogs would be needed. Not all independent NGOs can fulfil such a watchdog function on behalf of all parts of CS, especially if they are recruited and paid by the nuclear industry. But if Governments give resources to NGOs, this could result in a proper independent watchdog function (the Swedish example, see chapter 6) Also the French CLI / ANCCLI system could help ensuring participation of independent expertise in the NWM process.

Resources for participation have to be provided, otherwise it is uncertain if members of local communities, local or national NGOs and the interested public in general will be able to participate effectively. It is time-consuming to get access to information, to assess this information in the necessary depth and to write comments (in the usually very short permitted timeframes) or take part in a consultation, and it is even more time-consuming to go to Court. It costs money to organise independent expertise (expertise on which people are trusting) to assess all information and translate it into a language that the public can understand. Also, it costs money to take legal action. Resources for local communities must not be confused with compensation payments.

Decision-making – the right to veto?

An especially important topic is the method of decision-making. During the entire process of NWM, a lot of decisions are made, and it is not possible for all actors to take part in all of the decisions. But some decisions with high impacts should be taken particularly carefully – among those are decisions on repository host sites.

It is uncertain who will have a right to participate in the decision making. It is uncertain, if there will be a **right to veto** a chosen site, and if yes, who will be granted this right to veto? For phase 1, the right-to-veto-question was named often, also in connection with public support.

Besides the right to veto, it is also uncertain if the public will even get enough **influence to make reconsideration of decisions** possible.

A **regular assessment** of public engagement should be made. This could help monitoring the effectiveness of the participation procedure and enable amending the methods, if necessary.

Participation should be possible in criteria-setting. In defining the socio-economic criteria and for the long-term impacts, **CS should be involved** in local siting partnerships and the participation procedures.

Conclusions on uncertainties of public participation

A lot of uncertainties concerning participation were named, most of them for all the phases. It is obvious that participation procedures have not yet been provided in the necessary detail. Otherwise, the CS members would not have named so many uncertainties: who will be allowed to participate, who is seen as affected by NWM, how will the participation in different steps be conducted, will resources be made available, also for independent expertise? How will decisions be made, will there be the right to veto and who will get it? These questions are important and should be resolved quickly.

3.2.2.2 Uncertainties on transparency and communication

Background: In addition to participation, transparency is a key topic for the CS. Transparency in NWM is encouraged in Article 10 of the Radioactive Waste and Spent Fuel Management Directive. A large

number of the formulated uncertainties concern transparency and the fear of non-transparency. Many of the answers can be clustered into two main groups: uncertainties on transparency and transparency of uncertainties.

Uncertainties on transparency

In many answers, it is established that **the entire NWM process has to be fully transparent**. But it is perceived as uncertain, whether CS will have access to transparency from the early beginning until the very end.

What transparency should be based on, could be summarised by this answer: *"The highest ethical and moral guidelines directing the process with the best evolving social standards and environmental principles and laws, including human rights principles, avoiding conflicts of interest and corruption, and applying EU directives, the Aarhus and Espoo Conventions, and environmental quality standards."*

Some answers mention uncertainties concerning the implementation of the **Aarhus and Espoo Conventions and the relevant EU Directives**. These legal texts relate to access to information, public participation, and access to justice. The uncertainties that were mentioned include the non-sufficient implementation of these regulations in some countries, but also concern that their requirements are not met during the NWM process.

Information asymmetry was also named as a source of uncertainty. Information asymmetry is a theory in the economic sciences, according to which the different parties in a deal have different knowledge. This results in an imbalance of information between buyers and sellers that could lead to market failure. When developing this theory further, there could be some parallels to NWM: a contract is made between a municipality and the responsible WMO / authorities on disposal of RW; then, a sort of social contract will have to made with the affected public too. But if the stakeholders in the NWM process – the public, municipalities, regulators, TSOs, WMOs, etc. – do not have the full knowledge of the situation, the deal might fail.

It was mentioned that information could be withheld because it was perceived to be too difficult for the CS to comprehend. Another problem might be that information might only be made transparent in the part of a country siting the radioactive waste facilities and exclude the public in the other parts of the country (and also the transboundary public). In some CEE countries, non-transparency is experienced particularly in the nuclear sector.

Transparency is closely linked with **communication**. How is the information provided and how is it communicated?

Transparency is also linked to **trust**. Local people and society in general will receive a wide range of information and views on radioactive waste management. How will they decide, which information is to be trusted and believed? How can it be guaranteed that information from the authorities, but also the WMOs, is complete, true, not misleading and represents the best current knowledge of science and technology? The sources of information should be traceable.

Not only information, but also **responsibilities** need to be made transparent. Transparency is also necessary concerning the **role of the regulator.** Will regulatory overview be made transparent?

Transparency is not only a source of uncertainty when having CS in mind – it is also of importance that transparent feedback between all actors in development and decision procedures is ensured.

Can there be public support without transparency?

Transparency of uncertainties

Transparency is requested on uncertainties about technical and scientific issues and safety.

The following quotation illustrates how it could and should look like: *"Communicating to the public put simply: Here are the risks within the proposed system. They are sought mitigated in the following way.*

Here we remove the risk completely. Here we have a large impact, but although the risk is reduced, it is still there. Here we are unable to address the risk. These are the uncertainties, etc. Being honest and up front about these aspects is not reducing trust, quite the opposite."

In this context, it is suggested to avoid the term "safety". Rather than just communicating a project is "safe", total transparency should encompass explaining what the potential harms might be, how they could occur, what is in place to mitigate them. and importantly. what is the "increased risk" both to human health and the biosphere generally.

The potential for game-stoppers should be transparent – under which criteria will uncertainties result in a change of the radioactive waste management process?

Conclusions on uncertainties of transparency and communication

Transparency, participation, and access to justice go hand in hand. One is not complete without the other. This is recognised in the Aarhus Convention, and in the answers of many CS larger group members.

There is a need to increase the scope of EURAD: transparency of uncertainties is strongly linked to uncertainties of transparency; you cannot have one without the other; it is not enough to be transparent about a technical uncertainty if you have not built trust with a transparency and participation model throughout the whole NWM process.

Power imbalances might result in information imbalances and vice-versa. A high-quality transparency concept could help better balancing these asymmetries.

When communicating on uncertainties, the term "risk" instead of "safety" might be the better choice.

3.3.2.3 Uncertainties on the future of nuclear policies

Regarding uncertainties during phase 0 (policy, framework, and program establishment), the questionnaire answers underline the major impact of the uncertainties attached to the future of nuclear energy while trying to design phase 0 with little information available on what will be the nuclear policy in each considered country. For instance, this pertains to the **category and the quantity of the radioactive waste that are to be managed in the future**. Should the project only address certain types of waste, one can predict that new solutions will be required in the near/mid-term future. A member of the CS larger group asked the following question: *"If we do this, do we still have to make another decision in 50 years, connected with the future of the source of the waste (e.g., nuclear power plants)? If the public perceives that you solve an accumulated problem, only to continue to accumulate more waste (by running nuclear power plants), for which you have no plan, then the acceptance might indeed be hard to find."* Connected with this is the crucial question of the status of nuclear energy in each country. Does reaching a solution for some types of existing (or foreseen) wastes create a **blank check for more production of radioactive waste**? Countries like Belgium have strong uncertainties regarding the future of nuclear energy. The same for Hungary, where the number of nuclear reactors to be shut down in the next 50 years is unclear. Other uncertainties are attached to the Russian nuclear and NWM policies involving foreign countries.

During the subsequent phases of the implementation of GD, it is emphasised that, as each country will presumably not have more than one site to host the HLW, a considerable **pressure on the public to accept any type of waste** should be expected, including those it wasn't specifically designed for. This will create uncertainties on the safety of the facility that is not designed to host such wastes. **Overfilling the facility** should also be considered as an option in this perspective. with associated uncertainties on safety.

Conclusions on uncertainties about the future of nuclear policies

Uncertainty on future nuclear activities at national level creates uncertainty, doubts, and scepticism on the capacity of national policies to address effectively NWM in each country. It is also a major factor of reluctance for CS to accept RW facilities since it may represent a kind of **blank check on further production of radioactive waste.** As already indicated in the 1976 Sir Brian Flowers report, "There should be no commitment to a large programme of nuclear fission power until it has been demonstrated beyond reasonable doubt that a method exists to ensure the safe containment of long-lived, highly radioactive waste for the indefinite future[42]."

3.2.2.4 Uncertainties on governance

Background: The maintenance of safety performance along the successive phases of GD implementation is strongly conditioned by the continued existence of a performative regulatory and administrative framework that is mandated to ensure that appropriate means are foreseen and effectively implemented to achieve safety in the short, medium and long term. Considerable uncertainties are attached to the implementation of this framework.

Uncertainties here notably focus on the conditions for continued **independence of regulatory authorities**. The maintenance of regulator competency and actual independence is questioned, particularly in countries with close ties between the nuclear industry and the state. The limited capacity of the public institutions to secure the funding of RW policies (e.g., Bulgaria) is perceived as a major uncertainty.

The uncertainty on the possibility to maintain strong and fully independent regulatory structures over time is perceived all along the successive phases of implementation. It is also observed that in some EU member states, **legislative changes** have already been made **in order to ease siting processes**, giving less emphasis to safety requirements on geology.

It is also underlined that uncertainty includes the independence of the public that might be breached by compensation policies at the local level. – This is particularly relevant to areas where poor socio-economic conditions persist. These might diminish the awareness and reactivity of local inhabitants on safety priorities. Proper governance structure includes **subsiding independent and fully financed NGO / CS coordination body** (e.g., MKG / MILKAS in Sweden, Local Commissions of Information, and their national federation, ANCCLI in France). Uncertainty on governance also involves uncertainty on a continued access of both regulators and civil society to **independent scientific and technical expertise**.

There is also an expectation of path dependency because of the de facto independence of decision-makers from CS and that they might give too low a priority to safety. Because of the timescales and uncertainties involved and the urgent nature of requirement for the disposal of RW, how can we be sure that expediency will not triumph over ultimately the best practice. **Liability and consequences** live solely in the moral realm rather than the legal and financial, when even moderate timescales for elements of such a project far exceed a human lifespan.

The **behaviour of politicians** is also addressed as a major uncertainty, albeit because a potential lack of tenacity vis-à-vis more populist attitude (that could alternatively impede any decision on NWM or on the contrary give full priority to the industry priorities to the prejudice of safety). Highly uncertain appear to be political statements and guarantees that agreements, promises will be fulfilled (without delay) and that legislation will not be changed in the future against the interests of the local population. This assertion is based on shared experience that written agreements often are violated shortly after being signed. Possible **reluctance of governments** to take the initiative in defining a waste disposal strategy are perceived as possibly motivated by fear of unpopularity with the electorate. A government might fail

[42] https://en.wikipedia.org/wiki/Nuclear_Power_and_the_Environment

to recognise there is an issue with NWM that cannot be ignored, postponing decisions to a later date amongst other more pressing current issues.

The **commercial or private status of NWM operators** may create competitive pressure detrimental to safety priorities was also perceived as a problem.

Conclusions on uncertainties of governance

The main concern for CS regarding uncertainties of governance was for the continued existence of a performative regulatory and administrative framework to achieve safety in the short, medium and long term. This question is also linked with the uncertainty on continued access of both regulators and civil society to **independent scientific and technical expertise**. Perceived as relevant was also the **commercial or private status of NWM operators** that may create competitive pressure detrimental to safety priorities.

3.2.2.5 Uncertainties on trust

Background: Trust may not be a typical category for characterising uncertainties but was underpinning so many answers from the CS larger group that it makes sense to highlight its importance by preparing a special cluster of answers relating strongly to trust.

Trust is named quite often in the answers to the CS UMAN questionnaire in all phases. CS larger group members see uncertainties in trusting authorities, in trusting science, in trusting the nuclear industry, in trusting all actors that are responsible for radioactive waste management. It is not always specified who is seen as a possibly trustworthy and a possibly not-trustworthy actor. But what has become clear is that CS larger group members see a **relationship of trust and uncertainty.**

The following quotation from the CS larger group might be representative of its position on this issue: *"Local people and society will receive a wide range of information and views on radioactive waste management. How will they decide which information is to be trusted and believed?"*

General trust of a society in its authorities is differing between countries in Europe. *"Some states have historical reasons for trusting their nuclear industry to a larger degree, some to a lesser degree. Being honest about history is important when establishing a new program."* Such historical reasons for more or less trust might also be connected to former unsuccessful attempts to define a site for a DGR.

The policy of some states to weaken nuclear legislation for enabling nuclear projects with questionable safety preconditions leads to massive lack of trust. **Political influence should not override scientific facts**.

Trust in the organisations responsible for radioactive waste management is important – these organisations are sometimes part of state structures but can also be private companies. Will the same rules be applied to the different types of organisations?

Data can be of bad quality or even manipulated, institutions sometimes are corrupt – both may result in decrease of trust in the institutions and the state in general. How can this be avoided? **Trust in regulator bodies** is important as they have the control function over the whole process. It is seen as uncertain if regulatory capture is ensured over the whole implementation process. And **who is controlling the controllers?** Will there be a double-check by independent experts or bodies?

Corruption and fraud have a long and infamous history in the nuclear field in countries all over the globe. Tanter[43] (2013) made a survey on the widespread nuclear corruption after the criminal failures causing the Fukushima accident: *"A review of corruption incidents in the global nuclear industry during 2012–2013 reveals that the Japanese experience is not isolated. Gross corruption is evident in nuclear technology exporting countries such as Russia, China, and the United States, and in a number of nuclear technology importing countries. The survey results make clear that national nuclear regulatory regimes are inadequate and that the global regime is virtually completely ineffective. Widespread corruption of the nuclear industry has profound social and political consequences resulting from the corrosion of public trust in companies, governments, and energy systems themselves."*

If regimes do not counteract corruption and fraud, the population will lose trust. Honesty and especially **being honest about uncertainties** in communication is seen as advantageous in building public trust. It has an influence on trust if agreements and promises are fulfilled without delay.

Trust that **the legislation remains unchanged** over time is also important. Future changes in legislation might result in worsening the situation of the siting communities' population. Uncertainty was mentioned also in the **trustworthiness of CS** – parts of the population might be persuaded by money, resulting in a divide of communities or society.

Also **trust in science** is connected to uncertainties on the role and the monopoly of science (which tends to impose one particular discourse of full control even if uncertainties remain high), who might have the final word about important issues. There might also be differences between trust in technological design made in the own country or imported design.

Conclusions on uncertainties of trust

Trust is an important issue. Many uncertainties concerning trust have been named like the trustworthiness of actors, structures and rules and technologies. Lack of trust resulting from corruption and policy failures is an important topic.

3.2.2.6 Uncertainties on alternatives

Background: Geological disposal is often presented as a straightforward option to be implemented in a linear way. Considering the reality of the successive phases of its implementation brings a different picture with some uncertainty on what will actually be implemented at the end of the process.

For instance, it is **stressed by the members of the CS larger group** that although alternatives are in principle fully reviewed, very often there is only one option chosen at every stage of the process and everything else is denoted as not suitable without actual thorough inspection or assessment. This applies to all phases. **Alternative scenarios and fully elaborated alternatives to the DGR, with all their pros and cons, need to be fully reviewed and assessed beforehand as well as all along its implementation**.

While uncertainties regarding alternative options in many cases would be perceived as a source of risk, the existence of alternative options with some uncertainty about the final choice might be perceived as a factor of reinsurance of the quality of the decision-making process. **Even in the later phases, operational feedback and review of earlier decisions should be performed, including availability of alternatives (Plan B).**

[43] Tanter, Richard (2013): After Fukushima: A Survey of Corruption in the Global Nuclear power industry. In: Asian Perspective 37 (2013): 475-500.

Alternative options would then be adopted as more suitable (involving lower costs, being safer), or as a result of unexpected circumstances (sudden lack of resources or political will, or due to war or conflicts, necessitating fast implementation) before the evidence that the initial plan for disposing the wastes geologically is no more possible. **Risk of abandoning the project before completion** (due to detecting dangerous geological defects, political crisis, switching to another solution, etc.) are among these alternatives.

How can **lock-in problems regarding alternative methods and siting** be avoided? Here, it is important to demonstrate that real alternatives have been investigated, providing a plurality of choices. Uncertainties are here to stay. One should enter such a process realising that developing a plan addressing uncertainties and risks, is an organic process that takes time. It is highly uncertain whether one will be able to find a good alternative during the first try. It is important for the public that the plan is not a one-shot solution, and that a failure to find a “good enough” plan will lead to a plan B being sought out. Then the perceived uncertainty of the decision-making process itself may be reduced to the public.

Conclusions on uncertainties of alternatives

Alternative scenarios and fully elaborated alternatives to a DGR, with all their pros and cons, need to be fully reviewed and assessed before as well as all along its implementation. It is important for the public that the plan is not a one-shot solution, and that a failure to find a “good enough” plan will lead to a plan B being sought out. Then the perceived uncertainty of the decision-making process itself may be reduced to the public.

3.2.2.7 Uncertainties on retrievability, reversibility and recoverability

Background: The possibilities of reversibility, retrievability and recoverability are necessary prerequisites for a comprehensive error and safety culture in NWM. If errors have to be corrected, the decisions that have created them must be reversible and setbacks possible. In the context of disposal of RW in a DGR, reversibility means that it must be possible to retrieve the waste even in the post-closure phase after the end of the surveillance period (then it is called recovery) or at least for a very long period of time. Without evidence that waste can be safely retrieved without too much effort, it will be difficult to gain acceptance from CS when new sites for storage of RW are designated.

According to the members of the CS larger group, uncertainties on reversibility, retrievability and recoverability **pertain to all phases of the RW management process**, i.e., to policy, framework and program establishment, site evaluation and site selection, site characterisation, facility construction, operation and closure, including post closure. Reversibility and the possibility of full retrievability should be one of the determining criteria for choosing the proper type of disposal method (e.g., deep depository without recovery, shallow deposit with possibility of recovery, final depository only for reprocessing waste, etc.). Insisting on reversibility and retrievability could also create a powerful voice for local and regional CS, including the power to enforce reconsideration.

However, **doubt remains as to how these notions are defined in different countries** (including non-EU countries represented in the CS larger group) and how the question of retrievability is discussed and the scenarios assessed, including the verification of need and degree of retrievability. Considering the absence of reversibility and retrievability definitions, doubt was also expressed in regard to what degree reversibility and retrievability can aid in reducing perceived and factual uncertainties related to "permanent", long-term storage in geological formations. On the other hand, keeping the reversibility and retrievability options open, could be a guarantee for periodic re-evaluation of the disposal solution in question and facilitate keeping track with the most recent development in science and technology (e.g., if new technologies for NWM are developed in the future, will it be possible to extract the RW from the disposal facility for further processing?).

Conclusions on uncertainties of reversibility, retrievability and recovery

A characterisation of the needs for retrievability options and the corresponding criteria is needed in order to make it possible to plan for keeping these options open for as long as possible. The question was also raised, if it should be possible to retrieve the waste in case of an "incident". It was even suggested that full retrievability should remain a possibility unless there is proven lack of its necessity.

3.2.2.8 Uncertainties on costs and financing

Background: In order to solve problems stemming from NWM, resources have to be allocated both in the short and long term. Without sufficient funding, proper measures cannot be implemented that safeguard CS from the negative health and environmental impacts of dysfunctional NWM. Realistic cost estimates also have to be available to reach the wished-for quality standards and avoid cost overruns.

According to the members of the CS larger group, uncertainties on costs and financing are among other things if costs are not set accurately, lack of adequate funding, if responsible bodies cannot be identified or might vanish over time, issues regarding liabilities in case of a severe accident, negative health and environmental impacts caused by normal operation, and inappropriate dependency on funding providers by WMOs, TSOs and REs. Most of the uncertainties with respect to inaccurate cost estimates and lack of funding **pertain to all phases of the RW management process**, i.e., to policy, framework and program establishment, site evaluation and site selection, site characterisation, and facility construction, operation and closure, including post closure.

One of the main problems if not the most important problem that was identified by the members of the CS larger group is **the absence of binding European legislation to regulate the financing of NWM solutions**. This, in turn, leads to a chain of uncertainties and questions, which will be difficult to answer: What will happen if the estimated costs of RW infrastructure projects and operations are larger than projected? This is not unrealistic, considering the changing nature of costs over long time periods time and the distinctive possibility that nuclear industries might go bankrupt.

According to the members of the CS larger group, **cost estimates should be preceded by assessments** of the risks of delays and higher costs, the possible impacts of cessation of funds, the risk of abandonment of a project before it is completed (due to detection of dangerous geological flaws in the GR, political crises, switching to another solution, etc.), and the costs of a severe accident. Also, it should be investigated whether there is enough funding available to explore more than one alternative in a comprehensive manner.

Finally, it was suggested **that from the outset, planning must take the potential for increased budgets into consideration**, not least in order not to put undue burdens on future generations. This long-term financial planning must include costs related to decommissioning, monitoring, maintenance and retrievability, information infrastructure, inclusion of CS participation, physical protection, security and the risk of accidents.

Conclusions on uncertainties of costs and financing

The absence of binding European legislation to regulate the financing of NWM solutions is considered a major problem. From the outset, planning must take the potential for increased budgets into consideration to make assessments more accurate and the cost estimates must include the possibility of widening the scope of the planning both in terms of the timeframe and the range of issues that are covered.

3.2.2.9 Uncertainties on human resources

Background: Considering that nuclear power might not be a technology of the future, it is reasonable to assume that there could be an increasing shortage of human resources and qualifications all along the disposal process, given its considerable timeframe.

According to the members of the CS larger group, there must be vigilance regarding the financial provisions at the beginning of the process, during **phase 0 and the establishment of the program and policy framework**. A disposal facility operates over many human generations and must have the capacity to pay salary to the people working in it (experts, qualified workers, etc.). A lack of financial resources will have an impact on the availability of human resources. The main uncertainty of phase 0 relates to the capacity of the disposal program to identify all the human resources that will be needed for the implementation of the disposal facility and the related costs. Regarding these costs, there is also a risk associated to the sources of financing. Has the program identified robust sources of financing and gathered sufficient financial provisions to cover the risk all along the operational phases? Has the program identified alternatives in case of lack of financing?

With regard to the **operational and closure phases**, the CS respondents underlined the uncertainty related to the maintenance of competences during the entire process. With such an intergenerational project, there is at some point in time a risk associated to the emergence of lack of expertise and competences. This could be because of lack of institutional interest in NWM, but several causes are possible. To achieve a successful disposal facility, there is a necessity to maintain the scientific knowledge and expertise needed to implement it. Will the necessary information be available all along the operational phases?

Conclusions on uncertainties of human resources

The main uncertainties related to human resources identified by the CS larger group are the financial provisions and the intergenerational transmission of information needed to maintain a high level of competences for researchers and workers dealing with the implementation of the RW disposal.

3.2.2.10 Uncertainties on inventory

Background: Exact knowledge on the size and the composition of the RW inventory is necessary for the decision-making on the final disposal and public confidence in the methods that are applied.

According to the members of the CS larger group, during the first phases (program establishment, site evaluation and selection, site characterisation and facility design and construction), there is a **lack of clarity regarding the exact amount and inventory of waste** the disposal will effectively store: there is an absence of full and detailed overview of the future inventory content. There is also uncertainty related to the type of waste: will the facility include waste with characteristics not initially taken into account in its design? There are especially concerns on uncertainties related to **spent fuel characterisation** (and its status). Is or will the spent fuel be considered waste or not? Will it be included in the DGR? What are the **risks attached** to the disposal of spent fuel? Some answers also pointed to **uncertainty related to the lifetime of the waste**, also considering the chemical toxicity and the radiotoxicity of uranium.

During the operational phase, there is **uncertainty related to potential future waste** that will be included: added waste not initially planned for (due to production of new radioactive waste) and increasing the volume of stored waste. Will another facility be built, or will the operating disposal be receiving the new waste? Will only certain types of HLW be accepted for the operational life of the plant or will rules be ‘relaxed’ if/when new technologies potentially create different types of waste? Members

of the CS larger group also emphasised the uncertainty related to **potentially unknown material in canisters** (including types of waste the facility was not designed for), meaning an uncertainty related to the monitoring mechanisms ensuring (or not) a high-quality process.

CS larger group members also considered that uncertainty linked to inventory (amount and type of waste) may have an impact on its acceptance in society. The perception of people living near the facility could be different from the perception of the larger society. In addition, there are uncertainties coming from unclear definitions that make understanding and trusting the system difficult. For example: what are the differences between HLW, ILW and LLW, and why do they differ? Why are they stored differently, and how is this connected to the perceived dangers of radioactivity?

Conclusions on uncertainties of inventory

The uncertainties related to inventory identified by the CS larger group are mainly related to the waste inventory size and the nature of the waste for disposal.

3.2.2.11 Uncertainties on security, safety and risk assessment

Background: Security, safety and risk assessment is a very broad topic. In its safety glossary from 2018, the IAEA defines "nuclear safety" as follows: *"The achievement of proper operating conditions, prevention of accidents and mitigation of accident consequences, resulting in protection of workers, the public and the environment from undue radiation risks."* Security" is defined like this: *"The prevention and detection of, and response to, criminal or intentional unauthorised acts involving nuclear material, other radioactive material, associated facilities or associated activities. The prevention and detection of, and response to, theft, sabotage, unauthorised access, illegal transfer or other malicious acts involving nuclear material, other radioactive material or their associated facilities."*

The CS larger group members provided many answers on uncertainties about this topic, which relates to all phases of the NWM process.

Regarding matters of security, it is not clear if and how the problem of intentional or unintentional intrusions into a DGR can be resolved, or if uncertainties in this respect will have to remain. This is a topic of high relevance for the CS larger group not only in the preparation phase, but also during construction, operation, closure, and in the post-closure phase. The question was also raised: who will pay for security in the post-closure phase?

Uncertainties of human behaviour and human errors were also seen as relevant, especially in phase 0 (policy), phase 3 (construction) and phase 5 (post closure). First, the disposal process is considered at a certain time and with the available knowledge at that time. This means that something that is not considered an error at a certain point in time, can be considered as one several decades/(hundreds of) years afterwards. This calls into question the appropriateness of certain decisions and types of knowhow that have been taken/used at a moment where there existed more unknowns. Also, the fact that the disposal facility is constructed and managed by humans implies that unintentional mistakes can be made (because of working conditions, distractions, human fallibility, etc.), which can cause accidents and defects. Intentional mistakes or intrusion into a disposal facility (e.g., terrorism) can also happen. This cannot be predicted, but still be very harmful to the installation and people in the vicinity. Thus, the CS respondents consider such uncertainties to be very important.

In regard to risk assessment, many, still open questions were posed: what scenarios will be assessed? What are the criteria that will be used for this assessment? What are the potential impacts of this assessment? What scenarios will be defined as posing too much risk? It was established that a maximum accident scenario should also be assessed, which include all kind of possible accidents, with or without third person involvement (accidents, but also and intentional terror attacks, war etc.)

Furthermore, there is a need to **assess the environmental impacts of NWM**, including ecology and bio-enrichment of substances, chemical and radiologic ecotoxicity of uranium and its daughter isotopes. The projected levels of C-14 gas emissions generated by carbon rich waste inventories might exceed current regulatory limits in a near a field environment. The C-14 gas might ingress into agricultural soils and be absorbed by crops and farmed animal species.

Risk assessments should also include **cumulative risks of RW** to present and future generations. The inventory and types of wastes have to be clearly defined for their risk to be properly assessed. Also, risks need to be clearly explained, e.g., what are the time frames for canister degradation? It might be better to talk about "risk" and "more or less risky" than "safe" and "more or less safe" (see also chapter 4). It has to be made clear that NWM is reducing and not removing risk. Furthermore, how will the risk be assessed if there are no comparable cases? How can it be demonstrated that all current scientific and technical concerns can be addressed in the context of the safety case, which currently they are not.

Regarding **emergency preparedness and response**, for phases 3 and 4, it was mentioned that it is uncertain whether plans for emergency preparedness and response have been prepared and will be introduced in case of accidents. Will CS be involved in preparation of these plans? What is foreseen for the local population? What will happen to the radioactive waste in case of accident – will it be removed, and if yes, where to? And finally, will there be a budget for covering the costs of a severe accident?

Conclusions on uncertainties of security, safety and risk assessment

Security is an important issue that triggers uncertainties whether and how intrusions can be prevented, also in the very long-term. Many uncertainties were named concerning risk assessment, especially with a focus on the risk of accidents and the corresponding plans for emergency preparedness and response. The CS larger group members clearly preferred the term "risk" instead of "safety".

3.2.2.12 Uncertainties on site selection and decision

Background: Proper criteria and procedures for selection and decisions on the location of sites for DGRs are important for the public's trust in NWM. If they are not established from the outset, the public is likely to question all aspects of the ongoing NWM decision-making process.

The answers to the questionnaire by the CS larger group show that the CS members are concerned about uncertainties of site selection and decision-making all along the disposal, but more specifically before the operational phase. From phase 0 to 3, it is emphasised by the CS larger group members that *"uncertainty is increasing for the broad public when repository locations are to be chosen, and the issue of NWM has not been on their radar before that"*.

The respondents point out the need to ensure that safety criteria will not be reduced by economic considerations. To mitigate this type of uncertainty, there is a need of a clear definition of site selection criteria, entailing a set of mandatory minimum criteria and also exclusion criteria (that under certain conditions will constitute a game stopper for the site implementation). These criteria need to be broadly discussed.

Related to this aspect, the CS representatives identified **uncertainties related to the decision-making process for the site selection at the local and national levels**. This process should include independent review, transparency of information, public participation with an indication on how the public participation has been taken into account and justification of the decision. Public participation should include a very broad definition of the host/local community, which possesses the right to participate. Other communities in the vicinity could be impacted by the implementation of the facility and should be included in the discussions. After defining clear criteria, they should be honestly applied to select the

site in question and the decision-making process should be based on the availability of different site options with transparent comparisons and explanations of the decision at each step.

On the contrary, there is uncertainty related to the local community acceptance primarily based on financial incentives: no certainty the local acceptance will last on this basis and also no certainty the local community will continue to benefit from a continuing fund into the future. Bribery and no transparent financial incentives could compromise the site selection process.

In the latter phases, the respondents underline uncertainty related to socioeconomic impacts and influence on regional development related to the implementation of a disposal. There is a need for studies about social and economic potential external advantages and disadvantages not only at short term but also at long term: what will be the consequences for the activities on the territory?

Conclusions on uncertainties about site selection and decision

The main uncertainties related to site selection and decision identified by the CS larger group are linked to the transparency of the decision-making process, the effective public participation, the large inclusion of local stakeholders in the process (including neighbouring communities), the potential negative impact of financial incentives and the impact of disposal implementation on regional development.

3.2.2.13 Uncertainties on technology selection

Technology selection refer to the waste package technology and the engineered barriers in a DGR.

CS larger group members did only mention very few uncertainties on this topic. One reason for concern is the uncertainty where the line will be drawn between the theoretically best achievable technology and construction, and the **costs**. What risk will result from using material or techniques that to not correspond to the project, e.g., because they are cheaper? Concerns were also named that a technological concept might be made legal or is **licensed even before it is ready for use**.

3.2.2.14 Uncertainties on geology and hydrology

Background: Uncertainties on geology are things that are unpredictable in regard to the dynamics and physical history of the earth, the rocks of which it is composed, and the physical, chemical, and biological changes that the earth has undergone or is undergoing. Uncertainties on hydrology are related to the movement, distribution, and management of water on Earth, including the water cycle, water resources, and environmental watershed sustainability. Globally, uncertainties on geology and hydrology have to do with the physical environment where the facility disposal is envisioned to be constructed and hosting radioactive waste.

In regard to the question, **when do uncertainties on geology and hydrology arise**, the answers to the CS UMAN questionnaire demonstrate that members of the CS larger group are concerned about uncertainties on geology and hydrology along the disposal process before the site decision has been taken.

With respect to **what would be needed to reduce those uncertainties**, the CS larger group members insisted that there are strong uncertainties on the suitability of geology in the frame of both phase 1 and phase 2. e.g., the suitability of salt/granite/clay to the envisioned type of radioactive waste that will be disposed, and to the disposal facility itself. To assess the suitability of geology, clear criteria, and especially game stoppers, must be set. That would make it easier to choose the most appropriate

geological environment for the waste, and that would also help halting certain avenues of research, thus allowing to focus on more likely successful leads.

Emphasis was put on the necessity in phase 1 of the process to **consider several site options**, with a different geological and hydrological environment, and not only to select one site because the location is more acceptable for a majority of actors. Added to that, uncertainties in the understanding of the **geological and hydrological history of the proposed areas** need to be taken into account in phase 2. The historical analysis has to be carried out appropriately and it has to be figured out whether it is indicative of the future geological and hydrological activity on the site or not. This is part of the appreciation of the hydrological and geological environment, which must be as complete as possible in order to choose the most suitable option for disposal.

For CS larger group members who answered the questionnaire, uncertainties remain in phase 2 also on the extent to which the current thinking on the **theoretical "ideal" geology** is reliable and if an ideal geology really ensures that the next phases will work properly. Also, it is crucial to consider, what would happen if no suitable geology could be found in the country in question.

The other main uncertainties linked to geology and hydrology that have been reported deal with the effective recognition of all technical and scientific concerns in the context of the safety case.

Conclusions on uncertainties about geology and hydrology

Uncertainties on geology and hydrology are of importance to the CS larger group from the beginning of the disposal process until the site has been decided upon. They are connected to the knowledge and understanding of the geological and hydrological history of the sites that are considered for disposal, as well as to the recognition of technical and scientific features of geology and hydrology. It is crucial to make the best choice in site selection and site characterisation, thus optimising all the process.

3.2.2.15 Uncertainties on transport

Background: Uncertainties on transport are rooted in the fact that RW has to be removed from the place where it is produced (often nuclear power plants) to the facilities where it is temporarily stored or finally disposed of.

However, uncertainties on transport **did not seem to be a high priority** for the CS larger group members. Nevertheless, it has been highlighted by some of the respondents to the questionnaire that uncertainties about how best to transport waste to the disposal facility and emplace it need to be taken into consideration during phase 3 of the disposal process, i.e., facility construction. Also, some waste may be particularly fragile and more difficult to move without risking damaging it. Decisions on means of transport, including the choice of transportation container, must take risks of accidents into consideration. In case of delays of a DGR's start of operation, waste canisters have to be proved safe for longer interim storage.

3.2.2.16 Uncertainties on quality assurance now and in the future

Background: Most analyses of HLW disposal options led to the conclusion, that according to current knowledge, no other option than the deep geological disposal of RW is available for the long-term management of RW. However, the planning of a DGR poses serious challenges for science and technology, for the organisation of such a task and for the management of the programs. So far, no successful final repository for HLW has been built anywhere in the world. Consequently, there is very little positive experience to draw from.

According to the members of the CS larger group, uncertainties on quality assurance now and in the future are among other things that there is little experience with final disposal of HLW, how to guarantee safe and effective containment of radioactive substances over very long, if not virtually endless periods of time, controlling building quality, including the question, who will oversee construction, external threats such as climate change and long-time monitoring. Most of the uncertainties with respect to quality assurance **pertain to all phases of the RW management process**, i.e., to policy, framework and program establishment, site evaluation and site selection, site characterization, and facility construction, operation and closure, including post closure. All this could have immediate transboundary and even international impacts due to transportation, import and import of wastes. Thus, characterisation of international waste streams is necessary.

There were suggestions that a **guarantee of periodic re-evaluation of quality standards** is needed, which would mean keeping track of the most recent development in science and technology. Also, the question of reversibility is directly coupled with this type of uncertainty. Prior planning must include an effective contractor assurance regime. Technical and quality control and reporting would be needed, including a contracting structure involving subcontracting and oversight of sub-contractors, quality control and feedback, and not least whistle-blower facilities. Concerns were expressed in regard to the degree to which experience from construction is gathered and shared, to avoid mistakes. How will the design be evaluated and approved or otherwise? Who will oversee the construction? Prior planning must also include the capacity for effective external detection of any airborne radiological releases both near the site and beyond. Validation of construction quality and function (who does it, how, etc.) would need to be a part of the planning process, as well as monitoring.

Looking to the future in a 50–100-year time frame, climate modelling and in particular predicted sea level rises will need to demonstrate that sufficient account has been taken to rule out any potential repository site tunnel entrance that subsequently could be rendered unusable.

Conclusions on uncertainties of quality assurance now and in the future

Uncertainties on quality assurance are not least due to the fact that there is little experience with final disposal of HLW. Members of the CS group pointed to the need of a guarantee of periodic re-evaluation of quality standards. This would mean keeping track of the most recent development in science and technology. The lack of climate modelling was also considered an issue.

3.2.2.17 Uncertainties on trans-generational aspects

Background: Although radiation from RW decreases, it is a very slow process. For the short-lived RW, it will take centuries before the radioactivity reaches a safe level. The long-lived RW keeps its radioactivity almost infinitively - for hundreds of thousands of years or even longer. For a final disposal it must be certain that the layers surrounding the repository are not only impermeable, but also very stable. They have to keep their ability to isolate the waste for a very long time. The problem is scientific uncertainty: geology is not a predictive science and human intervention cannot be ruled out. The mathematic models that are applied are simplistic descriptions of complex developments in the underground environment and cannot be verified over extraordinary long-time frames. Thus, the uncertainties related to NWM in the long and even the mid-term have a trans-generational aspect, involving many generations, which raises the question, to what degree the current generations are entitled to make decisions (and particularly potentially irreversible decisions) on behalf of future generations.

The question of the long-term, changes of structures and views that can happen over time is also of concern for CS larger group members. Indeed, the longer it takes to go through the whole disposal process, the more chances there are that **changes will happen** (changes of political leaders, policy,

mentality, public views on NWM, law, knowledge, etc.). This has a direct impact on the process (modifications, slowdown, stop), and it creates numerous uncertainties.

According to the members of the larger CS group, uncertainties on trans-generational aspects include **information transfer from generation to generation**, the **risk of memory and data loss**, **warning over time**, **the time perspective of surveillance** (when can it be stopped?) and **responsibilities, also after the responsible bodies have disappeared**. Several questions have to be raised and answered: how early will non-technical issues such as risks of intrusion in relation to retrievability, how to provide information to future societies, etc. have to be addressed? Is credible post-closure security, including prevention of human intervention in the long term, even possible? Most probably, at some point in time nuclear technology could be widely forgotten, so how will the required knowledge and information transfer be secured, particularly into the **"deep" future**? Will uncertainties increase or decrease over time? Considering the uncertainties about data and records on a given disposal site and the difficulty of maintaining expertise and knowledge over time, how can future generations be warned of the location and its contents? Is it even wise to keep information on locations and inventories or does this constitute a risk factor in itself? How can information to future generations be passed on in a reliable manner at all and how can it be preserved? Is a pluralistic documentation centre a viable solution?

Almost all uncertainties in regard to NWM will have an unpredictable impact on future generations. This pertains to all phases of the RW management process, i.e., to policy, framework and program establishment, site evaluation and site selection, site characterisation, and facility construction, operation and closure, including post closure. Another significant uncertainty could emerge from the impacts of **climate change**, both in the operational and closure phase.

Conclusions on uncertainties about trans-generational aspects

Almost all uncertainties in regard to NWM will have an unpredictable impact on future generations. Members of the CS group identified information transfer, the risk of memory and data loss, warning over time, the time perspective of surveillance and responsibilities, also after the responsible bodies have disappeared as major issues.

3.2.2.18 Uncertainties on research

Members of the CS larger group mainly identified uncertainties on research **at the beginning and at the end of the disposal process**. During phase 0 and the establishment of the disposal program, the uncertainties relate to the independence of regulator research: will there be funding for regulator and TSO research independently from the implementer's research? The respondents also underline the existence of uncertainties related to the scope of research: is it broad enough? Will the scientific scope of disposal research include social and economic studies, research on alternatives to a DGR, on ecologic studies (example: chemical and radiologic ecotoxicity of uranium and its daughter isotopes)?

There are also concerns about uncertainties related to validation of technical knowledge and the methods to get pluralistic views on the research results. In regard to the post-closure phase, there is uncertainty related to long timeframes. How to test the models on long term and ensure results on safety of the disposal on such timeframes?

Conclusions on uncertainties of research

The uncertainties related to research identified by the CS larger group mainly pertain to the independence of regulators, the scope of research, methods of implementing pluralistic research and the viability of models testing safety in the very long-term.

3.2.2.19 Uncertainties on shared solutions and export/import

Background: Shared solutions between countries, including non-EU countries, comprising bilateral and multilateral shared nuclear facilities might lead to lower standards and environmental dumping if there is not a level playing field for all the stakeholders. e.g., the starting point for localisation of shared facilities must be national legislations in the concerned states that allow for the shared facilities to be located in all the states involved and in common licensing. Some of the questions that would have to be answered are: Who are the stakeholders, i.e., who should have moral and legal standing in the decision-making process? What means of persuasion are legitimate, particularly among uneven collaborators? Money, other benefits, etc.? Should there be as high as possible access to information, public participation and access to justice and resources for CS, where the shared facility is projected to be built? Are the cost efficiency and possible safety and security benefits (weighed against the increase of transports) of a shared RW facility more important than a principle, ensuring that every state takes care of its own RW?

According to the members of the CS group, uncertainty arises from the **size and characteristics of a RW inventory in a shared facility** because of the impact it might have on the acceptance in society. If the amount of waste to be stored is minuscule, it might mean less perceived risk in the larger society, but locally it could be seen as just as risky, and in some cases more "unjust" if the inventory is small ("If it is so small, why can't it be stored elsewhere?"). Shared nuclear facilities also increase the amount of RW that is transported over long distances and borders. Hence, there are serious international impacts which require an increased focus on the transportation and import of wastes and characterisation of the waste and the waste streams. For these activities, there must be clear criteria.

Conclusions on uncertainties of shared solutions and export/import

Uncertainty arises from the size and characteristics of a RW inventory in a shared facility, which also affects its acceptance to society. There must be clear criteria for all activities related to shared solutions and the export and import.

3.3 Answers to question 3

The overall tenor of the answers to question 3 was that **CS should participate in the discussion of all types of uncertainties.** Uncertainties exist during all the phases in question and changes might occur during the entire process. Hence, CS needs to be involved all the way.

It is also important that the full range of stakeholders in CS are heard, e.g., local government, community organisations, academics, business, etc. as well as NGOs and the general public.

Some CS larger group members think that the discussion on technical uncertainties is more appropriate, only after key concerns regarding transparency (and non-transparency), corruption, clientelism, etc. issues have been resolved in a way that does not allow any lack of trust or any doubts towards the responsible actors.

Before only talking about what uncertainties should be discussed, there are also the questions related to how such discussions should be organised? Who should organise it?

4. CS larger group members' definitions of uncertainty, risk and safety.

4.1 Background

Is uncertainty necessarily a problem?

This *Tale of the old Chinese Peasant* is provided here as an introduction to the discussion on the meaning of uncertainty: *The horse of an old Chinese peasant has just fled. His neighbours visit him and lament for him: "How will he survive now? How will you plough your field? What a pity!". But the old man tells them, "Is it a misfortune? Is it happiness? Who knows? We will see". Later on, the old man's horse returns to the stable accompanied by two wild horses. His neighbours visit him again and rejoice for him:" What a chance he has! He will be able to sell these new horses and put some money aside! ". But again, the old man tells them, "Is this happiness? Is it a misfortune? Who knows? We will see". Later on, the old man's only son breaks his leg while riding one of the wild horses. He is permanently crippled. The neighbours lament for him: "What a pity! His only son now crippled! How are they going to live now?". But the old man tells them, "Is it a misfortune? Is it happiness? Who knows? We will see ". Later on, a war is declared. All able-bodied young men of the village are mobilised except for the crippled son of the old man. They are all massacred…*

The tale reveals the difficulty to interpret uncertainty. Whereas neighbours immediately jump to conclusions, the old man seems wise and does not take position when new facts change the picture of uncertainties. However, as underlined by the participants, the old man seems strangely passive, without intention. This situation seems connected with a kind of fatalism, that is not necessarily comparable with our cultural context. Being confronted with uncertainty is inherent to the human condition. Basically, everyone in life would actively tend to mitigate and if possible, to avoid large uncertainties having potentially severe consequences. Uncertainty can be a source of opportunity or conversely a source of detriment. Every day we manage uncertain situations.

Is risk always a problem?

It depends on if I take a risk voluntarily, and on the consequences. Should we go hiking in the nature, we take risks voluntarily. With radioactive waste, we are no more in control as opposed to hiking. Another aspect is regarding the consequences of risk. Do we expect temporary or permanent consequences? It is not the same…

Does reaching a state of safety entail absence of uncertainty?

There is a common, but wrong idea that absence of risk is very much the absence of uncertainty. We often think absence of risk necessitates absence of uncertainty. This creates suspicion, create mistrust and panic. It should be made clear that the conditions for safety will evolve over time. There is a need to give interested people access to information and expertise. Otherwise, there will be a problem. If you are in the field of risk management, it is not always easy to pass on the knowledge to other people, it can be high science. It creates a kind of uncertainty too. One really needs to take into account people's worries.

Would it be unwise to dismiss the possibility of any severe undesirable incident occurring, even if its probability is remote?

In light of the many nuclear incidents and events over the years – not least the Chernobyl and Fukushima disasters - it could be argued that as nuclear plants and facilities continue to operate, there will always remain a residual risk (the amount of risk or danger associated with an action or event remaining after natural or inherent risks have been reduced by risk controls).

4.2 Input from CS larger group

Is uncertainty necessarily a problem?

The ICS workshop discussions underline the difference between known uncertainties and unknown uncertainties. Operational accidents could happened in a RW geological facility as a result of an unknown cause. Whereas when uncertainties are known they can be dealt with.

When does uncertainty stop being a problem? Uncertainty for whom? For nuclear operators or for CS? GD might be a lower uncertainty choice, but to local people (near facilities), it is creating high

uncertainties. It raises lots of concerns. What is too risky, not safe enough? Copper corrosion is a good example. High uncertainties are at stake. If there is one uncertainty in one part of the whole barrier system, the uncertainties in other parts are also impacted. In everyday life, we accept uncertainties. We accept this or that. It is also about the personalities and personal preferences, people have different ways to apprehend risks. We need to have awareness of the uncertainty. Knowledge helps and helps trust. Suspicion is not always a problem, but also part of the solution. There is always a balance on resources. The trend to do that demands a lot of effort, and we don't have an infinite of resources to put on this problem. In Swedish society, there is a common understanding that most people first have to accept some facts. Then, based on that, decisions can be taken.

Frank Lemy, in his presentation of UMAN during UMAN Seminar 1, underlined the differences between epistemic uncertainty (resulting from a lack of knowledge) and aleatory uncertainties where events occur according to a certain degree of randomness. Whereas epistemic uncertainties are, in principle, reducible (with more science for instance), the aleatory uncertainty cannot be reduced.

Is risk always a problem?

When focusing on waste, what possible solution in the management of the waste entails the least risk and uncertainty? Regarding NWM, one should compare the risks associated with having a repository with the risks associated with not having a repository. It might be more difficult in the context of ongoing discussions on new nuclear power plants, as acceptance of a repository could give justification for more nuclear generating capacity.

How to establish a degree of consensus? Consensus is not always needed. It is unclear that getting majorities is a viable option for making a decision on repositories.

Risk has to do with the coupling of uncertainty with its potential detrimental consequences. Reaching a state of safety means avoiding worrying about the possible consequences of a human activity. Never eliminate the risk entirely, just accepting a certain level of risk. Crossing the road, for example, is a notion of perception. We tend to exaggerate risk, maybe. It is amazing what level of risk we may accept. About radioactive waste, only a few people can realise what it is.

Does reaching a state of safety entail absence of uncertainty?

Uncertainty is not necessarily a problem, but it creates doubt. Uncertainty can be a reason for suspicion as can lack of information and transparency, which are also a cause of uncertainty. Uncertainty leads to suspicion. People experience suspicion and it will spread fast. On the other hand, uncertainty is also a reason for suspicion. Paired with ignorance, it could create unfounded rumours. Uncertainty is a reason for suspicion - among others in the public. For those who do not know a lot - discussions at the bar - uncertainty becomes fast a rumour and recreate rumours. Not only in regard to radioactive waste, but in general around nuclear. When there is a small disagreement about safety - even if it is not dangerous - there are directly rumours about the situation. Uncertainty is not necessarily a technical problem, but we need to work on it because of confidence.

Would it be unwise to dismiss the possibility of any severe accident occurring, even if its probability is remote?

Precursory events cannot be eliminated, the possibility of a future severe accident cannot be entirely excluded, and it would be unwise to dismiss the possibility of any severe accident occurring on the grounds of its remote probability alone as was the case with the Fukushima accident. Furthermore, with respect to nuclear installations and particularly nuclear power plants, residual risks could have particularly catastrophic consequences. This also pertains to radioactive waste management, although the risks and consequences, technology specific as they are, are somewhat different. Residual risks therefore cannot be dismissed. Lack of awareness of residual risk can complicate emergency measures.

4.3 Conclusions

Uncertainties, risks and safety are interconnected. Assessing the impact of uncertainties on risk exposure along the large periods of time involved by GD implementation makes it necessary to address possible evolutions of the context. Certain uncertainties may have a very different impact on risks for human health and the environment, according to the possible evolution of the context. A dynamic perspective is necessary. For instance, life-time extension of NPPs makes it necessary to reconsider the initial picture safety of NPPs not only because of ageing but also as a result of contextual evolution over time (e.g., density of neighbour population)

ICS discussions underline the difference between known uncertainties and unknown uncertainties. It is only when uncertainties are known that they can be dealt with. However, a long duration of GD implementation could be an asset and improve the technical picture of uncertainties attached to GD.

With respect to nuclear installations, residual risks could have catastrophic consequences. Precursory events cannot be eliminated, the possibility of a severe accident cannot be entirely excluded. It would be unwise to dismiss the possibility of any severe accident occurring on the grounds of its remote probability alone. Lack of awareness of residual risk can also impede emergency measures.

In everyday life, we accept uncertainties. We need to have awareness of the uncertainty. Knowledge helps and helps trust. Uncertainty can be a reason for suspicion. Suspicion is not always a problem but can also part of the solution. Lack of public information and transparency is a cause of uncertainty.

When does uncertainty stop being a problem? Uncertainty for whom? For nuclear operators or for CS? A repository might be a lower uncertainty choice, but to local people (near facilities), it is creating high uncertainties. It raises lots of concerns. One should compare the risks associated with having a repository with the risks associated with not having a repository.

Does reducing NWM risks create new risks? Does reaching a solution for some types of existing or planned wastes create a kind of blank check on further production of radioactive wastes? In the context of ongoing discussions on new builds (NPPs), acceptance of a repository could give justification to more nuclear power. Connected to this is the crucial question of status of nuclear energy in each country. If the public perceives that you solve an accumulated problem, only to continue to accumulate more waste (by running new NPPs), for which you have no plan, then the acceptance might be hard to find.

5. CS larger group members' views on uncertainties in the safety case

5.1 Background

What uncertainties should be considered in the frame of the safety case?

The project of disposing radioactive wastes in the geology in general is associated with various kinds of uncertainties and risks. Some uncertainties are potentially impacting safety and should be taken into account by the safety case review by the public authorities (see the background presentation by Frank Lemy).

Some uncertainties relate to the **technical capacity** of a RW project to reach its overall goal: *to provide a safe long-term disposal for RW without any foreseen human active safety contribution after a given limited period.*

The considered uncertainties are attached to technical performance of the project components such as the waste packages, the repository concept, quality of the selected geology, monitoring, etc.), along the successive steps of the project (at the stages of authorisation, during operation, before closure, after closure).

There are also uncertainties attached to the **future development of science and technology**.

Some uncertainties are related to **external events that may impact safety** – e.g., lack of resources to operate the project (financial resources, human technical and scientific skills, etc), or other events such natural threats or war. There are also other kinds of uncertainty attached to other fields of knowledge

that need to be considered: ecology, biology and biochemical concentration. For instance, the chemical toxicity of uranium and its daughter isotopes.

Should the safety case include uncertainties that matter to CS?

According to the IAEA Safety Guide SSG-23: *"The safety case is the collection of scientific, technical, administrative and managerial arguments and evidence in support of the safety of a disposal facility".* The safety case review is achieved in the context of a regulatory framework. Problems occur notably when regulators are too much influenced by the implementers. Cases of corruption are reported in some EU member states where research funding on safety is allocated by public authorities to organisations that do not fulfil their obligations. This calls for a truly independent authority. It is also emphasised that political developments can lead to a lowering of NWM standards. Sudden interruption of a NWM program can also lead to safety uncertainties.

What about uncertainties in the societal interpretation of the safety standards over long periods of time?

Sometimes governments and institutions work on the principle laid out by Groucho Marx: "*Future generations have done nothing for me, why should I think about them?* ".

Sound and fair decisions should be made within the framework of an open political process, until the end of the decision-making process. Given the existence of uncertainties along the successive phases of the repository program, the decision on whether or not GD can be authorised cannot be a blank cheque. An essential dimension of the political process is to take on board the various concerns of society. Uncertainty in the outcome of the decision-making is proof that there is a real decision to be made. Otherwise, it would signify that the decision has already been taken.

A difficulty lies in the very long-term perspective attached to the NWM and the intergenerational dimension of NWM projects. Asserting today that a given option is safe, by no mean entails that future generations would agree. Would we today accept battlefield surgery conditions endured by soldiers in the 17th Century? For the coming generations, changes in interpretation of safety requirements constitute a genuine part of the fairness of the political process. In this perspective, changes in the interpretation of the regulation framework can certainly be anticipated.

Should we consider political uncertainties as relevant for the safety case?

Among the uncertainties to be considered, Milestone 21 identifies the question of uncertainty in the outcome the political process as one uncertainty to be addressed in the safety case:

Although some uncertainties may always arise and others can be considered as irreducible (political decisions, veto right of locals, intrinsic variability of the host rock, etc.) the overall uncertainty is expected to decrease over time, except for rare events whose likelihood is difficult to assess (Milestone 21, p. 16, TSO).

Some WMO pointed out as the major ones, the societal and political uncertainties to which the decisions (national policies) are related, the siting and the financing. (p.9 - WMO).

Public acceptance of a repository is of course an issue, part of the "general feasibility" and potentially even more acute in countries with a high density of population. (p. 10 - WMO).

Social opposition is a large source of uncertainty (p.10 - RE).

Even if societal acceptance has made repository construction possible, it is not sure that this acceptance is granted forever (p.14 - RE).

5.2 Input from CS larger group

What uncertainties should be considered in the frame of the safety case?

It is expected that the long duration of implementation will be seen as an advantage to change the technical picture of uncertainties attached to GD and in particular to remove or mitigate uncertainties so that only those remain at the end uncertainties one can live with.

Should Safety Cases include some important uncertainties that matter to civil society?

CS participants stressed the importance of uncertainties on the **continuity and stability of the governing institutions and associated expertise resources**. Uncertainties relate to the **continued availability and integrity of the governance framework** that over a long period entails the continuity of government, the existence of independent regulatory, authorities with relevant independent expertise, the continuity of the RW operator (public or private according national contexts). This is also underlined in Milestone 21: *"Timescale can also be seen as the risk regarding the lack of stable policies or national waste programs and may affect the plausibility of such a long process." (p.23 - WMO)*

A precondition here is the independence of the decision-maker during the program. However, according to CS participants this is already problematic at present in some EU member states and neighbouring countries.

There is also a conviction that such a goal (preserving continuity and independence of governing bodies) **cannot only be achieved on a national basis**. It also entails interactions with other countries, especially in the EU context. As the two tracks - safety and decision-making - are connected, transparency has to increase. It is also a CS concern to watch how democracy is handled in neighbouring countries and how this can impact safety. Nuclear law is not the same all over Europe (it depends on the way EU directives are implemented at the national level). The current tendency goes in the direction of loosening the reins. Too many standards can also be a problem because it could make the decision-makers choose short term instead of long-term solutions.

From these considerations on the necessity to maintain regulatory independence arises the question of the role of the **public and of the awareness of CS vis-à-vis the safety of radioactive waste management**. One should keep in mind the role political power can play in these issues. It would be beneficial to involve CS representatives in the decisions of the governing institutions, in order to increase confidence in the system. CS is very important to the upholding of the safety standards. However, it is reported that in France, CS participates in the decision-making process, but has little influence (according to the CS participants). Political uncertainty has an impact on technical uncertainty and thus on the safety standards. Proper legislation could be an answer. High standards have also to be promoted by nuclear law.

Safeguarding the **independence of the public** is also an issue. CS participants observed that the local communities could change their mind on the safety case, if they receive subsidies. On the other hand, the human factor can be one of the weak links in the project. Humans can, on occasion, be irrational and unpredictable. Presenting the safety case to the public is important in this perspective. It was noted that CS members can usefully provide parts of the safety case review, even with their limited technical knowledge. Having an independent, vigilant and knowledgeable public is definitely a part of the sustainability of long-term governance framework of NWM.

RW governance uncertainty can also **impact the financing of NWM** and future final disposal (financing of NWM is already problematic in many countries). It is important to point out what the insufficient financing could mean with regard to nuclear safety.

Availability of a fair, transparent and democratic governance framework (independent regulator and expertise) over a long period is an essential dimension of safety: uncertainty on the availability of the governance framework should therefore be considered.

What about uncertainties in the societal interpretation of the safety standards over long periods of time?

According to the members of the CS larger group, the GD safety case has to evolve over time. Things can change with time (e.g., see the copper corrosion case in Sweden). The safety case starts very early,

and different countries have different approaches. But the safety case itself is a part of an iterative process. Uncertainty on the outcome of the decision-making process has consequences for safety. It is important to include this possibility in the NWM process (e.g., the postponement of the GD project during the course of its implementation). This introduces the question of reversibility and retrievability as an important aspect to the safety issue.

In this perspective uncertainties on the evolution of the interpretation of the safety requirements should be anticipated as a proof of the fairness in the decision-making process. Thus, changes in interpretation do not represent a kind of uncertainty that one should mitigate. **On the contrary, it is a genuine dimension of the fairness of the political process for future generations.** Whereas Milestone 21 states, *"political changes leading to changes in the framework as well as, in some cases, the interpretation of the emerging regulatory basis create uncertainties that challenge the confidence in the disposal programme (p. 10 - WMO)"*, it should instead be stressed that **introducing flexibility in the interpretation of safety standards, could promote more confidence in the decision-making process in the long run**.

Another way to ensure proper updating of the safety standards over time is to ensure the implementation of the BAT principle. CS participants would see it as a powerful means to push back against only the application of minimum standards and reach for the highest possible reduction of risk.

Should we consider political uncertainties as relevant for the safety case?

This is an important question for CS participants. It is clear that the possible variability of political decisions might create some challenge for safety (e.g., should the governing bodies cut off the resources of the GD program?). The safety case needs to be linked to a political and social context. Society remains the final beneficiary of NWM. SC is not a purely neutral object, not a black-and-white issue. In this perspective, potential consequences of each political option at all stages of the program should be carefully addressed in the safety case. The implementation of a GD project is expected to reach several phases - authorisation, experimentation, operation and closure - necessitating a long duration, in many cases more than a hundred years. As a result of the socio-political contingencies, the safety of an interrupted GD project might become uncertain. This should be considered in the safety case as a possibility and duly taken into account.

However, as mentioned above, **lack of uncertainty in the outcome of the decision-making process is a proof that there is a real decision to be made**. **Otherwise, it would mean that the decision had already been already taken**. In this perspective, it would be paradoxical to include political uncertainties in the list of uncertainties to be addressed in the safety case, in order for them to be mitigated or avoided.

The one who is building is naturally trying to gain acceptance of the building project, in order to be able to build, so it is necessary to take a step back from the project itself. Independence of regulatory authorities is necessary in this perspective.

The safety case is a collection of evidence which has to be compiled, based on calculations. It is oriented towards third parties. Its aim is to produce and demonstrate safety in terms that are convincing and understandable. The demonstration is really related to the acceptability of the society as a whole. One must understand that there is an overall common interest in reaching a safe solution as a result of a GD program.

Societal preferences or requirements may come into play when there are alternative options with different impacts on safety. Reversibility might represent, on one hand, a breach of safety (because closure is postponed). On the other hand, it can be beneficial in case of failure. Introducing reversibility is a social requirement and, in this perspective, an overriding political orientation.

Some CS participants saw as problematic the connection between safety case and public acceptance. Public acceptance includes the safety case, but at the end of the day, the decision involves a larger perspective. It was stressed that **the political and societal decision to authorise a GD is not a**

unidimensional consequence of the acceptance of the safety case presented by the authorities (even within the appropriate conditions of transparency). **Public acceptance of the safety case is only a precondition for the authorisation.** The decision should not only be made by safety authorities. The local and national political dimension of such a decision must be acknowledged. This entails other aspects than safety.

Constructing a DGR is by no means only a technical task. To incorporate GD in the geology of my territory (the place where I live) is connected with the concrete relation I have with my territory and with other humans and non-human elements of my environment. This is not a matter of education, **it is linked of my vision of the world, of the future, of the human destiny**. There is often some public reluctance with idea of GD that goes beyond the question of safety. Reaching a decision to host or not to host a DGR entails many complex human and contextual aspects. **Refusing to host a repository is legitimate and cannot be reduced just to a NIMBY attitude**.

5.3 Conclusions

Societal expectations on safety standards will vary over time due to the long timeframes involved. Given the existence of uncertainties along the successive phases of the repository program, the decision on whether or not GD can be authorised cannot be a blank cheque. The GD safety case has to evolve over time and be influenced by science and interaction with society. Evolution of the interpretation of the safety requirements should be anticipated as a proof of the fairness of the decision-making process. Flexibility on the interpretation of safety standards could boost confidence in the decision-making process in the long run.

There are political uncertainties associated with NWM in the long term. Considering the long duration of GD implementation, the political and societal context is a source of uncertainty. Political and societal priorities may shift, thus neglecting NWM over time. While interrupting NWM programmes, safety of the on-going NWM activities might be compromised. Societal expectations vis-à-vis safety standards may increase. Should all those uncertainties be addressed by the safety case? Safety uncertainties associated with socio-political contingencies is clearly an issue for the safety case. Provisions should be provided (a plan B) in case of unexpected political outcomes, as a part of the safety demonstration. Uncertainty of the outcome of the decision-making is a proof that there is a real decision to be made. Otherwise, it would mean that the decision is already taken. In this perspective, aiming to reduce uncertainty in the outcome of the political process would mean impeding the democratic process.

It is underlined that non-technical uncertainties should also be investigated in the framework of EURAD. Constructing a DGR is by no means only a technical task. Political and societal decisions to authorise a GD are not a unidimensional consequence of the acceptance of the safety case by the authorities. Its acceptance is only a pre-condition for the political decision. Reaching a decision to host or not to host a repository entails complex human and contextual aspects. Refusing to host a repository cannot be reduced to a NIMBY attitude. These issues should be further investigated.

6. Views of CS larger group members on uncertainties in transparency and public participation

6.1 Background

A short introduction to transparency and public participation

Besides issues of risk, safety and security, transparency and public participation are key topics for CS engagement in nuclear topics.

The international anti-nuclear movement has had to fight since the 1970s for transparency and public participation (T&PP) in nuclear projects. Today the importance of T&PP in the nuclear sector is widely recognised, also at the legal level (Directive 2014/87/Euratom, Directive 2011/70/Euratom).

The Espoo and Aarhus Conventions provide an important legal basis for T&PP, also in nuclear procedures. The Convention on Access to Information, Public Participation in decision-making and Access to Justice in Environmental Matters (**the Aarhus Convention**), drawn up by the United Nations Economic Commission for Europe (UNECE), was signed in Aarhus, Denmark, in 1998 and entered into force in 2001. In October 2017, 47 states including the European Union were parties to the Aarhus Convention. Among these 47 states are also all 28 EU states.

The Aarhus Convention aims to link environmental rights with human rights. According to the Aarhus Convention, all stakeholders must be involved to achieve sustainable development; future generations must also be taken into account.

These rights relate to three areas:

1. The public's right of access to environmental information vis-à-vis administrative authorities and also private parties with public responsibilities for environmental protection.
2. The public's right to participate in certain environmental decision-making processes.
3. The public's right of access to courts or tribunals in environmental matters.

The **Espoo Convention** on Environmental Impact Assessment in a Transboundary Context is also an instrument of the UNECE for the participation of affected countries and their public in EIA procedures in other countries for projects that may have significant transboundary impacts. The Espoo Convention was adopted in 1991 and has been in force since 10 September 1997. It has been signed by 40 states and the EU.

The **SEA (Strategic Environmental Assessment) Protocol**, an amendment to the Espoo Convention, was adopted by the UNECE in Kiev in May 2003. The Protocol has been in force since 11 July 2010 and has been ratified by some EU states and the EU itself. Transparency in the nuclear sector includes informing all persons and stakeholders in a way that they can assess the risk of a nuclear activity. Information has to be provided complete and early enough.

Participation means that all stakeholder, among those especially environmental NGOs, siting communities and the public, can take part in legal procedures like Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA), in hearings and in other consultation fora. Especially important is the question of participation in decision making.

Reflections on the view of T&PP in the EURAD project

When doing a search on the keywords “public”, “transparency” and “participation” in UMAN draft deliverables, the first quotation already gives a lot of insight how EURAD UMAN experts correlate to the public: *“No principal differences were observed comparing the point of views of TSO, WMO and RE both on key uncertainties and on their evolution in the various phases of the repository program. In the same way, actors from less advanced and more advanced national programmes share rather similar views on the uncertainties of the safety case. Coherent and complementary views were well observed when interpreting the discrepancy between the rather promising results of quantitative safety analyses and the sentiment of uncertainty prevailing in the larger public.”* (UMAN Draft D10.5 = milestone 21 from 27 March 2020, p. 3)

The “sentiment of uncertainty” and the “quantitative safety analyses” are presented here in a simple, binary model: The public has feelings, while the scientists and technicians have quantitative results.

This core assumption can be found in the EURAD questionnaire: in some answers to of WMOs, TSOs and REs, in the interpretation of their answers, and even in some of the questions of the questionnaire – for example: *“3.1.4 Safety assessments of geological disposal concepts and associated uncertainty management by WMO have shown consistently in several countries that the disposal would*

provide safety for hundreds of thousands of years and that no release is usually expected for the first thousands of years. Still many people have fear from radioactive waste disposal." (UMAN Draft D10.5 = milestone 21 from 27 March 2020, p. 20)

In this question it is claimed that people fear disposals even though scientists declared disposals to be safe. In our opinion, fear is a normal reaction to a dangerous activity, especially if people are not informed adequately, if authorities and organizations in charge are not trustworthy or if safety issues seem to be less important than economic criteria.

The UMAN expert group members therefore prefer to shift this discussion from simple binary categorization of the public versus scientists to the focus on transparency and participation of the public.

Two examples for dealing with uncertainty in public participatory procedures.

1. **About CS having access to independent expertise (the Danish and Swedish examples)**

The Danish example could offer a way to proceed: Since 2016, there has been an **institutionalised model for transparency and public participation in the decision-making on radioactive waste management in Denmark**. This was deemed a political necessity due to the resistance from the five municipalities that were initially designated as potential host sites for the Danish final repository for radioactive waste. A **national contact forum** for radioactive waste was established under the auspices of the Ministry of Higher Education and Science, consisting of all the relevant stakeholders. Currently, the national contact forum, which meets regularly, has more than twenty members, including initially representatives from concerned local citizens' groups (now reorganised into a national organisation), NGO representatives, Local Government Denmark, Danish Regions, representatives of the regulating agencies – i.e. Danish Health Authority (Radiation Protection) and Danish Emergency Management Agency - Danish Decommissioning, Geological Survey of Denmark and Greenland, and Danish Agency for Institutions and Educational Grants. A **local contact forum** in Roskilde, where an intermediary storage facility is to be built, has also recently been established. More fora are underway, when new possible host sites for a deep geological final repository are designated. Overall, the contact fora are perceived to be a success by most if not all the involved parties.

Affiliated with the contact fora is a **panel of scholars from Danish universities** to facilitate replies to technical questions from the general public on radioactive waste management. The panel members have been selected by The Danish Council for Independent Research, which provides independent scientific counselling to the Danish Government. In the context of radioactive waste management, the expert panel submits written answers to questions on nuclear physics and nuclear energy, health physics and radiation protection, environmental impact assessment and environmental law, public governance and general ethics.

Sweden also provides an interesting example of transparency, public participation and access to resources: **The Swedish NGO Office for Nuclear Waste Review, MKG** - a cooperative effort between among others the Swedish Society for Nature Conservation and Nature & Youth Sweden – is mainly financed by **The Nuclear Waste Fund**, a government authority with the primary task of administrating fees that have been collected from nuclear power reactor owners. MKG is tasked with monitoring and reviewing the nuclear power industry's planning for identification of methods for repositories for radioactive waste from nuclear power plants and the industry's plans on siting of repositories and participates in the legal proceedings regarding the proposed Swedish repository for spent nuclear fuel near the Forsmark NPP.

The Swedish environmental courts also represent a positive example of **access to justice**. There are five regional environmental courts and one superior environmental court, the Environmental Court of Appeal. The Swedish environmental legal system also includes twenty regional boards and about 250 local environmental bodies. Environmental courts have legal jurisdiction over both land use and environmental areas, including radioactive waste management, incorporating civil and administrative

but not criminal powers. Generally, the Environmental Courts have high credibility and are fully accepted by the Swedish NGO community[44].

2. Uncertainties in Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA) in the EU legislation

In every EIA procedure, the operator of a repository has to provide an EIA Report. In Directive 2014/52/EU (the **EIA-Directive**) in Annex IV the content of this EIA Report is defined. Amongst others, the following information is demanded:

"6. A description of the forecasting methods or evidence, used to identify and assess the significant effects on the environment, including ***details of difficulties*** *(for example technical deficiencies or lack of knowledge****) encountered compiling the required information*** *and the* ***main uncertainties*** *involved."* (EIA Directive 2014/52/EU, Annex IV) (own emphasis)

The same is true for every SEA (e.g., for national radioactive waste management programs under Directive 2011/70/Euratom):

"(h) an outline of the reasons for selecting the alternatives dealt with, and a description of how the assessment was undertaken including ***any difficulties*** *(such as technical deficiencies or lack of know-how)* ***encountered in compiling the required information****;"* (SEA Directive 2001/42/EC, Annex I) (own emphasis)

Reality Check: Some European countries held a SEA on their national waste management programs. Austria participated in these SEAs. In the respective expert statements on the SEA documents the following assessment can be found:

- **Germany:** The SEA Report was not able to evaluate quantitative effects on the environment because no sites and no technological concepts for repositories were chosen at the time of the SEA. Only qualitative effects were discussed in general. Therefore, discussed measures for minimising or preventing negative impacts of a repository are seen as not binding. *(Lack of knowledge on future sites and the technological options that will be chosen lead to non-committal in assessing environmental impacts.)*
- **Italy:** No information was given on difficulties or lack of know-how.
- **Czech Republic:** The authors of the SEA Report only mentioned that they did not have any difficulties in preparing the report because they received enough material from the Ministry in charge.
- **Hungary:** Hungary plans to monitor the environmental situation before the construction of waste management facilities to have reference values for assessing environmental effects to reduce uncertainty. *(This should be good practice anyway; the promise of monitoring is not a way to deal with uncertainty.)*

These examples cannot be called a meaningful discussion of uncertainties, lack of knowledge or difficulties. The implementation of the above-mentioned articles of the EIA and SEA-Directive needs to be improved. It would be a valuable outcome of the EURAD project if in future EIA and SEA procedures dealing with uncertainties in NWM could be improved substantially, e.g. by producing guidelines for best practices.

6.2 Input from CS larger group

[44] Ulf Bjällås, Experience of Sweden's environmental Courts, Journal of Court Innovation 180 (2010), https://law.pace.edu/sites/default/files/IJIEA/jciBjallas_Final%203-17_cropped.pdf

At the UMAN Working Group Day, the following questions were discussed in the breakout sessions:

1. What are your experiences with information on uncertainties in nuclear issues and discussing uncertainties in participation procedures?
2. How is-it possible to ensure transparency and accountability of uncertainty management across the entire planning and development process?
3. How should uncertainties be dealt with in participation procedures?
4. Uncertainties are not only of relevance for planning a GD, but also for transport, conditioning, and interim storing of waste. How should these areas be included in a transparency and participation management?

Results of the discussion:

There are **differences in transparency in Europe** between Eastern countries and Scandinavian countries and the UK. CS members from Hungary, Slovakia and Czech Republic report lack of information, lack of transparency and being ignored or even observed. When NGOs decide to follow legal options, it is a hard job. In some countries, NGOs are not working any longer on nuclear issues.

Private companies do not need to be transparent: Example of Javys, which is 100% state-owned, and not subject to the freedom of information act. SKB in Sweden is a private company with no transparency, i.e., not covered by the freedom of information act in Sweden. **This could be addressed as an issue in EURAD– all actors should be obligated to demonstrate transparency.**

Trust and mistrust: it is not easy to inform CS about uncertainties, perception might lead to **mistrust.**

The information from regulators or WMOs is a one-way stream and does not identify uncertainties. Even in Sweden (a country where people tend to trust the authorities), SKB says that there are no uncertainties.

The role of the media is different in different regions: In Western countries, the problem of fake news arises, social media and fake news constitute a real challenge to T&PP. Many people in the UK are not aware of nuclear issues at all, or on waste issues. Hence, a national conversation would be needed. In Eastern and Central European countries (CEE) non-state media face threats and suppression. In the Czech Republic, there is only official information, which is heavily reflected in the one-sided media coverage. There is need to widen up the debate and make NGOs more visible and respected, so that they can provide the public with a more balanced picture of the situation.

The time factor: the more a NWM project is advanced, the less it is possible to open the floor to discussion. We are still in the early phase of CS involvement.

The **Danish model** was emphasised as a model for the future.

A lot of discussions are focusing on DGR, but uncertainties play a role in **the whole NWM process**, in LLW, in challenging wastes…see the Belgian example: only a DGR is discussed.

EIA and SEA should be standardised, we should know what to demand.

6.3 Conclusions

There is no disagreement about the fact that T&PP is a basic need in NWM. In different countries there are different transparency regimes. Especially difficult is the situation in Eastern European countries.

Focus should be on missing transparency of private companies involved in NWM – they should also be subjects to the requirements in the relevant legislation and international Conventions. The role of the media should not be neglected. Media to a large degree only reports what governments want them to, but also the emerging of fake media. Good or best practices like the Danish model should be evaluated and promoted.

Participation in EIA and SEA procedures could be better standardised when providing information on uncertainties and lack of knowledge. Guidelines for providing better quality information on uncertainties in the EIA- and SEA-reports would be a helpful result of the EURAD project.

7. CS larger group members' ideas on managing uncertainties

Uncertainty is an uncertain concept in itself and often invested with a moral quality, that equates uncertainty with something that is bad and should be reduced. However, the notion of uncertainty has identifiable dimensions, such as unresolved long-term modelling weaknesses, which among others require decision-making authorities to permanently monitor the safety of GD. Thus, if correctly acknowledged and taken into consideration, uncertainty can also be a positive driver for more scrutiny, ensuring that unresolved issues cannot be inaccurately presented to society as if they were already solved.

7.1 Background

NWM is a complex and dynamic issue. There is already a significant amount of RW in existence today and more will be produced in the EU with future nuclear operation as well as with decommissioning.

A project (not yet a reality) of disposing RW in the deep geology is considered. This project could be beneficial but also very detrimental. With GD, it is sought to reach a situation of passive safety, where human action is not expected to maintain actively a state of safety. However, there are existing approaches to NWM that entail permanent human action to maintain safety.

Along the successive phases of the GD project development and implementation, the picture of uncertainties evolves as a result of successive phases of the project that include activities of validation, experimentation and research of a certain duration. However, the initial decision of authorisation should by no means be a blank check. Even in the closure phase, it is not expected to avoid all uncertainties, but only the uncertainties that are deemed unacceptable.

Long term security provisions would be needed if such retrieved packages contained fissionable (explosive) material such as separated non-dispositioned plutonium (i.e., not immobilised in a ceramic or synthetic matrix to impede malevolent accessibility).

So, the question is: **which types of uncertainty management principles would gain the most support from and best ensure the safety of CS?** And furthermore: in regard to NWM, where and how would in particular **the precautionary principle** be relevant and in what sort of governance could the uncertainty management principles best manifest themselves?

With respect to the nuclear fuel chain, the precautionary principle could provide valuable guidance in decision-making in all of its phases. Regarding NWM, it could be relevant for policy, framework and program establishment, site evaluation, selection and characterisation, and facility construction, operation, closure and post-closure. Not least, it could help determine the choice between short term and long term, and reversible and irreversible options, e.g., between interim storage and disposal, deep geological repositories and deep borehole technology, etc. And because it is an environmental principle, it takes precedence of economic calculations of costs and benefits by putting environmental considerations first.

The precautionary principle is a **legal**[45] as well as an **ethical principle** and is considered one of the pillars of European environmental law. Its origin is among others Principle 15 of the Rio Declaration that

[45] The description of the precautionary principle is mainly based on Jan H. Jans and Hans H.B. Vedder: European Environmental Law, 3rd edition, Groningen: Europa Law Publishing, 2008, p. 37-42 and Patricia Birnie and Alan Boyle: International Law and the Environment, Second Edition, Oxford: University Press, 2002, p. 115-121.

defines it the following way: *"In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."*

This means that if there is a strong suspicion that a certain activity may have environmentally harmful consequences, it is better to act before it is too late than wait until full scientific evidence is available that unequivocally demonstrates a causal connection between the activity in question and its possible impacts. Systematically, the precautionary principle is a sub-category of the prevention principle, which says that is easier to respond to environmentally harmful activities before rather than after they occur, by preventing them.

The precautionary principle **generally justifies action or inaction to prevent damage and avoid potential risks** (in dubio pro natura). In European law, the principle is consolidated in Article 191 (ex Article 174, Treaty on European Union, TEC) in the Treaty on Functioning of the European Union (TFEU). One of its implications is that the European Commission has the right to establish the level of protection of the environment and human, animal and plant health that it deems appropriate[46]. Although the principle concerns risk management, **this does not mean that all risks must be reduced to zero**. Where action is deemed necessary, measures based on the precautionary principle should be proportional to the selected level of protection, non-discriminatory in their application, consistent with measures already taken, based on an assessment of the potential benefits and costs of action or lack thereof and subject to review in the light of new scientific data.

The precautionary principle has also been **applied by the European Court of Justice (ECJ) in its case law**, allowing the EU institutions to take protective measures without having to wait until the reality and seriousness of the risks become fully apparent.

However, the problem is that **NWM constitutes an exception in this regard: the Euratom Treaty, which is the foundation of European nuclear law, is not subject to the application of the precautionary principle or other environmental principles**, i.e., the principles of a high level of protection, the prevention principle, that environmental damage should be rectified at source (the source principle) and the polluter pays principle. Euratom suspends Article 191, paragraphs 1 and 2, in the TFEU. Obviously, this has an effect on how radioactive waste is managed in the EU.

Nonetheless, there is an **exception to the exception**: the "basic standards" mentioned in Article 30[47] and the subsequent articles in the Euratom Treaty's Chapter 3 on Health and Safety are minimum standards (also known as the "minimum harmonisation clause"). Consequently, Member States are allowed to set stricter standards than those laid down in the directives warranted by the Euratom Treaty[48]. ECJ case law seems to require that the consequences of the additional requirement are consistent with the objective pursued by the directive in question. This could mean that the above-mentioned environmental principles, including the precautionary principle, could come into play in the Member States' national legislation.

One of the RW governance regimes, in which the precautionary principle would be a determining factor, is the so-called **rolling stewardship model**. The rationale behind this model is the notion that the criterion that should be applied for the disposal of RW, when there are no known probabilities of future

[46] Commission guidelines on how to apply the precautionary principle: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Al32042

[47] Article 30: "Basic standards shall be laid down within the Community for the protection of the health of workers and the general public against the dangers arising from ionizing radiations. The expression 'basic standards' means: (a) maximum permissible doses compatible with adequate safety; (b) maximum permissible levels of exposure and contamination; (c) the fundamental principles governing the health surveillance of workers." Link to the EURATOM Treaty: https://europa.eu/european-union/sites/europaeu/files/docs/body/consolidated_version_of_the_treaty_establishing_the_european_atomic_energy_community_en.pdf

[48] Case C-376/90 Commission v. Belgium (1992) ECR I-6153 and Jans and Vedder, p. 98-101.

events, is selecting the option, whose worst possible consequences are better than the worst possible consequences of all other options. This would make it impossible to finally dispose of the radioactive waste until there is sufficient knowledge of how to do it in completely safe manner. Ethically speaking, the concept implies a willingness not to choose the immediately easiest solutions, but to make considerations for most other people the highest priority now and in the future.

Rolling stewardship was first mentioned in 1995 in a study by the U.S. National Research Council[49]. At that time, it had a more limited scope than today, planning for stewardship only one generation ahead. The study recommended rolling stewardship as an option for addressing contaminated sites that pose significant clean-up problems and where no technological solutions currently exist.

The concept in its current form is to some degree attributed to Gordon Edwards, who is the president of the Canadian Coalition for Nuclear Responsibility (CCNR) [50]. Broadly speaking, it signifies an **intergenerational management concept requiring monitoring and maintenance of the RW for an indefinite period of time**, with responsibility being passed on from one generation to the next, preserving the possibility of retrieval, recharacterisation and repackaging of the waste. It also requires a mechanism for reinstructing the next generation, which provides detailed information on the nature of the wastes and the associated hazards, ensures the next generation is fully aware of the need to spend time and money on the RW and if necessary, to see that corrective action is taken in a timely way. This process could last until a final safe solution is found which would no longer require constant care and memory.

More specifically, rolling stewardship provides a **framework for a chain of management decisions** that can be changed over time, empowering each generation with greater information on stewardship tools and practices. Instead of focusing on an infinite, unpredictable future, it touches on practical problems that can be solved in the short term with some guarantee of success (NEPI 1999: 4-5). Moreover, it includes institutional control mechanisms that are meant to address among others legal, technical, financial, administrative, and R&D issues (NEPI 1999: 6-8, 16-18, 21-26). Among these are:

Development of overriding principles to guide stewardship activities: common principles might be useful, without insisting that they be implemented the same way in every context. As previously mentioned, the precautionary principle (and the other environmental principles) would be relevant here, after being subject to further definition and interpretation in the light of the situation, to which it is applied, particularly in regard to the time horizon of the issue in question.

Determining guidelines for rolling stewardship activities: e.g., these could be a comprehensive and credible characterisation of the RW, definition and delineation of administrative responsibilities (also in the long term) and proper means of funding, transparency, public participation, access to resources, and monitoring. Such guidelines can result in larger public acceptance of long-term strategies, although there is political pressure to choose short term solutions, primarily for reasons surrounding budgetary pressure.

Dissemination of information: relevant here is, who will be in charge of information on stewardship in a given context and ensure its integrity and passage to future generations?

Promotion of adaption capacity: the notion of adaptability -- that NWM decisions and perceptions of risk should be revisited and improved based on new science or technologies becoming available – could be in conflict with any type of GD. Thus, it is necessary to develop new tools of adaption, including

[49] National Environmental Policy Institute (NEPI): Rolling Stewardship: Beyond Institutional Controls, Preparing Future Generations for Long-Term Environmental Cleanups, December 1999, p. 10: http://nonuclear.se/files/rolling-stewardship-nepi199912.pdf

[50] Gordon Edwards: Comments on Consideration of Environmental Impacts on Temporary Storage of Spent Fuel After Cessation of Reactor Operation, submitted by the Canadian Coalition for Nuclear Responsibility to the US Nuclear Regulatory Commission, Docket ID No. NRC-2012-0246, 2013: http://www.ccnr.org/CCNR_NRC_2013.pdf See also: CCNR: Nuclear Waste: Abandonment versus Rolling Stewardship (undated): http://www.ccnr.org/Rolling_Stewardship.pdf

suitable institutional mechanisms. Investments in new technologies and better science would be needed.

Funding: how should the different aspects of rolling stewardship activities be funded and who should hold and distribute the funds? How can the public be confident that it will not be squandered? Furthermore, the funding must not only support stewardship, but also *rolling* stewardship. There is a difference between addressing problems arising here and now and taking on issues with a very long timeframe. The financing should mainly be based on current spending, through commitments to future spending or through trust funds.

7.2 Input from CS larger group

The main questions put forward to the CS larger group were: what levels of uncertainty could be acceptable from CS perspectives, and which could not? How should they be managed? And more specifically: when comparing current on-going NWM to GD, what would be the most important differences regarding the types of uncertainty and risks entailed by each of these options? Should the precautionary principle be fully integrated into European radioactive waste management decision-making, including regulations at all levels, and be one of the dominant, if not the dominant management principle? And last, but not least: how could rolling stewardship involving CS be operationalised?

When comparing current on-going NWM to GD, the most striking difference was perceived to be the fact that the former due to the timescale is a well-known entity which has existed for more than half a century, whereas the latter is still an unproven technology that has not yet stood the test of time. Every DGR will be the first of its kind. There was also an agreement that there has to be a structure in place for both options – economically, socially and in regard to knowledge - that hands over management of uncertainties and risks from generation to generation. What the next generations want to do is up to them.

Equally, in regard to the precautionary principle, there was a consensus that **regulation of NWM has not much credibility if the precautionary principle is not integrated at all levels of management decision-making**. Legally speaking, RW should not be treated differently from other dangerous wastes, which must also be reflected in European nuclear law. Thus, amendment of the Euratom Treaty to make it more environmentally friendly was not regarded as a controversial, but as a mainstream idea.

Arguments were presented for and against implementation of the rolling stewardship model: the main objection is that rolling stewardship cannot practically be sustained for tens or hundreds of thousands of years. Basically, you take the soundest management principles from long-term interim storage and extend their use indefinitely. If that were to happen, it would put undue burdens on future generations. In reality, the notion of rolling stewardship is more of a political strategy of procrastination and postponement than a realistic management principle. It might come in handy as an argument in situations, where public trust in the ability of the authorities to dispose of long-lived waste is low and there is a need of a safer method of conventional disposal.

Nonetheless, it was argued by many that the notion of rolling stewardship as the least irreversible NWM solution **represents the most appropriate manifestation of the precautionary principle**, because it addresses the problem of collapse of memory and reversibility and retrievability better than any other option. It is also not a thing of the future, considering that it already reflects the current default reality of NWM. The Danish NWM model for transparency, public participation and access to resources (see Section 6.1), could be the first step in a sustainable rolling stewardship. But the people who set up the Danish model are not the same who will be making the decision on final disposal. They are only doing the pre-work.

Similar points of views emerged in most sections of the UMAN CS questionnaire (see Chapter 3), including in the sections on uncertainties on transparency and communication, on the future of nuclear policies, on governance, on trust, on retrievability and reversibility, on human resources, on inventory,

on security, safety and risk assessment, on technology selection, on quality assurance now and in the future, on trans-generational aspects, and on the human factor. The uncertainties identified by the CS group members in the questionnaire related to all phases of NWM, including policy, framework and program establishment, site evaluation and site selection, site characterisation, facility construction, facility operation and closure and post closure.

7.3 Conclusions

To summarise, it was agreed in the CS larger group that there are a lot of common features between the risks associated with current on-going NWM and GD that could be addressed by the precautionary principle, if it is implemented in the NWM decision-making process. The notion of rolling stewardship could be an appropriate manifestation of the precautionary principle, but its long-term practicability has yet to be determined by future generations. It also has to be researched more thoroughly and be brought to the attention of the general public.

8. Conclusions and next steps

This CS UMAN keynote paper presents the results of our work in the first one and a half years in EURAD. It documents the understanding of uncertainties in the CS larger group: what definitions have different CS group members of uncertainty, risk and safety, what are in the view of the CS larger group important uncertainties in different phases of radioactive waste management (NWM) and how should and could CS participate in dealing with uncertainties?

Should there be a hierarchy in uncertainties, are some more important than others? And if yes, who decides about the importance, what “main” uncertainties are? In the CS larger group, no voices were raised for a hierarchy. If an uncertainty is named only in one country or under specific circumstances, this may in the future be of relevance for other countries or circumstances, too. In this first phase of the EURAD project, the goal was to identify uncertainties without any need to rank them.

But in the next EURAD phases, **decisions have to be made concerning what identified uncertainties will be studied further, and what will be outside the scope of the project**. The uncertainties that have been identified in the CS larger group are not completely identical with the uncertainties having been defined in the UMAN working package.

In these conclusions, we first name uncertainty issues that are of special importance to the CS larger group and where we as UMAN CS expert group believe that those topics need further attention in the EURAD project. This does not mean that all the other uncertainties that have been identified are of less importance, but as they have been listed in the work of UMAN subtask 3.1, they should be in the focus of the UMAN team anyway.

Guidance by the precautionary principle

It was agreed in the CS larger group that there are **a lot of common features between the risks associated with current on-going NWM and geological disposal (GD) that could be addressed by the precautionary principle**, if it is implemented in the NWM decision-making process. Regulation of NWM has not much credibility if the precautionary principle is not integrated at all levels of management decision-making. Legally speaking, radioactive waste should not be treated differently from other dangerous wastes, which must also be reflected in European nuclear law.

Unclear future nuclear policies

Not only for members of the CS larger group but also for NGOs working in the field of energy policy and environmental protection, it is of concern that reaching a solution for a DGR now can create a kind of blank check on further production of radioactive wastes.

Some national NWM programmes do not include radioactive waste from possible future NPPs in their capacity planning yet. This would result in the need of a second final repository. But if only one suitable site will be found in the next years or decades, pressure might occur on the then existing DGR to take in all radioactive waste and maybe even be overfilled.

The uncertainties about the future amount of radioactive waste may be out of scope of EURAD, **but the aspect of safety of a DGR in case of overfilling should be considered in EURAD**.

Transparency and public participation (T&PP)

A lot of uncertainties concerning participation were named all along the NWM process by members of the CS larger group. It became obvious that public participation procedures have not been provided yet in the necessary detail. Otherwise CS members would not have named so many uncertainties: who will be allowed to participate, who is seen as affected by NWM, how will the participation in different steps be conducted, will there be resources made available, also for independent expertise? How will decisions be made, will there be the right to veto and who will get it? These questions have high importance to be answered quickly. Good participation practice like the Danish model should be evaluated and pushed.

Participation in EIA and SEA procedures could be better standardised when providing information on uncertainties and lack of knowledge. **A guidance for providing better quality information on uncertainties in the EIA- and SEA-reports would be a helpful result of the EURAD project**.

T&PP and access to justice go hand in hand. One is not complete without the other. This is recognised in the Aarhus Convention, and also in the answers of many CS larger group members.

There is a need to broaden up the scope of EURAD: Transparency of uncertainties is strongly linked to uncertainties of transparency – you cannot have one without the other. It is not enough to be transparent about a technical uncertainty if you have not built trust by using a high-quality T&PP model throughout the whole NWM process.

Different countries have different transparency regimes. Especially difficult is the situation in Eastern European countries. Focus should also be put on missing transparency from private companies engaged in NWM – they should also be subject to the relevant legislation and international Conventions. **EURAD may recommend standards for a transparency regime as an outcome of the project**.

When communicating on uncertainties, the term “risk” instead of “safety” might be the better choice.

Independent regulators, independent expertise

Uncertainties on governance are a major concern for CS members in EURAD. Continued independence of the authorities, especially the nuclear regulators, is a precondition for effective safety case review. Considerable uncertainties are attached to the continuity, availability and integrity of the governance framework (governing institutions and associated expertise) over long periods of time. According to the CS members, this is already problematic at present in some EU member states. Preserving independence of governing bodies cannot only be achieved on a national basis. Safety standards depend on how **democracy** is handled. The role of CS is very important in the upholding of the safety standards. To increase confidence in the system, CS representatives should be involved in the decision-making of the governing institutions and should get the necessary resources for this work. Uncertainty also concerns bribing the public by compensation policies at local level that can impede local inhabitant’s awareness of safety priorities.

Corruption and fraud in radioactive waste management

Corruption and fraud have a long and unfamous history in the nuclear field, in countries all over the world. It is not clear if and how nuclear regulatory regimes are fit to battle corruption and other criminal behaviour among the actors involved in NWM, but also among the regulators themselves. Unfortunately, also the responsible authorities can be corrupt. Who will control the controllers? What mechanisms can

be established to improve this situation? The mechanism of IAEA missions and peer reviews seem not to be enough to reduce the resulting uncertainties. This should be a topic for EURAD.

Security, risk assessment and emergency preparedness and response

CS larger group members clearly prefer the term “risk” instead of “safety”. Many uncertainties were named concerning risk assessment, especially focussing on risk of accidents and the corresponding plans for emergency preparedness and response. Security is an important issue that raises uncertainties if and how intrusions can be prevented, also in the very long-term.

Alternatives and “Plan B”

Geological disposal is often presented as a straightforward option to be implemented in a linear way. The reality of its implementation brings a different picture with some uncertainty on what will actually be implemented in the end. Societal preferences come into play when there are alternative options with different impact on safety. Alternatives options would then be adopted as more suitable, involving lower costs, being safer, or as a result of unexpected circumstances – sudden lack of resources, of political will, war or conflicts necessitating fast implementation – in front of the evidence that the initial plan of disposing geologically the wastes is no longer possible for diverse reasons. It is most important to demonstrate for instance that real alternative options (“Plan B”) have been investigated in parallel to “Plan A”, providing a plurality of choices. Uncertainties are here to stay. One should enter such a process realising that developing a plan addressing uncertainties and risks, will be an organic process that takes time. It is also uncertain, whether it will be possible to find a good alternative during the first try.

The importance of the post-closure phase for CS

When initiating the work in EURAD, six phases were defined used for describing the whole NWM process:

- Phase 0: Policy, framework, and program establishment
- Phase 1: Site evaluation and site selection
- Phase 2: Site characterization
- Phase 3: Facility construction
- Phase 4: Facility operation and closure
- Phase 5: Post closure

But during 2020, this list of phases was changed. Now the following phases seem to be used:

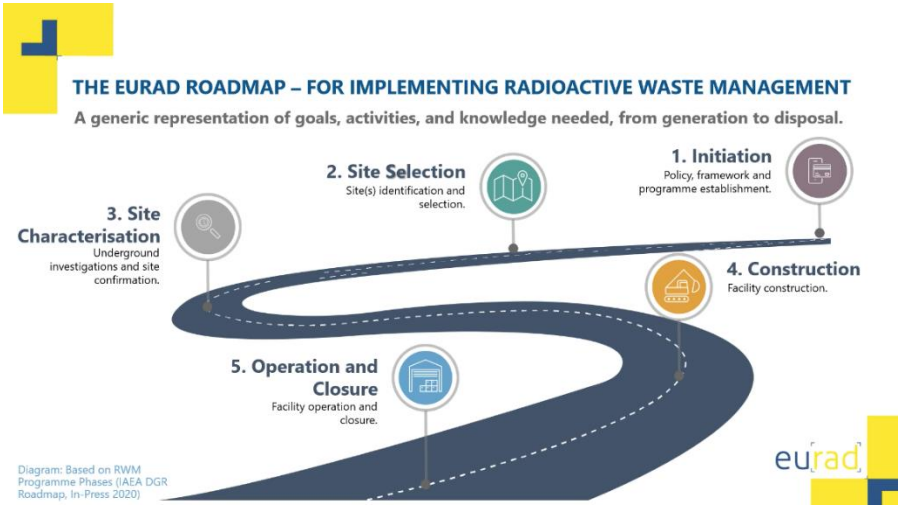

Figure 8: This figure was presented in the Introductory Course on EURAD on 2020-09-14.

The post-closure phase has been taken out of the picture, even if the road in the figure signals that it is not out of the way, only out of view (and it is a very long part of the road that is out of view). When asking in the Introductory Course in Sept. 2020 why the post-closure phase has been skipped, the answer was

that "*the post-closure phase is at the heart of the safety case and therefore considered throughout all the phases preceding it.*"

This leaves a lot of questions open. First, the post-closure phase is still not a properly defined issue: how long should an active and a passive monitoring phase last after closure? Should retrievability and recoverability of radioactive waste be possible and if so, for how long? If these important questions are subsumed under other discussions, they might be postponed or even neglected which is not in the interest of CS experts.

Second, there is no common understanding yet if future generations should be warned about the DGR and, if so, how they can be informed. Even if there is a will to inform them, it is not clear how this can work over several 100,000 years or even longer. **The post-closure phase needs to be defined and researched in the scope of EURAD.** The length of the post-closure phase should not be set by the end of the license validity!

Third, the members of the CS larger group named a lot of uncertainties in the post-closure phase (see especially chapter 3.2.2.17). It is yet unclear, if they will be considered in EURAD and if work will be undertaken to reduce these uncertainties. The CS expert group will monitor what will happen with uncertainties related to the post-closure phase in the following years of the EURAD project and bring them into discussion whenever necessary.

Rolling stewardship models have to be researched.

According to the members of the CS larger group, the notion of rolling stewardship as the least irreversible NWM solution **represents the most appropriate manifestation of the precautionary principle**, because it addresses the problem of collapse of memory and reversibility and retrievability better than any other option. However, its long-term practicability has yet to be determined by future generations. It also has to be researched more thoroughly and be brought to the attention of the general public.

Next steps

A main objective of the UMAN Work Package is to develop a common understanding among the different categories of actors (WMOs, TSOs, REs and CS) on uncertainty management and how it relates to risk & safety, but without necessarily mitigating all differences in the views of the different groups.

In this sense we are going to discuss this keynote paper with the CS larger group members during the autumn of 2020, and also send it to UMAN members.

Appendix: UMAN CS Questionnaire

CS-QUESTIONNAIRE IN PREPARATION TO THE Interaction with Civil Society (ICS) UMAN Working Group SESSION

Name:

Organization:

Country:

1. **Six phases for the backend of high-level waste management have been defined in the EURAD project. Please indicate for each phase the most important uncertainties from your perspective.**

	Important uncertainties from Civil Society's perspectives
Phase 0: Policy, framework and program establishment	
Phase 1: Site evaluation and site selection	
Phase 2: Site characterization	
Phase 3: Facility construction	
Phase 4: Facility operation and closure	
Phase 5: Post closure	

2. **Please give us your feedback on the presentation of Bernd Grambow from 6 May 2020 who informed you about results of the UMAN (task 3) questionnaire.**

- What is your overall feedback on the presentation of the UMAN-questionnaire?
- What are the 3-5 uncertainties from the views of Technical Support Organisations (TSO), Waste Management Organisations (WMO) and Research entities (RE) that you agree with and why?
- What are the 3-5 uncertainties presented from the views of TSO, WMO, RE that you do not agree with and why?

3. **In the discussion on which uncertainties should Civil Society primarily participate?**

Appendix B. UMAN Seminar 3 Terms of references

European Joint Programme on Radioactive Waste Management

Terms of reference
UMAN Seminars

In order to ensure fruitful discussions in mutual respect, it was suggested to elaborate terms of reference that will be agreed by all the participants in the UMAN Task 5 seminars. These terms of reference establish a set of prerequisites to attend the seminar, notably based on elements of the procedure for establishing the group of CS representatives involved in EURAD that have been validated by the EURAD PMO and Bureau.

1- The participants in the UMAN seminar will have to support the EURAD vision hereunder and commit to contribute constructively to the exchanges that will take place in EURAD, respecting the goals of EURAD described hereunder:

EURAD vision:

"A step change in European collaboration towards safe radioactive waste management (RWM), including disposal, through the development of a robust and sustained science, technology and knowledge management programme that supports timely implementation of RWM activities and serves to foster mutual understanding and trust between Joint Programme participants"

EURAD goals:

- "Support Member-States in developing and implementing their national RD&D programmes for the safe long-term management of their full range of different types of radioactive waste through participation in the RWM Joint Programme;
- Develop and consolidate existing knowledge for the safe start of operation of the first geological disposal facilities for spent fuel, high-level waste, and other long-lived radioactive waste, and supporting optimization linked with the stepwise implementation of geological disposal;
- Enhance knowledge management and transfer between organisations, Member States and generations."

2- The participants in the UMAN seminar recognize that the objective of the seminar is to foster a common understanding or understanding of the different viewpoints among the different categories of actors on the management of uncertainties associated with the management of radioactive waste and how it relates to safety.

3- It is not intended to reach a consensus. Rather, the discussions during the seminar will seek to allow for a nuanced understanding of the issues at stake and a better understanding of the arguments of the various participants, without prejudice to their position with regard to a particular option.

4- The seminar will promote the clarification of the implicit elements leading each actor to establish his choices and preferences, while creating a climate of mutual listening and respect for the views of each participant. The discussion will be based on a freedom of expression of views. The plurality of categories of participants, or at least a plurality of views, experiences and professional profiles, is therefore desirable to foster an in-depth discussion that takes into account a wide range of issues.

5- The animation of the seminar will require pluralistic and transparent governance, i.e the organisation of the seminar and the facilitation of the discussions will be done by a pluralistic team gathering representatives of different categories of actors (WMO, TSO, RE and CS).