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Strategic Monitoring - A Proposal for the Institutional Surveillance of Complex and Long-Term Nuclear Waste Disposal Programmes

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Abstract

Deep geological repositories for nuclear waste objectively are a long-term issue (regarding long-term safety) and require long-term institutional involvement of the techno-scientific community, the waste producers, the public administration, non-governmental organizations and the general public. The demonstration of their long-term safety is avowedly very challenging and monitoring techniques may contribute to substantiate evidence, support decision making and legitimate the programme [1]. What, where and when to monitor is determined by its goal setting. Therefore monitoring may be operational, confirmatory (in the near field) or environmental (in the far field). Strategic Monitoring, as proposed in this paper, may contribute to process, implementation or policy and institutional surveillance. The "preservation of records, knowledge and memory across generations" as labelled by the corresponding Nuclear Energy Agency, NEA initiative should encompass the tailored transfer of knowledge [2], concept and system understanding, insights, experience and documentation to specific audiences such as above. Strategic Monitoring is devised to be an integrative tool of targeted yet adaptive management. It is applicable to other long-term sociotechnical energy-resources-environmental fields such as Carbon Capture and Storage, CCS or (conventional) special toxic waste. The proposal is based on extensive empirical work in all three fields of application - as documented - but meant to be a conceptual framework for further/new empirical studies in precisely "strategic monitoring".

Keywords: Deep geological repositories; Institutional surveillance; Long-term governance; Radioactive/nuclear waste; Strategic monitoring; Technical and social robustness

Setting the Problem(S)

(High-level) "nuclear waste management has the deserved reputation as one of the most intractable policy issues facing the United States and other nations using nuclear reactors for electric power generation" this 20-yearold quotation is still valid and no corresponding repository has been built yet worldwide. Radioactive waste management was called a "wicked problem" though "messy" may be a more adequate term: Such problems are complex, ill-defined or ill-structured, their framing is difficult and there is a lack of stopping rules (no "closure" - no "solution"?). "Ill-defined" is meant in the sense that there is not one silver-bullet or standard solution but there are, e. g., many (national) solutions [3-5].

Dealing with a complex sociotechnical system such as the disposition of radioactive waste needs an integrated perspective. Much of the widespread blockage faced in this sensitive policy area may be ascribed to the neglect of looking at the various dimensions involved. This multidimensionality requires an appropriate reference system. Normatively, the principle of sustainability (incorporating protection as well as control) seems to suggest itself, for two reasons. Firstly, it facilitates a stepwise analysis according to various dimensions: not only the triad of ecological, economical, and social but also temporal, spatial, technical, political, and ethical [6,7]. Secondly, it forces upon stakeholders, including decision makers, an examination of these dimensions and, consequently, it is apt to incorporate all/most parties' perspectives, needs, targets/goals, and knowledge systems [8] (Table 1).

The long-term objective (ecological) dimension of highly toxic waste is of outstanding ethical relevance: The ones who make the profit (e. g., of energy of which waste is a result) most likely do not bear - possible - risks from the waste (Fig. 1). The decisional situation is such that the current generations (we!) have to decide (postponement is also a decision), and: Apart of winners (this waste producing society) there will be losers (locals and future generations). This is a formidable risk-benefit asymmetry. To be able and competent to handle such complex issues needs an adequate tool - we propose to introduce a Strategic Monitoring for this purpose.

On the Evolution of Concepts

Sixty years ago, it was proposed to bury radioactive waste in deep geological formations [9,10] - a pioneering idea, bearing in mind that industrial waste, at the time, was usually dispersed and diluted. Forty years ago, final disposal, without the intention of retrieval, was favoured - consistent with the insight to rely on natural and passive barriers, instead of institutional barriers, due to the long toxic potential of radionuclide's [11-13]. Thirty years ago, as to knowledge management, the sole issue remained to preserve adequate information for future generations to keep them from inadvertently boring into the underground facility [14-16] (Figure 1 and Table 1).

During the 1990s the technical community gradually realised that a "repository is, by definition, a long term project, extending over centuries … or even much longer periods for repositories in deep geological formations, receiving [high-level waste, HLW] with long

Table 1: Relations (and hierarchy) of consensus and dissent at diverse levels. The middle region is amenable to good chances for some "common ground", being above the non-negotiable core beliefs and below practical project management where a compromise is best to achieve (source: (20):214).

Level	State of agreement	Perspective/goal/fields (examples)
Secondary beliefs		
Implementation (dependent on policies, funding, authority)	Compromise	"Real" project/site
Procedure/methodology	Consensus	Siting, monitoring
Roles, decisions (instrumental and institutional goals)		Performance assessment, quality assurance, inclusive reviewing
Protection goals (passive protection, active control, involvement, power of decision) (= "success criteria")	Consensus	Safety and control goals
Factual constraints	Consensus	Waste existent
Concept of sustainability	Compromise ("weak" sustainability (19)[a])	Practical trade off of dimensions (technical and social goals)
Core beliefs		
Attitudes of stakeholders	Dissent	Pro- *vs.* anti-nuclear
Models of rationality	Dissent	Technocentric/anthropocentric *vs.* biocentric or even ecocentric worldview

[a]"Weak" sustainability allows for substantial substitutability of resources.
Where to possibly reach "common ground" and where not.

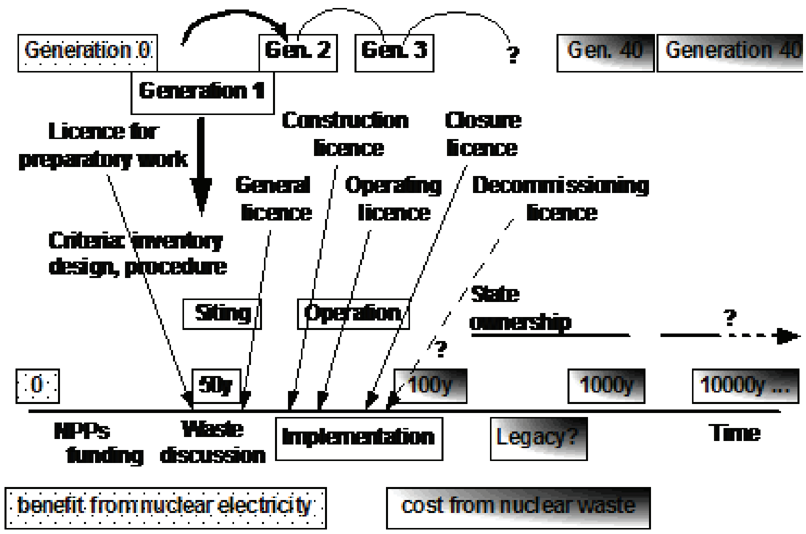

Figure 1: Radioactive waste governance has a long-term safety and a long-term project character. It must be backed up by the technical community, the political decision makers and the general public over decades. While still benefiting from nuclear electricity we, at present, are "Generation 1" having to start implementing the respective programmes. Some duties - of monitoring, etc. - must be handed over to "Generation 2" (explored in [17]). Information procedures and knowledge management play a pivotal role in success or failure of the undertaking (Source: [18]).

Time dimensions of radioactive waste disposal.

lived radionuclides. A repository project involves a relatively long lead time (possibly more than 20 years for HLW or spent fuel) and is then anticipated to receive waste during several decades. After closing the repository, a surveillance and monitoring period will almost certainly be carried out even [sic!] for shallow land burial type repositories with [low- and intermediate-level waste]. This underlines once again the importance of the continuity factor not only from a contractual but also from a technical point of view (possibility/obligation to transfer/receive waste, waste acceptance criteria and quality of waste, control and monitoring, etc.). On the other hand, continuity is of equal importance for the proper functioning of the cost sharing arrangements and the respective payments" [21]. Still valid today, the "official" philosophy holds "… the disposal concept requires that the presence of waste may safely be forgotten, after a period of institutional control to prevent early inadvertent intrusion" [22].

Having said this, it, nevertheless, is by no means an advocacy of perpetual surveillance. For analyses of institutional monitoring of radioactive legacies in the USA demonstrate in frustrating openness: "It is now becoming clear that relatively few … [Department of Energy, DOE] waste sites will be cleaned up to the point where they can be released for unrestricted use. 'Long-term stewardship' (activities to protect human health and the environment from hazards that may remain at its sites after cessation of the remediation) will be required for over 100 of the 144 waste sites under DOE control …. The details of long-term stewardship planning are yet to be specified, the adequacy of funding is not assured, and there is no convincing evidence that institutional controls and other stewardship measures are reliable over the long term" [23]. Strohl was of the opinion in 1995 already: "… institutional instruments, although indispensable with regard to long-term safety, should only be considered as making a contribution of relative importance and of limited duration, and this must be made clear" [24]. This perspective has been maintained ever since [25].

The predicament is to find an adequate tradeoff between long-term passive safety with respective confidence in performance assessments and active control based on a suitable institutional constancy, both to be decided by the present society, with due respect for the environment and societies to come. The societal aspects go far beyond considering local interests (unlike asserted in [25]). To create - at least attempt - such robust bonds over many, many years, is the aim of this contribution, a proposal for Strategic Monitoring (Table 2).

Basic Rules and Procedure to Follow

The nuclear community recognises that the long-term safety of repositories "is not … a rigorous proof of safety ... but rather a convincing set of arguments" [39]. It has, however, been difficult to "live" its sociotechnical nature [40]. Albeit the waste problem is driven by technology and, indeed, a technological constraint, in the end, it has to be solved by society. Building upon the defence-in-depth principle, the concept of integral, technical and societal, robustness was developed [41]. A system is "socially robust" if most arguments, evidence, social alignments, interests, and cultural values lead to a consistent option [42]. The concept attempts to consider technical and social issues in parallel, as to force players (both from the technical community and society) to keep in mind (and strive at) an integrative "solution", satisfying technical (passive safety) and societal needs at the same time. This combination sets it apart from other approaches, either purely technocratic along the conventional decide-announce-defend line or the voluntaristic policy some national programmes have reverted to in

Table 2: Criteria (normal)and respective attributes (Italics) to monitor and evaluate institutions for an appraisal of governance and other theoretical concepts (bold) in order to develop Strategic Monitoring. Example: A national disposal programme may rely (persist) on a concept of the 1980s (steel canisters; path dependence) and invest only little money in alternatives such as ceramics (research financing) (own tabulation, work in progress).

Area	**Approach/concept**			
	"Good" governance	**Regulatory (and other) capture**	**Safety culture**	**Path dependence, lock-ins**
References	[26-28]	[29-31]	[32-35]	[36-38]
A. Formal (system) structure	Legitimation	Asymmetry	Continuous system learning	Persistence
	Legislation: goal, time frame, players, boundary conditions, etc.	*Research & development plan*	*Code of conduct, guidelines, etc.*	
	Degrees of participation by players/stakeholders	*Resources (staff, financial)*	*Feedback from staff and stakeholders*	*Research financing*
	Goal orientation, effectiveness and efficiency	*Competence(s) and experience*	*Education, permanent training; team learning*	*Review organisation*
	Degree of consensus, inclusiveness, capacity building	*Expert blocking*	*Organisational learning*	
	Rule of law			
B. Understanding of roles	Division of roles	Institutional analysis	(Senior management) commitment	Openness of decision making
	Programme tasks	*Interrelations with other players*	*Leadership*	*Comparison of options*
	Strategic planning	*Structure analysis*	*Employee involvement*	
	Responsibility			
C. Internal (organisational/ personnel) structures	Transparency Accountability Equity	Mental models	Failure culture	Resistance *vs.* innovation
	Justification of decisions	*Recurrent key statements*	*Openness of communication, culture*	*Mechanism of selection*
	Framework and respective guidelines	*Terms of reference, code of conduct*	*Trust*	*Components of self-reinforcement*
	Controlling: target analysis	*Performance analysis*	*Compliance analysis*	
	Responsiveness	*Agenda analysis*	*Incident reporting*	
	Quality management		*Complacency*	
	Reviewing		*Norms, values and basic assumptions*	

Evaluation aspects for strategic monitoring.

the face of the failed technocratic approach (e. g., Sweden, Japan, UK, USA) or any unsystematic negotiated mixed versions [43,44]. Based on international experience [17,20,45], we proposed a 3-step approach for a site-selection procedure, followed by a proposal for an integrative assessment framework (cf. [46]):

- Step 1: Discuss - comprehensive societal discourse

- Step 2: Decide - "common ground" in goals and stepwise strategy

- Step 3: Implement - start programme and prepare long-term knowledge basis

The rules and criteria of site-selection procedures have to be consented to before the start and adhered to during the process. Revisions should undergo a careful review and be consented to. A clear distinction between implementer and regulatory bodies is vital. The regulators must establish a platform for inclusive knowledge generation, based on a (pre)defined set of criteria. This necessity to integrate different requirements, the step-by-step approach, the chance of "institutional constancy", and the in most countries perceived "national" task of the issue call special attention to the role of the authorities [47]. Issues like regulatory capture, expert blocking, or technological lock-ins have to be duly considered (Table 2).

In view of a successful transfer of knowledge, it is vital to explore contextual issues and tacit/implicit knowledge - they determine the degree of societal understanding of the eventual disposition system. Unless the rationale of conceptual reasoning is appropriately handed over to next - technical, political and societal - generations, the entire undertaking is bound to fail [48].

Back in 1984 Parker et al. concluded that, in the end, one can only "… try to develop as broad a consensus as possible in support of the solution that is finally reached. It has to be recognized that there will always be an irreducible amount of uncertainty in the outcome of any solution" [49]. Over thirty years ago, Luther Carter called in to find "a common ground" in managing radioactive waste yet without specifying [50]. By focusing on "common ground", rather than "consensus", it has to be emphasised that it is not intended to call for as many voices but for as many perspectives as possible so as to incorporate all relevant facets in the dimensional discourse: ethical, technical, ecological, economical, political, societal, spatial and temporal. Consensus, at that, would probably amount to majoritarian deliberation anyhow [51]. This is not to avoid the issue of representativeness or, by no means, to devitalise claims for wider participation, but to focus on a dimensional discourse as inclusively as possible. In view of this multidimensionality, it is also an avenue to find society's way to some sort of sustainable "closure" of the issue [52]. On this background, it is useful to specify what might be understood by "common ground". Trying to decompose ever-used buzzwords like "consensus" or "compromise" one may outline where and how "common ground" is likely to be achieved (Table 1). It cannot be assumed to reach consensus "at heart", in the stakeholders' core beliefs [53]. Society must, however, agree on three levels [20]:

- Problem recognition: The waste exists; the problem must be tackled, eventually "solved", at least set on track to be solved;

- Main goal consensus: The degree of protection and intervention must be defined; according to the scientific consent passive safety must prevail;

- Procedural strategy: The "rules of the game" (to find a suitable site and to implement disposal) have to be clear from the outset.

The involvement of stakeholders means to consider as many relevant perspectives (not necessarily as many individuals as possible). Pros and cons must be thoroughly scrutinised, to successfully "close" certain issues, and proceed to the following step, stage or phase.

The long-time process has to be overseen, e.g., by a widely credible and trustworthy body. In 2002, Flüeler suggested a "National Council for the Safe [and Secure] Governance of Radioactive Waste"as the guardian of the process [41], the Swiss expert committee EKRA foresaw a "Disposal Council" [54]. It should be pluralistically composed, independent of the industry yet knowledgeable and not driven by daily politics. A periodic policy evaluation is vital to assess whether a programme is on track (see e. g., [55]). Some respective criteria to develop a Strategic Monitoring are suggested in Table 2. They are based on extensive technical and institutional analyses, e. g., [7,8,20,41,46,68,69,70], the development of the concept of integral robustness[7,20,41], and a thorough consideration of procedural and agent aspects [17,18,43,44,45,47].

Conclusion

Dealing with persistent complex sociotechnical systems - and long-term energy regimes are such - requires acknowledging some basics [7,41,20]. It

- Needs an integrated perspective: It is not sufficient to "solve" subtopics and to subsequently add them up;

- Is "transscientific" in nature. We are reminded of Weinberg's dictum that questions "which cannot be answered by science" are "trans-scientific" [56]; thus it

- Can only be decided on by society. This does not diminish the role of experts, science and research - to the contrary, they are more challenged than ever in the sense that the issue

- Is transdisciplinary. Such research goes as far as "to make the change from research for society to research with society" [57];

- Is often a transgenerational issue (the risk situation and project management mentioned?

- Has to be transpolitical (to overcome ephemeral politics such as NIMTOO effects = Not in My Term of Office).

To consider both technical and social issues needs an inclusive, systematic and participatory approach to single out goal priorities (presumably with safety first). Setting up a respective process is a prerequisite to proceed in site selection (and further programme steps). It is essential to have a (national) lead agency in conjunction with a clear division of roles among the players, rules of the "game" and criteria to judge. The proposed oversight body surveils the programme and its focused implementation. The complex and long-lasting procedure necessitates extensive resources on all sides and of all types over time.

Our society's success in credibly addressing intragenerational issues might convince future generations to be willing to carry on the programmes when needed. According to the concept of social robustness, the concerned and deciding stakeholders must achieve consent on some common interests, at least on three levels: the problem recognition, consensus on the main goals, and the procedural strategy ("rules of the game") [17]. As to knowledge transfer, the challenge is to ensure a continual process so that the broadly consented goals can be understood, agreed to and followed by generations to come.

It has become clear that the institutional aspects are more and more getting to be the linchpin of the issue - and maybe of the solution:

- The long-lasting and entwined project character rests on the constancy of competent and trusted institutions;

- Society may only exert indirect control on such complex technological projects as the one at hand, via institutional paths

[58,59,60]; the main quality check in science, at that, is institutional peer reviewing [61,62,63];

- The public appraises technologies, thus nuclear, as a whole, including the respective institutions and their achieved "degree of safety" as Vlek & Stallén put it [64,65];

- The debate on risks is also a debate on democracy and progress, it is sparked off by the "controversy over the institutionalisation and regulation of the progress of technological knowledge" [66]; Kasperson and colleagues went so far as to coin the "risk crisis" to be truly an "institutional crisis" [67].

The broader the societal agreement on key issues is (e.g., what is the main goal of a programme, what are complementary goals? Where is consensus, where dissent, where compromise? How safe is safe enough? When shall monitoring be terminated, on what grounds?) The more valuable - "robust" - and useful is the social-pool [68], and, at that, also the technological, resource the future generations can draw from. Strategic Monitoring may serve to cover the mentioned aspects in radioactive waste governance. It is planned to apply the concept to other long-term sociotechnical policy fields such as Carbon Capture and Storage, CCS or (conventional) special toxic waste [69,70,71].

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