

INTRODUCTION

Toward a repository for high-level radioactive waste: Perspectives and approaches

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Abstract • The future is unpredictable. Under these circumstances, how can we plan and construct a nuclear waste repository that is supposed to safely store the waste for up to a million years – an endeavor that may in itself take more than a hundred years? In this introduction to the special topic on the future of nuclear waste disposal, we take a first look at this question by searching the literature for answers and by giving a short overview of the current status of site selection in different countries, including possible challenges.

Auf dem Weg zum Endlager: Perspektiven und Ansätze

Zusammenfassung • Die Zukunft ist unvorhersehbar. Wie können wir unter diesen Umständen ein Endlager für nukleare Abfälle planen und errichten, das die Abfälle für bis zu eine Million Jahre sicher aufbewahren soll – ein Unterfangen, das an sich schon mehr als hundert Jahre dauern kann? In dieser Einleitung zum Schwerpunkttheft über die Zukunft der Atomüllentsorgung werfen wir einen ersten Blick auf diese Frage, indem wir in der Literatur nach Antworten suchen und einen kurzen Überblick über den aktuellen Stand der Standortwahl in verschiedenen Ländern geben, einschließlich möglicher Herausforderungen.

Keywords • nuclear waste, future, public participation, disposal policy

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Introduction

The stupendous time perspective of one million years, which is often associated with the disposal of high-level radioactive waste, opens up an immensely wide temporal horizon and an irritatingly vast future space. The dimensions of this period are significant because of the persistence of the radioactive hazard that in the case of disposal in an underground repository requires stability of geological formations encasing it. It is a problem, a task, a project that can to some extent be quantified and thought through, but that in a way is also unimaginable or even incomprehensible. Nevertheless, there is a need for action – in the distant future, but more urgently in the present.

The future can be far away and present at the same time. This is certainly true for the final disposal of high-level radioactive waste. According to the law the siting decision for a final repository in Germany should be taken in the year 2031 – though this time frame is considered unrealistic by now (see below). What appears to be the future in this country has already dawned in Switzerland. In our neighbouring country, a site has been proposed in September 2022. This marks the beginning of a new phase with its specific tasks and challenges. It is also very interesting to look at Finland, which was the first country in the world ever to realize a deep geological repository for highly radioactive waste from the civil use of nuclear energy. The future developments in Switzerland, the way emerging problems are handled there and the way they were handled in Finland – from a technical and societal point of view – thus (still) offer interesting insights for all the others who still have this phase ahead of them and want to prepare themselves.

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The confrontation with the future

In general, dealing with the future is not easy. Especially because it has not yet occurred, because it is not yet here, not yet manifesting itself. What can be dealt with are ideas about the future. Here we will take a brief look at the bridge that connects the past future with the futures that are in front of our eyes, with an emphasis on the possibilities and opportunities of dealing with the future (for other possibilities for bridging this gap see Grunwald et al. 2020).

The future is being made – is the future being made? The impression that human endeavor for the future reaches its limits arises above all when one looks in retrospect at the end and swansong of developments and new technologies that are abolished or perish in another way. A technology that was future ends. What was future ends. The present that was future is not the present that was once expected – not least because former futures ended prematurely (Radkau 2017). What stays is the task of safely and responsibly taking care of the technology's remains; for example, to end the peaceful use of nuclear energy in Germany, which was once considered a great hope for the future in this country (Radkau and Hahn 2013). Nuclear power plants need to be dismantled and the waste taken care of. Unexpected events or unforeseeable interactions in and in between actions and events raise doubts that the future can be made.

The roots of the approach to accompany new technological developments in an anticipatory way in order to avoid undesirable side-effects and consequences have themselves become historical: Since 1957 the Study Group for Systems Research has established interdisciplinary and practice-oriented policy advice based on innovative models of thought and research concepts (Brinckmann 2006, p. 14). Technology assessment (TA) has a broader approach and also draws on other sources. If technological progress is not without its downsides, then the “forward-looking consideration of the possible consequences in their entirety [...] is called for in order to avoid illusions and blind wishful thinking, to enable well-informed and reflected decisions and to promote the responsible shaping of technological change and the use of its products” (Grunwald 2022, p. 19, own translation). One of the hopeful innovative approaches that TA is promoting today is vision assessment (Frey et al. 2022). The empirical exploration of visions as socio-epistemic practices responds to the ubiquity of visions of the future and their efficacy in all areas of society, in science and politics as well as in civil society and mass media. The research group ‘Repository Research and Long-term Governance’ at the Institute for Technology Assessment and Systems Analysis (ITAS) in Karlsruhe – to which two of the three authors of this text belong – focuses on this topic (Hocke et al. 2022).

Also in politics, the question of how to deal with the future is present: The Federal Government of Germany is currently building structures to deal more effectively with the future and future issues in general. At times, techno-optimism can be observed, such as when the ‘digital minister’ Volker Wissing point-

edly demands: “We need to stop discussing visions of the future and move on to concrete implementation” in order to resolve the existing digitalisation backlog (Voß and Rusch 2022, own translation). On the other hand, however, are the other, broader activities: Chancellor Scholz has convened a new ‘future council’, which has started its work. In addition, a unit at the Federal Chancellery is being tasked with the new approach of strategic foresight. Furthermore, following scientific recommendations, a separate ‘future laboratory’ could be set up, in which, for example, far-reaching decisions of the government would be examined in advance for their ‘future compatibility’ (Rusch and Ronzheimer 2022).

Overall, also the scholarly perspectives on the future are diverse: from a philosophical perspective, Hans Blumenberg (1986) has focused on and thought through the mortification that every single human being has to live with the fact that the world and humanity will simply continue to exist and carry on after his or her death. The publicist Alan Weisman (2009) took an even more radical approach: He describes the world after the extinction of humanity. As concretely as it is described, as abstractly monstrous or remote, even unbelievable, it appears to human thinking. What is relieving, perhaps even comforting, is the idea that there will be no human being left. Only animals and plants. And the nuclear waste.

In a novel, the writer Annette Hug approaches the question of how to deal with the future fictitiously and debates how methods can be developed “to document knowledge about the dangers of nuclear waste and reliably pass it on from generation to generation” (Hug 2021, cover text, own translation). In the international debate, different approaches to this can be found ranging from atomic priesthoods to markers and art projects (NEA/RWM 2012; Grunwald 2018).

Has jurisprudence lacked imagination or have the wrong reference points simply been set? In any case, law and jurisprudence do not find it easy to deal with questions about the future. Almost simultaneously with the introduction of the state goal of protecting the livelihoods of future generations, Michael Kloepfer (1993) popularized the metaphor of the impending eco-dictatorship. In 2013, Klaus Ferdinand Gärditz (2013, p. 16) argues for a stronger focus of environmental legislation on present-day problems. On the other hand, with its climate decision of 2021, the German Federal Constitutional Court strengthened the intertemporal freedom rights of future generations and the importance of effective climate protection.¹ More generally, Jens Kersten and Elisabeth Kaupp ask “How open to the future is the Basic Law?” (Kersten and Kaupp 2022, p. 473, own translation).

In sum, the stale taste remains that an entire generation, according to the publicist Bernd Ulrich (2019, p. 82), has not done enough for the future, for environmental and climate protection, despite knowing better: “If you look at the totality of all ecological measures in Germany, you will then hardly discover the

1 Decision of the Federal Constitutional Court of March 24, 2021-1 BvR 2656/18, Decisions Vol. 157, pp. 30–177.

contours of a turning point forward, but rather the escape routes of politics from the people and even more from the economy” (ibid., p. 200, own translation).

The sociologist and contemporary diagnostician Heinz Bude noted an “inversion of the direction of fear” in the “younger generation’s perception of reality” (Lobe 2022: p. 21, own translation; Kaltenbrunner 2022): The worst is not (any longer) over; the worst is yet to come! In other words: “The perpetuated crisis narrative changes something in our perception and perspective: The future is no longer a space of possibility, but a space of danger. Not something to be actively shaped, but something to be prevented” (Lobe 2022, p. 21, own translation). In fact, a dystopia has come true in Zaporizhzhya: The largest nuclear power

The development of a storage concept and the search for a suitable site for final disposal are – according to the Centrale Organisatie Voor Radioactief Afval (COVRA N. V.) – currently still in the research phase. The spectrum of plans for the commissioning of the repositories in the four countries under consideration thus ranges in time from about 2025 to 2125 or beyond. Further decades will pass before the repositories are closed.

In Germany, the Bundesgesellschaft für Endlagerung (BGE) has been mandated “to identify a site in the Federal Republic of Germany with the best possible safety for a final disposal facility for domestically produced high-level radioactive waste by means of a participative, science-based, transparent, self-questioning and learning process”². This task was supposed to be

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plant in Europe is being shelled in the war between Russia and Ukraine (col/AFP 2022). No wonder, young Germans would rather live in the past than in the future (KIG/dpa 2022). And yet, work must continue on the project to realize a final repository for highly radioactive waste in Germany, ...

Long-term project on final disposal

... in many other countries, and for a very long time.

The time scales and future perspectives for the final disposal of high-level radioactive waste in Europe are currently very diverse. Nations such as Finland, the Netherlands or Germany have each chosen their own concepts and procedures to realize final disposal. The time spans over which the disposal programmes are to be realized differ significantly in some cases.

In Finland, the construction of the ONKALO repository for high-level radioactive waste, which was approved in 2015, is already well advanced. Operation is expected to start in the mid-2020s (Posiva Oy 2022). In France, the implementer Andra is expected to submit a construction application for the central repository Cigéo in the near future. Commissioning of this facility is planned for around 2040 (Nagra 2022 a). In Switzerland, as already mentioned, the implementer Nagra submitted a site proposal in September 2022. If this proposal successfully completes all further licensing steps, from today’s perspective operation of the deep geological repository for high-level radioactive waste can begin around 2060. Nagra expects to be able to close the repository in about 100 years, around 2115 (Nagra 2022 b). However, since Switzerland provides for a basically unlimited monitoring phase after completion of emplacement, closure may also take place much later. In the Netherlands, high-level waste is temporarily stored in a surface repository for a period of approximately 100 years until a deep geological repository is available.

solved by the year 2031 (BGE 2022). However, in the meantime, somewhere between 2046 and 2068 has been proposed by the BGE as realistic timeframe. This does not come as a surprise to various experts, who have considered this timetable unrealistic already before – also against the background of experience in other European countries – and a significantly longer timeframe is expected for site selection even now. For example, an expert who advised the German commission ‘Lagerung hoch radioaktiver Abfallstoffe’ expects that it will take considerably more than 100 years after the start of the site selection process until the German repository for high-level radioactive waste is finally closed and decommissioned (KLA 2016).

In Germany, this is followed by a period of 500 years during which monitoring should take place and retrievability be ensured. By the time the repository will be finally closed, many generations of specialists will have been involved in the endeavor. In order to ensure safety and security, for example, a passing on of knowledge and skills is essential although some of the technologies which are used at the site may be outdated in the future.

Impact of current events and developments

A lot can happen in 100 years, let alone 600 or more years. The present demonstrates that profound changes are possible even in a short time, which can have an impact on the final disposal of high-level radioactive waste.

² Repository Site Selection Act of 05.05.2017 (BGBl. I p.1074), as last amended by Article 1, Section 2 of the Act of 07.12.2020 (BGBl. I p.2760). Available online at https://www.gesetze-im-internet.de/standag_2017/StandAG.pdf (in German), last accessed on 17.10.2022.

The war in Ukraine has clearly shown that interim storage facilities and facilities for the treatment of high-level radioactive waste can become targets of attacks in the event of an armed conflict (IAEA 2022 a, IAEA 2022 b). Deep geological repositories offer more protection in the event of war than surface facilities. It is therefore possible that the experience of war will ultimately lead to an effort to accelerate the disposal of high-level radioactive waste in deep repositories.

Climate change is increasingly leading to extreme weather events worldwide and associated natural hazards such as drought, forest fires, floods and landslides (IPCC 2022). The need to reduce greenhouse gas emissions has thus become more obvious; the urgency is felt politically more strongly than before. The Eu-

addressing them (Schult and Verbarq 2022; NEA/RWM 2021). It is therefore conceivable that the next generation will judge and shape final disposal differently than those who currently assume responsibility for this task.

All those involved in shaping final disposal as a learning process (Röhlig et al. 2021) will face significant challenges with such changed social framework conditions and assessments. Considering the 600-year schedule, one might despair and concede that it is impossible to plan ahead for such a far-reaching future. Still, it seems worthwhile and even necessary to prepare and reflect on the repercussions our current actions could have on the future. For example, what could be characteristics of a resilient institutional set-up for long-term governance that

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ropean Union aims to make Europe the first climate-neutral continent by 2050. In this context, it has, among other things, classified nuclear energy as sustainable in 2022 – provided that a detailed plan is in place to bring a final repository for the high-level radioactive waste from nuclear power plants into operation by 2050 (European Commission 2022). In the European Union, this development also increases the urgency of putting final repositories for high-level radioactive waste into operation.

New technological developments facilitate the exploration of the geological subsurface and the construction and operation of repositories. Geological data are increasingly stored on central platforms; developments in information technology enable more differentiated evaluation of data sets. The feasibility and economic efficiency of underground structures is improving due to new investigation and tunnelling techniques (e.g. American company for infrastructure and tunnel construction services *The Boring Company*); robotics offers perspectives for the safe emplacement of radioactive waste in a repository (Andra 2019). The construction and operation of repositories could thus be accelerated.

Current crises such as the COVID-19 pandemic, the war in Ukraine and the consequences of climate change tie up considerable societal resources. Therefore, it stands to reason that society might give lower priority to final disposal in the future than is currently the case. Resources dedicated for final disposal would then be diverted to achieve other goals that are judged to be more important and urgent – such as mitigating climate change or securing societal peace.

Involving young people in waste management within the framework of participation is proving difficult in many cases at present. For many adolescents and young adults, the disposal of highly radioactive waste is apparently not a topic they particularly want to get involved in – or those responsible for public participation at project developers and authorities do not succeed in

makes it at least more likely that someone will be there 400 years from now, who is able to read and interpret the monitoring data? Checks and balances in decision-making in combination with a web of research activities could be part of the answer (Kuppler and Hocke 2019). This Special topic contributes to exploring further approaches to thinking about how the present shapes those future challenges and how they in turn resonate today.

Overview of contributions

The fact that looking into the future and dealing with it is not easy is also reflected in the submissions to our call. Hardly any contribution is dedicated to a situation in the future. The majority of the contributions continue current developments or seek to derive conclusions from current observations. What is striking is the shift into a reflection on time, its duration and its power. When is the right time to begin the future? In our opinion, it is now. This Special topic is an invitation to start a discussion on the many questions that should be thought through and dealt with in time.

Which timescales should we talk about? Margarita Berg and Thomas Hassel point out in their contribution that when discussing about high-level radioactive waste in Germany, we mostly talk about the near and the far distant future. What we neglect is the medium-term period of 500 years after closure of the repository, when many decisions still need to be made. They suggest that one reason may be that it is much easier to talk about the future when it is fixed to a specific date (2031) than when it stands in relation to another, undetermined date (500 years after closure). One million years after closure seems to be an exemption, as it is an incredible and intangible amount of time. Looking at existing approaches to communicate time, they suggest

that focusing on passing knowledge from generation to generation could be part of the solution and help with thinking about time. They consider ‘time literacy’ to be an important aspect of nuclear waste management.

Sacha Frenay and Céline Parotte also take up the issue of time, highlighting its framing power in choosing a waste management strategy, using Belgium as an example. They suggest that the concept of ‘timeprints’ is helpful in understanding how stakeholders frame different waste management options and how the timeprints act as a form of ‘tacit governance.’ Based on a Delphi study with 193 participants they identify four timeprints for the Belgian case: the ‘trajectorism’, the ‘promise economy’, ‘radioactive waste identity’ and the ‘multi-situated.’ In the identification of the timeprints, (economic) promises, the naming of radioactive objects, and the idea where the waste should be stored play a role. They point out that the silences that accompany these timeprints, as well as their interactions and entanglements, influence current radioactive waste programs. Therefore, they believe it is worthwhile to look at such timeprints in other countries as well.

That nuclear waste should be disposed of within one’s own borders is an established paradigm in many countries. Matti Kojo, Markku Lehtonen, Tapio Litmanen and Niina Kiviluoma take a closer look at this notion, by framing it as an ‘umbrella promise’ – a form of techno-scientific promise – and trace its construction and transformation in Finland. They identify three developments that are changing this promise: (1) the lack of cooperation among different nuclear power companies, (2) the idea of ‘international responsibility’ that includes a network of repos-

the Young Generation’, whose task would be to keep the interests of future generations present in the current decision-making processes. This would also mean that society acts and is recognized as a corrective authority in a system of ‘checks and balances.’

Another aspect of participation is the subject of the contribution of Rosa Sierra and Konrad Ott. Using the two principles ‘justice’ and ‘safety’, they discuss what kind of participation can be considered appropriate in the different phases of the site selection process, referring to Habermas’ ideas of deliberative governance. Based on the literature and a workshop on participatory aspects of procedural justice, they discuss how and with what goal the public should be involved in different cases: In the case of compensations for negative impacts, the public should be given decision-making power when issues such as quality of life and economic impacts are being negotiated. When making safety-relevant decisions, such as to close a repository, they argue that in democracies, decision-making power should rest with elected representatives because they are best able to weigh aspects of justice and safety.

In her contribution, Dörte Themann discusses whether the current institutionalization processes in the field of nuclear waste management in Germany show signs of logics inherent in Elinor Ostrom’s ideas on commons governance. She draws on participatory observations of current public events in the context of the German site selection process and analyzes the extend, to which each of these meets eight different criteria that Ostrom identified as key to successful and long-term commons governance. She shows that, in particular, the desire for civil so-

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itories for imported waste in Finland, and (3) the idea of small nuclear reactors at household level that raises the issue of decentralized disposal. They conclude that it is worth taking a closer look at techno-scientific promises beyond hype cycles to better understand and regulate technologies.

Lucas Schwarz discusses in his paper how intergenerational justice can best be addressed in the various stages of a site selection process (pre-selection, selection, post-selection). Drawing on ideas from the debate on environmental justice, he explores the hypothesis that intergenerational justice can best be achieved by ensuring “high standards for procedure, distribution, and recognition” (this TATuP issue, p. XX). Based on a quantitative public survey and qualitative observations, he concludes that the best way to create intergenerational justice is to ensure a high-quality site selection process today. Another measure would be to involve an institution such as the ‘Council of

society to self-organization as a corrective can be interpreted as a form of independent control that corresponds with the idea that nuclear waste is a shared responsibility for which the best solution must be found. She concludes that principles of commons governance may prove helpful in the long-term management of radioactive waste, such as trust-building, adaptability and longevity.

In the interview, Tim Vietor provides information about the future of deep geological disposal in Switzerland and reflects on the role of the implementer Nagra in this process. In September 2022, Nagra submitted a site proposal for a repository for low-, intermediate- and high-level radioactive waste. With the expected end of the site selection process, new challenges arise. New tasks for research and regional participation are emerging – and the implementer also faces changes, such as a large construction site.

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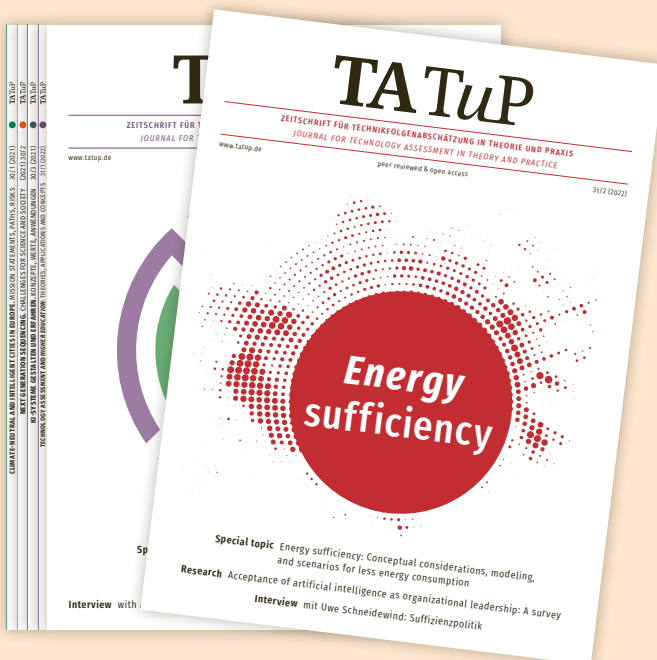
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