„Nuclear Waste: How to Handle our Legacy to Future Generations"

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Abstract

The fact that nuclear waste and the problems involved with it are and need to be passed on by the polluters and today's society to those coming after us, is well-known. However, the targeted strategy of final or deep storage in specially designed mines leads to a shift of responsibility to countless future generations. Not only humans and the biosphere must be protected from the radioactive inventory in the repository, but any underground repository itself must also be protected against human interference over an inconceivably long period of time. For even a once installed repository can always be re-opened by future generations, for whatever purpose. This double legacy left behind by only two generations, which benefited from nuclear power, is affecting numerous future generations with the burden to technically handle the radioactive waste safely. Even more, it also requires an enormous social commitment of the affected societies over unimaginably long storage periods. The long-term conflict potentials have hardly been discussed so far. These and possibilities to control it from today's point of view will be highlighted in our lecture.

Key Words*: Basic challenges of nuclear waste disposal: legacy, social and technical defiances, risks and possible approaches in the organization and handling of a long-term risk-project*

Anyone who raises the question of how to hand over to future generations the radioactive legacy, which is primarily due to the production of bombs and their Siamese twin, the peaceful use of atomic energy by nuclear reactors, can immediately realize the enormity of this task. For decades, several generations have benefited from the electrical energy produced by nuclear reactors without a single project for the "care-free" management of the waste produced in the process having been successfully implemented. The interest of the beneficiaries in the consequences of their actions is usually small. Our societies simply accept this waste as an unalterable fact and remain silent or optimistic in their search for solutions for the disposal of the waste in the geological underground. A glance at the estimated storage periods clearly shows the dimension of this problem: we are talking about periods of time which are several times longer than the lifetime of the species "homo sapiens", and which should be respected by insuring that no harm is done to man an environment (Fig. 1).

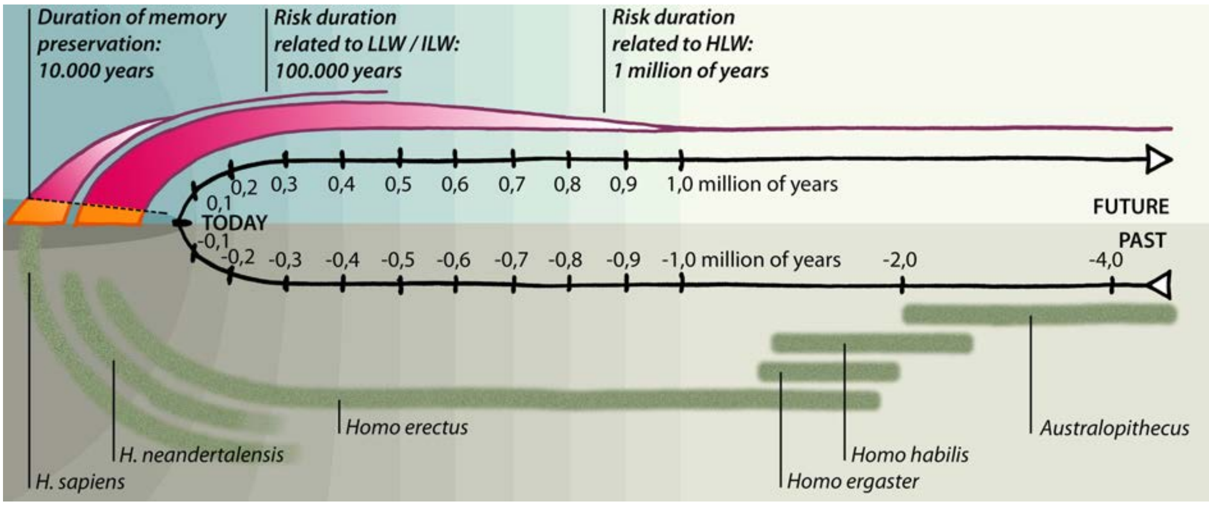

Figure 1: Timescales of risk duration (100’000 to 1'000'000 years) and memory preservation (10’000 years)

1. How trust is lost

The responsible physicists, scientists, developers and also decision makers knew about the danger and the longevity of atomic ashes. Anyone looking at how society has dealt with radioactive waste over the last seven and a half decades will therefore have to ask a number of fundamental questions about the institutions responsible. For the conclusions about the handling of these long-term hazardous substances are shattering:

Vast areas in the world have been polluted by bomb testing and fallout, specially between the forties and the nineties of the last century for periods exceeding thousends of years;

Vast areas in the world around uranium and plutonium facilities and reprocessing plants have also been severly polluted, also by severe accidents – and that for periods exeeding thousands of years;

Vast areas in the world as well have been equally severly polluted by mine activities.

Those areas became almost inhabitable.

The radioactive waste management failed. Today, we should better speak of nuclear waste miss-management if we consider the so-called solutions implemented during decades: all type of wastes – including high-level waste – had been diluted in rivers or dumped into the sea, disposed off through huge filtration basins, ponds, disposal trenches, cribs, or simply injected in former oil- and gas-boreholes etc.etc.etc.

All these areas can be considererd zones sacrified to nuclear experiments. The example of the American plutonium factories in Hanford is representative of the hair-staking practices of the time. The factories diluted their wastes into the Columbia River, deposited them in countless trenches and cribs on the site. The sludges with highly radioactive wastes from the plutonium extraction were majorly stored in single-shelled steel tanks with large storage capacities. [1]

The radioactive contamination of the area in the following decades reached gigantic proportions. [2] Meanwhile, the American Department of Energy (DOE) is trying to secure the site, dismantling buildings and collecting wastes as far as possible. These cleanup activities will extend well beyond the year 2050. The remaining costs of the cleanup operations are estimated to excel the astronomic sum of 110 billion dollars. [3] At the same time, the disposal of the restored wastes has not even been taken into account.

Hanford is often referred to as the most radioactively contaminated site in the western hemisphere. In the eastern hemisphere, the grounds of Majak are considered to be a counterpart to Hanford. But these plants and areas are only the peaks of a problem that is, as far as possible, banished from human consciousness. Wherever you look, regarding the treatment and disposal of nuclear waste similar disregard for environmental protection arise. Deficiencies and risks of the entire disposal system are becoming increasingly apparent, even in the so so-called most successful method of deep geological storage in mines, intended to concentrate the radioactive legacy.

Significantly, all three repository projects that have been implemented so far failed or got serious difficulties. In the final storage facility for low- and medium-level waste (SMA) in the former West-German salt mine Asse, groundwater penetrates into the mine through the flank of the salt diapir. Although the quantities are still low and constant with some 14 m^3 of water per day, the water inflows are menacing. The whole mine could therefore be flooded.

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[1] Nucleonics (1955): How Hanford Discards Hot Equipment, Nucleonics 13, May, 1955, p. 32-33; Pearce, D.W., Linderoth, C. E., Nelson, J. L., Ames, L. L. (1959): A Review of Radioactive Waste Disposal to the Ground at Handford, Monaco Conference 1959, Vol. II, Conference proceedings International Atomic Energy Agency, Disposal of Radioactive Wastes, p. 347-363; Honstead, J.F., Foster, R. F., Bierschenk, W. H. (1959): Movement of Radioactive Effluents in Natural Waters at Hanford, Monaco Conference 1959, Vol. II, Conference proceedings International Atomic Energy Agency, Disposal of Radioactive Wastes, p. 388-399; Lipschutz, Ronnie (1980): Radioactive Waste: Politics, Technology and Risks, Union of Concerned Scientists; Stenehjem Gerber, Michele (1992/2007): On the Home Front, The Cold War Legacy of the Hanford Nuclear Site, University of Nebraska Press, Lincoln and London, p. 374, 120, 122, 137, 149;

[2] DOE (2014): 2015 Hanford Lifecycle Scope, Schedule and Cost Report, Department of Energy, Richland Operations Office, December 2014, p. I-6; DOE (2017): Hanford Site, Office of Environmental Management, https://energy.gov/em/hanford-site (17. August 2017); Lipschutz, Ronnie (1980): Radioactive Waste: Politics, Technology and Risks, Union of Concerned Scientists, p. 114-117.

[3] Annette Cary, Tri-City Herald, Nuclear-Nightmare: Hanford Cleanup Now 112 Billion', 9. February 2012 (https://limitlesslife.wordpress.com/tag/nuclear-nightmare-hanford-cleanup-now-112-billion/); Annette Cary, Tri-City Herald, $107.7 billion needed to finish Hanford cleanup, 22 February 2016, (http://www.tri-cityherald.com/news/local/hanford/article61912837.html);

Scientists warned against this scenario. Warnings by scientists of such a scenario were not taken seriously into account by the responsible institutions and persons until the incidents occurred.[4] It is ironic and embarassing that the Asse mine has been regarded for many years as the model repository by the International Atomic Energy Agency as well by many national waste disposal organizations in the world (Fig. 2).

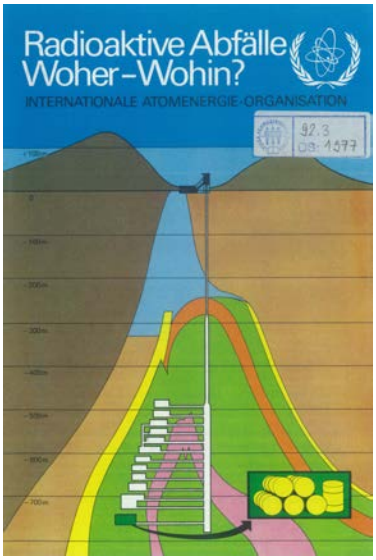

Figure 2: Failed Disposal Project „Asse" - the model encouraged by the IAEA in 1977

The example of the Asse mine shows the basic patterns of todays "safety cultures": the systems responsible for the planning and execution of repositories ignore warnings consistently and systematically. This behaviour is seen in many failed projects, as well for many projects currently underway, where once decisions of project management are defended by all soils against doubts and new findings. In the case of the Asse mine, the failure of the project is also caused by fundamentally incompatible strategies: the final disposal of waste in a mine designed for salt winning. [5]. Some authors called this unfortunate amalgamation a "foundation dilemma".[6] Cost considerations and the prevailing pressure of the responsible administration became determinant.

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[4] Jürgens, Hans-Helge (1979): Atommülldeponie Asse II: Gefährdung der Biosphäre durch mangelnde Standsicherheit und Ersaufen des Grubengebäudes, 1979; Bündnis 90/Die Grünen Niedersachsen (2012): Abschlussbericht Parlamentarischer Untersuchungsausschuss zum Atommülllager Asse II, Niedersächsicher Landtag, 15. 10. 2012, https://www.fraktion.gruene-niedersachsen.de/fileadmin/docs/fraktion/infopakete/Asse_Abschlussbericht-PUA_21.pdf, p. 70.ff.; Ipsen, Detlev, Kost, Susanne, Weichler, Holger (2010): Analyse der Nutzungsgeschichte und der Planungs- und Beteiligungsformen der Schachtanlage Asse II, Endbericht, Universität Kassel, 8. März 2010, p. 15, 45, 47, 52, 59, siehe http://www.uni-kassel.de/fb6/AEP/pdf/Endbericht_Asse_II.pdf

[5] Ipsen, Detlev, Kost, Susanne, Weichler, Holger (2010): op. cit., p. 21; siehe auch Möller, Detlev (2007): Endlagerung radioaktiver Abfälle in der Bundesrepublik Deutschland, Studien zur Technik-, Wirtschafts- und Sozialgeschichte, 15, Peter Lang, Internationaler Verlag der Wissenschaften, p. 199.ff.

[6] Ipsen, Detlev, Kost, Susanne, Weichler, Holger (2010): op. cit., p. 20, 71;

Planning and implementation errors led to serious accidents in the two other repositories: the second German repository Morsleben in the former GDR[7] and the final repository for transuranic waste from the military production of fissionable nuclear materials - the Waste Isolation Pilot Plant (WIPP), New Mexico. [8] In both cases, elementary safety principles were violated. In the case of the WIPP, a decay of safety culture ensued, leading to accidents and operational interruptions during several years.[9] The accidents in the WIPP, which has been considered by the nuclear community as a lighthouse project for over a decade, also puts into question the very concept of final disposal.

In spite of these failures, the search for repositories continues obliviously in the same pattern, whether in Sweden, [10] Finland[11], France[12], Switzerland or, more recently, in Germany. [13] This is evidently logical. No other concept or technology has been developed yet to treat the waste in order to reduce harm. Transmutation ist not working at this levels and is far too expensive. And a indefinite storage is simply not acceptable from the ethical point of view. Thus, deep geological disposal is not the best solution, but just the least worst pathway to deal with this radioactive legacy: the nuclear waste dispersed in the environment and emanating from nuclear facilities and cleanup processes. Long-term safety of underground disposal is demonstrated by a so called "safety-case" – which is nothing but a black-box of assumptions, models, algorithms and calculations that always leads to the conclusion that radiological standards are respected at every time over the very long disposal process of one million of years.

The responsible institutions for deep underground storage repeatedly claim that "political opposition, not technical hurdles, poses the biggest challenge to finding permanent storage sites for deadly radioactive material." [14] As we have seen, these "technical hurdles" are precisely the real challenges. The promises made by the operators of these facilities on the technical feasibility, the reversibility of decisions and the long-term safety, have not been hold in the past, which feeds distrust in the local populations.

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[7] Bundesamt für Strahlenschutz (2009): Plan zur Stilllegung des Endlagers für radioaktive Abfälle Morsleben, p. 156.ff

[8] Alley, W., Alley, R. (2013): To Hot Too Touch – The Problem of High-Level Nuclear Waste, Cambridge University Press, p. 156, 157; Mora, Carl J. (1999): Sandia and the Waste Isolation Pilot Plant 1974 – 1999, Sandia National Laboratories Albuquerque SAND99-1482, p. 35-38.

[9] Butler, Declan (2014): Call for better oversight of nuclear-waste storage, Nature, Vol. 509, 15 may 2014; Buser, Marcos (2016): op. cit., 47.ff.

[10] Ozharovsky, Andrei, Kaminskaya, Maria (2016): Radioactive waste and spent nuclear fuel: Public involvement in radioactive and nuclear waste management in Sweden and Finland, Bellona, August 9, 2016, http://bellona.org/news/nuclear-issues/radioactive-waste-and-spent-nuclear-fuel/2016-08-21710

[11] Gibney, Elizabeth (2015): Why Finland now leads the world in nuclear waste storage, Nature, 2 december 2015

[12] Butler, Declan (2010): France digs deep for nuclear waste, Nature, 10 august 2010;

[13] Buser, Marcos, Walter Wildi, diverse Beiträge auf www.nuclearwaste.info.

[14] The Swedish National Council for Nuclear Waste (2016): Nuclear Waste State-of-the-Art Report 2016, Risks, uncertainities and future challenges, Translation of SOU 2016:16, Stockholm 2016, http://www.government.se/49bbd2/contentassets/ecdecd2ee26c498c95aaea073d6bc095/sou-2016_16_eng_webb.pdf ; Oroschakoff, Kalina, Solletty, Marion (2017): Burying the atom, Europe struggles to dispose of nuclear waste, Politico, 19/21 July 2017, http://www.politico.eu/article/europes-radioactive-problem-struggles-dispose-nuclear-waste-french-nuclear-facility/

2. What goes wrong? The double legacy as an immeasurable challenge

What is going wrong with the search for repositories? Why has not a single project been successfully implemented and completed worldwide? Why, after more than 70 unsuccessful years, the responsible state authorities do not intervene at last and ensure that other independent organizational structures adopt more advanced waste management concepts and projects?

The reasons for this development are diverse. An eminently important factor is undoubtedly the strong historical dependence between state, military and industrial interests as well as scientific institutions. Weaknesses in the management of programs that are based on planning and competence deficits are equally important. The problems with budgets and costs also contributed significantly to the quality of the waste management beeing inadequate. In addition, there are fundamental conceptual misjudgements as to how a long-term disposal project should be tackled.

A basic reason for this development is the fact that responsible project managers and authorities are strategically single-tracked. From their point of view, the material constraints created by nuclear waste had simply to be solved by introducing the dangerous legacy into the deep geological underground. In fact they believe, the security and the concerns of future generations can be satisfied for all time periods by this way.

The nuclear industry and the competent authorities have only gradually realized that a repository in the underground is a permanent source of danger. The long-term protection of the population should now include warning programs with markers (Figure 3), records and memory preservation plans lasting over a period of 10'000 years. [15] This task should be implemented by the implementers - the nuclear industry or the substituting state.[16] They never doubted their capacity to successfully execute a repository and to guarantee long-term security, just as they considered themselves as the only capable and legitimate institutions for this task. With this attitude, they deprived the communities living in the affected regions of their ability to assess the dangers of ultimate disposal and to preserve the long-term rights of their descendants.

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[15] Benford, Gregory, Kirkwood, Craig, Otway, Harry, Pasqualetty, Martin (1991): Ten Thousands Years of Solitude? On Inadvertent Intrusion into the Waste Isolation Pilot Project Repository, Los Alamos LA-12048-MS/DE 91 010299.

[16] Eine kurze geschichtliche Entwicklung dieses Prozesses findet sich in Buser, Marcos (2013): Preservation of Records, Knowledge and Memory across Generations (RK&M), A Literature Survey on Markers and Memory Preservation for Deep Geological Repositories, NEA/RWM/R(2013)5, OECD-NEA, Organisation for Economic Co-operation and Development (OECD), Nuclear Energy Agency (NEA)Paris, https://www.oecd-nea.org/rwm/docs/2013/rwm-r2013-5.pdf.

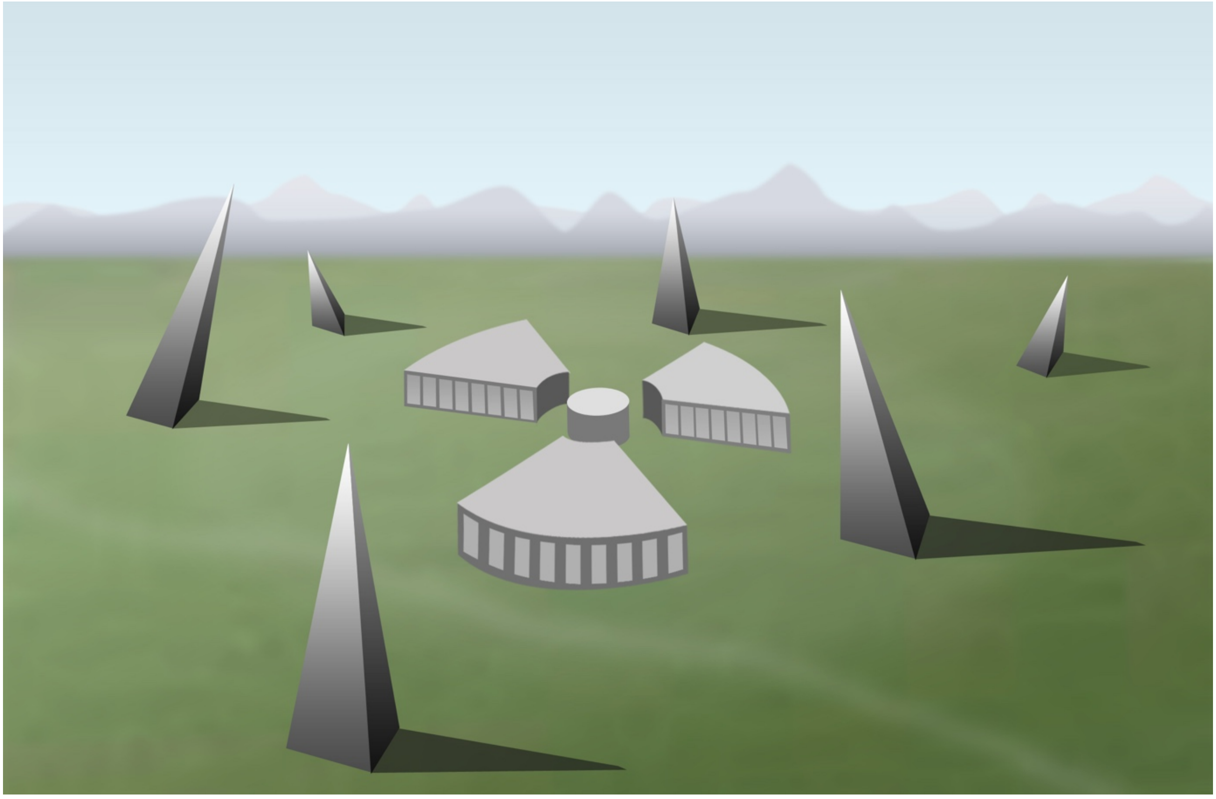

Figure 3: Timescales of risk duration (> 100'000 years) and memory preservation (10'000 years)

Meanwhile, so-called participation rights are world-wide approved by implementers and authorities in the siting-programms for waste disposal. But these "participation" rights are just limited, because the affected population is not integrated in the decision-making. Even today, the institutions responsible for disposal primarily pursues a strategy which should only provide protection of man and the environment from the repository. But long-term protection of the repository against intrusion must be guaranteed as well – though a dual strategy (Figure 4). This second strategy is particularly challenging, because of the tremendous advances in to-day and future technologies. This reversal and the simultaneous enlargement of the protection objectives must lead to a fundamental rethinking of the roles and responsibilities in the planning and design of waste management programs and ultimately also has to reconsider the concept of the deep storage.

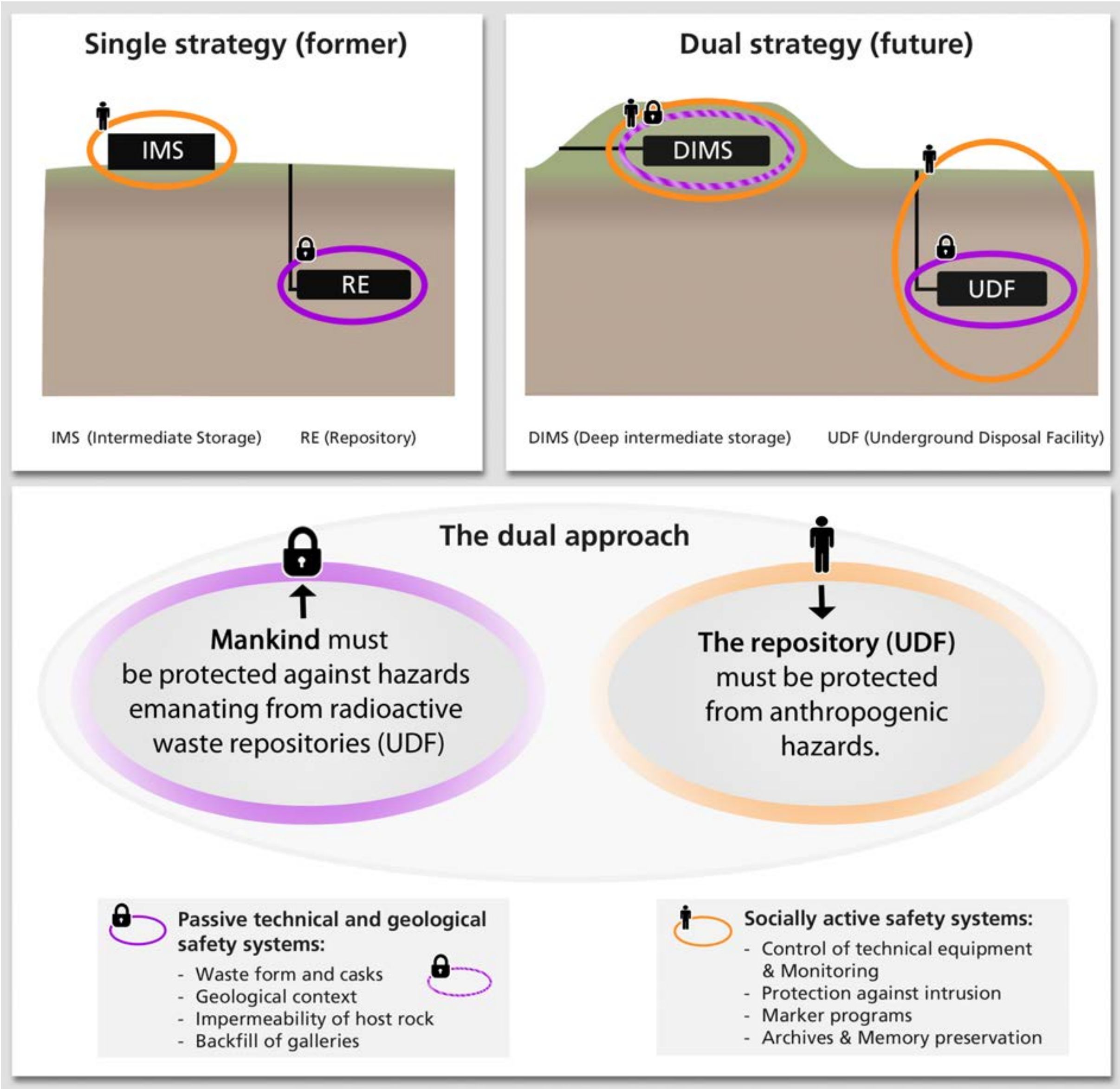

Figure 4: The dual strategy with two main actors: implementers authorities one side and local and regional communities on the other

If the final disposal projects are to be developed and implemented by technically competent institutions so that the first of these objectives can be achieved as far as possible, the custody of the repositories and the maintenance of the memory of this legacy must be transferred to the locals and the regions. Who else should take over this task over such long periods? This dual tasks leads to a leveling of responsibilities between those who want to get rid of the waste and those who are to take over this waste. Only under these circumstances communities willing to take over the burden of a repository will be found. The integration of these communities and the transfer of far-reaching decision-making rights to them, are fundamental prerequisites for sustainable nuclear waste management.

3. The open future

Today we are in a transitional phase, concerning the realization of deep underground repositories. It is hardly conceivable that the decision to construct such facilities can simply be made on the basis of site investigations, some further research, a few long-term experiments and a safety case based there-on. The decision-making process needs to be broken down more clearly. Thus, successfully completed pilot phases are required for all relevant process steps in order to obtain at least some security for the storage operation. In Switzerland, as an example, the Swiss Commission "Disposal Concepts for Radioactive Waste" (EKRA) suggested in 2000 that a pilot phase should precede the storage process. Because of little experience, a pilot phase lasting some decades at least, should allow to test on a large scale the industrial feasibility and the sustainability of the tracked concepts. Until the termination of this trial phase all nuclear wastes should be kept in a longer and safe intermediate underground storage. A similar strategy has been advocated by scientists for at least two decades, asserting that "burying uncertainity" should be avoided.[17]

For society and for the local and regional communities, this approach would yield important advantages. In the first place, no rash decisions would need to be made on a week scientific basis. The implementing organizations would have more time to carry out their work in a clearly defined process, which would provide sufficient time for comprehensive and broad review. The review and the process control could be strengthened and professionalized. Without the proof of industrial feasibility, no final storage should be built. The danger of creating new nuclear contaminated areas, that will have to been cleaned up with big public financial support ("super-fund"), has to be decidedly countered.

The fact that the global risks should have grown to such an extent that final storage solutions now have to be pushed into the express train is a pre-emptive argument from the nuclear industry and the governments that support it. After 70 years of inactivity and failures in waste disposal policy, the promotors of atomic energy seek to present as soon as possible final disposal projects. This strategy is intended to show, that nuclear industry is willing to solve the delayed problems in order to find acceptance in the implementation of future reactor lines of the IV generation. The forced implementation of deep underground repositories, as is currently being observed in Finland, Sweden, France and Switzerland, is in strong contrast to sustainable strategies and developments.

Thirdly, it is important to check whether the envisaged concept of deep underground disposal in host rock at a depth of 500 or more meters, is at all times a sustainable long-term "disposal" strategy in view of the worsening conflicts of use of the subsurface,. The exploration of the earth's surface in search of raw materials, energy and water, as well as the disposal of industrial waste, has assumed gigantic proportions. The upper earth crust in industrialized countries looks more and more like a Emmentaler cheese, with a multiplicity of deep boreholes which damages natural protective layers in the depths. It is precisely this damage of the rock that has led to the abandonment of some major repository projects

[17] Shrader-Frechette, K.S. (1993): Burying Incertainity, Risk and the case against geological disposal of nuclear waste, University of California Press, Berkeley Los Angeles London

(Lyons, Kansas[18]) or the displacement of a site to better locations (WIPP, New Mexico[19]). Advanced concepts should further be developed, such as the deep drilling concept at several kilometers depth as well as new conditioning and placement techniques should be assessed. However, in the face of the many project failures it seems mandatory, that no project of deep underground disposal is implemented without a basic reassessment.

Fourthly, the techniques of underground exploration have made tremendous progress in recent decades. Today, to mention only an example, Shaft Boring Machines (SBM) are available on the market which reach a depth of up to 2'000 m in a few months, with drilling diameters up to 12 m.[20] The same is true for tunneling techniques or mining techniques. This development suggests that exploration and exploitation of the subsoil should be revolutionized over the next few hundred years. Underground repositories are here in the way and à piori endangered by such developments. In addition, the protection of the deep water resources is becoming more and more important for mankind.

Fifthly, it is an illusion that a location secured in a spatial plan can be protected against intrusion processes of this type over an extended period of time. All attempts to maintain effective use of bans over time have failed, as archaeological research clearly shows. [21] How should a society be able to make predictions about the protection of the subsoil in this enormous and rapid technical change?

The enormous acceleration in technology makes it virtually impossible to develop scenarios for the future development of societies and their legacies. However, what is apparent from the historical experience so far is that man has never really taken his waste problems seriously, as demonstrated by the way in which modern industrial societies deal with their radioactive and chemo-toxic waste in the last 200 years.[22] Waste continues to be subject to a littering-mentality and should therefore not cost anything.

4. Other processes required

The way the future will actually look, is beyond our imagination, as well as the dangers and possibilities it offers to society when dealing with highly toxic waste,. Whether or not future generations will accept the decisions of their ancestors to operate repositories as we imagine today is, incidentally, also on another sheet. Especially when dealing with short-term financial interests of one or a few generations against long-term security at the

[18] Walker, Samuel J. (2009): The road to Yucca Mountain, University of California Press London.

[19] Mora, Carl J. (1999): Sandia and the Waste Isolation Pilot Plant 1974 – 1999, Sandia National Laboratories Albuquerque SAND99-1482, p. 35-38.

[20] Z.B. Produktpalette der Herrenknecht AG, Schwanau, BRD, (https://www.herrenknecht.com/de/produkte/kernprodukte/mining/shaft-boring-machine-sbm.html).

[21] Buser, Marcos (2013): Preservation of Records, Knowledge and Memory across Generations (RK&M), A Literature Survey on Markers and Memory Preservation for Deep Geological Repositories, NEA/RWM/R(2013)5, OECD-NEA, Organisation for Economic Co-operation and Development (OECD), Nuclear Energy Agency (NEA)Paris, https://www.oecd-nea.org/rwm/docs/2013/rwm-r2013-5.pdf.

[22] Buser, Marcos (2016): Rubbish Theory, The Heritage of Toxic Waste, Reinwardt Academy, Amsterdam University of the Arts.

location. The social tensions that might arise from cross-generational conflict situations, for example, have not even at first been analyzed.

The problems are complex, the open questions numerous. Answers cannot be found with police sticks and massive repression, as happened recently in Bure in France in August 2017.[23] The responsibility for the planning and implementation of strategies for the protection of man and the environment and the preservation of the memory of these deposits must definitely involve the concerned communities. This also means that the generations living today have to be able to make decisions about the safety issues of a repository. Their descendants bear the risks, and not the present decision-makers in the remote located institutions. The fact that a completely new dialogue and decision-making culture is necessary in the handling of nuclear waste is the most important finding in dealing with this highly dangerous long-lived radioactive legate. Decision-makers must be able to act on equal terms. This is why it is so important that the communities affected by repositories demand and receive a completely new involvement in the nuclear waste disposal programs.

[23] Bure will be their downfall, Struggle against nuclear waste landfill project (CIGEO) in Bure – France, http://en.vmc.camp