10

SPECIAL TOPIC

The future of radioactive *waste disposal:*

What are the developments and challenges after site selection?

Die Zukunft der Endlagerung:

Was sind die Entwicklungen und Herausforderungen nach einer Standortentscheidung?

Edited by U. Smeddinck, A. Eckhardt, S. Kuppler

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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 Schwerpunktheft über die Zukunft der Atommüllentsorgung 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.

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 pointedly 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.

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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 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, …

The worst is not (any longer) over; the worst is yet to come!

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. 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 solved by the year 2031 (BGE 2022). However, in the meantime, somewhen 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 2022a, IAEA 2022b). 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 European 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 addressing them (Schult and Verbarg 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 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.

What could be characteristics of a resilient institutional set-up for long-term governance?

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

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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 repositories 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 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 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.

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.

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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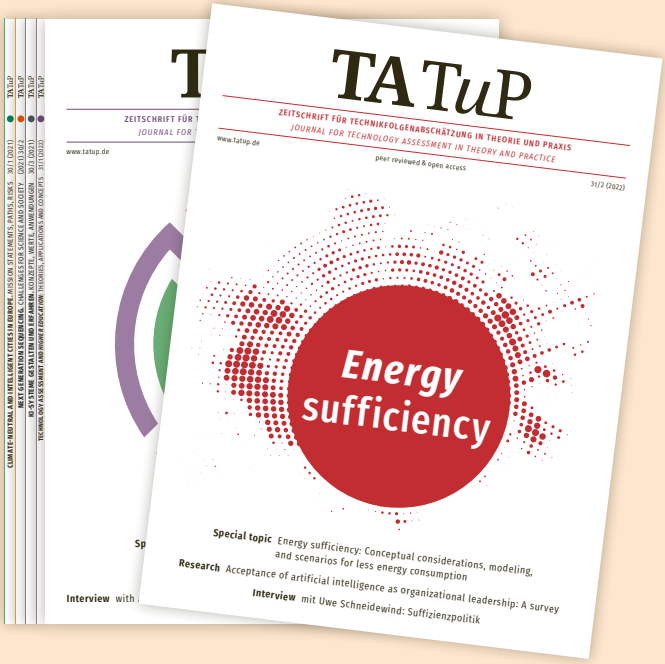

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RESEARCH ARTICLE

Challenges in communicating the future of high-level radioactive waste disposal: What future are we talking about?

Margarita Berg*,[1], Thomas Hassel[2]

Abstract • Of the three main time horizons specified in the German Repository Site Selection Act (the year 2031, 500 years after closure and one million years), the current public discourse largely neglects the "medium term". However, many important choices will have to be made during this period. The article discusses different conceptions of time that could help to improve public understanding of the time horizons for high-level radioactive waste disposal and the decisions that still lie ahead.

***Herausforderungen in der Kommunikation über die Zukunft der Entsorgung hochradioaktiver Reststoffe**: Über welche Zukunft sprechen wir?*

Zusammenfassung • *Von den drei wesentlichen im Standortauswahlgesetz genannten zeitlichen Horizonten (das Jahr 2031, 500 Jahre nach Verschluss und eine Million Jahre) wird die mittlere Perspektive im gegenwärtigen öffentlichen Diskurs meist vernachlässigt. Allerdings werden in diesem Zeitraum viele wichtige Entscheidungen zu treffen sein. Der Artikel diskutiert unterschiedliche Zeitkonzepte, die dabei helfen könnten, das öffentliche Verständnis für die Zeithorizonte der Entsorgung hochradioaktiver Reststoffe sowie die noch anstehenden Entscheidungen zu verbessern.*

Keywords • *conceptions of time, future studies, high-level radioactive waste disposal, science and art*

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Introductory observations

Conceptions of time are highly relevant in addressing the subject of high-level radioactive waste disposal. However, talking about the future (and especially the far future) is extremely complex, mostly hypothetical and riddled with complications and imprecisions. This article aims to determine which time horizons of the future are currently addressed in the discourse on high-level radioactive waste disposal and where communication could be improved. These deliberations were originally inspired by the site selection process in Germany but will include insights from other countries where appropriate.

Following § 1 of the German Repository Site Selection Act[1], there are three different time horizons which might be broken down into smaller sections if appropriate. Germany aims to have located a site for final storage of high-level radioactive waste by 2031, the waste is supposed to be recoverable for 500 years after the repository is closed, and the selected site must be the safest one for isolating the high-level radioactive waste from the biosphere for one million years. The goal of 2031 was set due to the expiring licences for the interim storage facilities and the need to find a final storage site before public awareness of this problem dwindles after the end of nuclear power use in Germany. Recoverability was included in the German Repository Site Selection Act due to the problems in the Asse repository for low- and

1 Repository Site Selection Act of 05. 05. 2017 (BGBl. I p. 1074), as last amended by Article 1 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.

medium-level radioactive waste. It is assumed that knowledge of the storage facility will not last for more than 500 years after closure. The containers should be recoverable during that period. The one million years of safe storage is based on calculations of half-life and uncritical radiation levels (Wollenteit 2019).

This broad range of future time horizons (from a few years to one million years) poses interesting challenges for the communication on high-level radioactive waste disposal. However, two of these time horizons are currently discussed almost exclusively. News reports following the interim report on suitable subareas (BGE 2020) referred amply to the year 2031 (which local politicians in particular often described as 'a long time from now') and to the one million years (albeit in a very abstract way). Similarly, the first 'Streitgespräch' (a disputation format established by the German National Citizens' Oversight Committee) discussed mainly the next decade in the conversation itself, with the one million years brought up afterwards by a question from the audience. In contrast to the generational approach in France (see below), there have been no specific attempts to facilitate public understanding of the different time horizons in Germany so far, with the exception of a short TV documentary (Geiger 2021).

It is perhaps understandable that discussions currently focus on the year 2031, because it is reasonably soon and deals with the initial step of finding a site, and on the period of one million years, probably due to its almost fantastical scope. However, the 'medium term' of 500 years after closure is mostly neglected in the public discourse even though many important decisions will still need to be made during this period (and during the preceding, temporally unspecified period of filling and operation of the repository), e.g. concerning criteria for potential recovery, marking of the site and knowledge transfer. Therefore, it needs to be made very clear that the issue will not end in 2031 and that the selection of the site is only one step in the overall process of final storage.

Statements about the future development of a system become possible by looking into the past. The farther one can look back and understand the developments up to the present, the farther one can predict further developments in the future. Following this approach, one is able to predict changes of the host rock for about one million years. This is possible because the geological processes that took place in these rocks have largely been understood at least for the past 250 million years of earth history. This approach cannot be directly transferred to technological developments. However, humans are capable of conceiving and producing buildings or technical systems with a long durability, so that from a technical point of view as well, we can find the best possible solutions for safe final disposal, at least for the near future. Such safety promises for functional endurance of the technical system become more difficult if it is not subject to maintenance, as is the case with the final storage containers after closure of the section. In order to be able to describe the future behaviour of this system, data is needed that depicts changes in properties over time, which can then be extrapolated into the future. The quality of the data and the temporally exact system development are extremely important to keep uncertainties and insecurities in the statements on future system behaviour as small as possible. It is precisely in the consideration of the 'medium term', which appears to be the most undefined and obscure in the public discourse, that the most accurate knowledge of the system's behaviour is required.

Statements about the future development of a system become possible by looking into the past.

Furthermore, since the period of one million years is established in the German Repository Site Selection Act (with similarly long-time horizons in the equivalent laws of other countries), "engaging with such radically long-term timespans is no longer just for the astrophysicists, theologians, palaeontologists, geologists, evolutionary biologists, or archaeologists among us. It has become our collective task" (Ialenti 2014, para. 10). What might be called 'time literacy' (here understood as the ability to conceive of and discuss vastly different time horizons individually and together, without losing sight of the medium term) is an important part of empowering civil society to handle this future task in a responsible way.

Therefore, one of the first challenges of communicating the future of high-level radioactive waste disposal is to find appropriate ways to actually address all time horizons of the future that are of relevance. The article will proceed, first, to discuss why it is so difficult to communicate the time horizon of 500 years after repository closure at all, and the one million years in a concrete, meaningful way. Second, suggestions for improving communication, e.g. focussing on generational approaches, will be made.

Different conceptions of time

Apart from the obvious fact that the next decade is a lot easier to conceive of than half a millennium, the difference between the A series of time (*Modalzeit* in German) and the B series of time (*Lagezeit* in German) might help to explain why it is easier to communicate about 2031 than about '500 years from x' (x being the time when the repository is closed). The distinction between A series and B series was initially proposed by McTaggart (1908). Events in the A series are ordered in terms of past, present and future; the B series orders events in terms of "earlier

than" or "later than". While in the A series, the present or the starting point of a time sequence is a necessary reference point, events in the B series can be located e.g. with the help of a calendar or a clock. '2031' is a designation according to the B theory of time, while '500 years from x', following the A theory, makes sense only with reference to the exact starting point, which is not yet known and thus makes the period in question more difficult to talk about with certainty. Arguably, 'one million years from an unspecified starting point' is also a designation according to the A series. However, the very unusualness of this long-time horizon is probably reason enough to talk about it.

Our scope of action concerning the long-term goal of safe disposal is located only at the very beginning of the overall period of one million years. Delays in the storage and closure phases would not change the fact that safe containment of the radioactive material will subsequently have to be guaranteed for one million years. Despite this fact (and although we think we have a relatively good overview of the early stages of disposal after site selection), it is difficult for us to deal with these periods because they relate to the A theory and their starting points are still unknown.

Our scope of action concerning the goal of safe disposal is located only at the very beginning of the overall period of one million years.

Concerning the subject of high-level radioactive waste disposal in particular, a number of other ways to distinguish between different time horizons have been proposed. For instance, the final report of the Preservation of Records, Knowledge and Memory across Generations Initiative (RK & M) distinguishes between three timeframes: "The 'short term' refers to the period of time that ends with repository closure. This period includes both the pre-operational and the operational phases of the repository. The 'medium term' refers to the period of time with oversight activities that would follow repository closure. The 'long term' refers to the period of time with no repository oversight" (RK & M Initiative 2019, p. 49). Closure and end of oversight are the decisive points in this delineation.

Another differentiation is proposed in an article on future generations in the context of high-level radioactive waste: "We define 'close future generations' as generations who still have memory of the waste and its location, and 'remote future generations' as generations who have lost its memory" (Kermisch 2016, p. 1799). Here, the line is drawn between memory and memory loss at some unspecified point in the future.

An article on the French deep geological repository project Cigéo describes the coexistence of two forms of time in separate spheres: the manageable historical time of generations above ground and the geological time of deep storage below ground (Poirot-Delpech and Raineau 2016, p. 1826). The authors suggest that the gap between these two time horizons is apparently bridged by the Observatoire pérenne de l'environnement (OPE). This permanent observatory is tasked with monitoring the environmental conditions around the storage site and preserving biological samples, which future generations may retrieve and analyse. "The OPE thus makes the environment of the future repository, that is, its 'surface world,' an extension of the underground world: it represents the continuity between the present and the future; what is transmitted from one generation to another, and thus constantly redefined" (ibid., p. 1822). This approach (and the ones discussed in the following paragraphs) might help to address the 500-year period in particular. However, even with the work of the OPE, the actors involved in Cigéo cannot picture the very long intermediate period between the transmission of information and memory about the repository from generation to generation and the containment of the nuclear waste over geological periods: "Between the two there appears to be a horizon that cannot be represented, a sort of representational blind spot" (ibid., p. 1826).

In order to empower citizens to preserve nuclear memories, Andra, the French agency for nuclear waste management, has established memory groups (*groupes mémoires*) at all sites where it currently maintains storage facilities or projects (Andra 2021, p. 11). These groups are formed by residents who – with the help of artists – consider ways to transmit the memory of the storage sites to future generations (ibid., p. 15).

In a similar way, albeit not related to nuclear waste disposal, Bjornerud (2018, p. 176) suggests that "intergenerational commons" such as oral history projects or community gardens are needed for people of all ages to gather and become aware of their intergenerational and intertemporal entanglements with other people and the world around them.

This intergenerational approach is shared by Icelandic writer Magnason who invites his daughter to imagine the time span covered by the lives of people with whom she can feel a personal emotional bond. With her great-grandmother who was born in 1924 and her own potential great-grandchild who might live until 2186, she might personally know and influence people who are alive over a period of more than 250 years (Magnason 2021, p. 22). From such an intergenerational point of view, the perspective of 500 years suddenly does not seem that long at all.

The plethora of suggested temporal differentiations, blind spots and unknown points in time discussed in this section does not make the situation any easier, but it can perhaps serve as an invitation to think about time horizons of nuclear waste disposal in a more encompassing and creative way. Incorporating the appreciation of such different conceptions and delineations of time (and the various tasks that have to be addressed at the different stages) into communication efforts might help to im-

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prove the public's awareness and understanding of the relevant time horizons of high-level radioactive waste disposal and the important choices one can still get involved in once a site has been found and a facility has been built.

Considering the future

Another interesting aspect is that thinking and writing about the future as a sphere that can be influenced by humans is a relatively recent concept. The initial way of talking about future events considered them as something that would happen to people regardless of their own choices. The future was seen as something that comes towards people. However, at the turn from the 17th to the 18th century, a new way of addressing the future developed. In this modern conception, it is the human being who moves through time and can actively shape the empty space of the future (Hölscher 2016, p. 42). Given this relatively recent change in our consideration of the future, it is perhaps not surprising that we struggle particularly to conceive of the far future and our potential role in it.

Furthermore, it must be noted that people normally think into the future within a limited topic (e.g. climate, technology or final storage) and do not incorporate many contingencies. Issues outside the respective area of consideration are usually excluded as improbable or not mentioned at all. For the discussion in the ongoing site selection process and the legal stipulations on the scope of final disposal (up to one million years), a certain stability of other thematic strands is therefore assumed. In order not to pull the rug out from under the feet of the future planning of final disposal, the social or political development (even though it may include drastic changes) must remain constant as a basic prerequisite to develop one's own thematic strand. However, the farther we think and plan into the future, the more drastically divergent the thematic strands can become. This is illustrated in Figure 1, and it can be deduced that it seems safer to focus on shorter periods of time in the overall system in order to maintain a realistic chance of success through the still-existing proximity of the thematic strands.

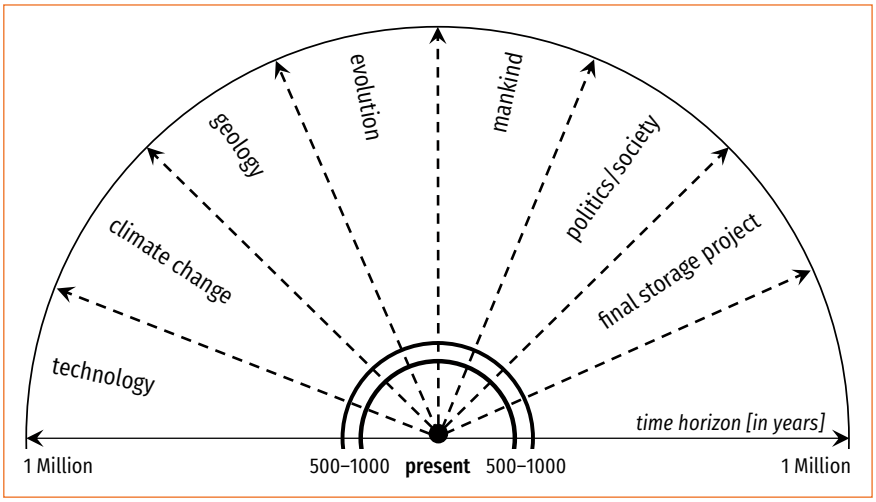

Fig. 1: Potential divergence of thematic strands from each other on the path to the future.
Source: authors' own compilation

Inspiration from other scientific disciplines and artistic approaches to time

In any case, one million years seems far removed from the years and decades of an individual human life or the centuries, maybe millennia of human societies. Even thinking hundreds of years into the future is unusual for political sciences, legal studies or engineering. However, for other disciplines, such as evolutionary biology, palaeontology or geology, considerations of thousands, millions or even billions of years are tools of the trade. Looking at the way geology in particular understands and represents time might provide some valuable insights for the communication of the time horizons of high-level radioactive waste disposal.

Geologist Marcia Bjornerud (2018, p. 163) describes her polytemporal way of looking at her surroundings: "I often feel I live not just in Wisconsin but in many Wisconsins. Even when I try not to, I can't help but sense the lingering influence of the many natural and human histories embedded in this landscape: the forests still recovering from nineteenth-century clear-cutting […]; contorted gneisses that are the surviving roots of Proterozoic mountains. The Ordovician is not a dim abstraction; I was there with students just the other day!" (The Proterozoic is a geological eon spanning the interval from 2.5 billion years to 541 million years ago, the Ordovician is a geological epoch lasting from 508 to 440 million years ago (ibid., p. 184)).

Another way to conceive the depth of time is through the collaboration of science and art. For instance, Hamburger Kunsthalle hosted an exhibition called 'Futura' in spring 2022. One exhibit, 'Perpetuum Mobile' by Nina Canell, showed a sack of cement next to a water basin agitated by ultrasonic waves. The water vapour from the basin caused the cement to harden slowly. According to the museum information, this display is supposed to trigger thinking about the irreversibility of certain processes. This installation resonated strongly with the topic of high-level radioactive waste disposal for two reasons. First, cement (as concrete) is one of the materials employed in the storage process of radioactive waste, and second, high-level radioactive waste is – at present – not fully recyclable (since only some of the materials involved can be reused and transmutation has not yet been successfully developed).

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In 2014, the US National Academy of Sciences dedicated an exhibition to the visualization of geological deep time (the depth of geological time compared to historical time). 15 artists were invited to consider the role art might play in comprehending such vast time horizons, which are way beyond the experience of individual humans and *Homo sapiens* as a species. The organizers suggested that "[u]nderstanding deep time lies, perhaps, in a combination of the rational and the intuitive" (Talasek 2014, p. 7).

In another attempt to grapple with deep time, artist Rachel Sussman has been researching and photographing living organisms older than 2,000 years, such as brain corals in the Caribbean or actinobacteria from Siberian soil samples which are at least 600,000 years old (Sussman 2014). These examples show that deep time is not only the domain of inanimate rocks but that certain living organisms might help to bridge the gap between historical time and geological time.

Another creative way of representing geological time is employed by the DeepTime Walk app (Deep Time Walk C.I.C. 2022). This app accompanies users on a 4.5 km walk through the history of the earth in a location of their choice (one metre equates to one million years) with an audio file combining scientific information and a poetic approach. Starting 4.5 billion years ago, what this Deep Time Walk makes particularly clear is the extent of time during which not very much happened, while events follow in quick succession during the last 500 metres. A similar approach is taken by representations of the history of the earth on a twelve-hour clock face. If twelve hours represent the 4.5 billion years of earth history, one second on the clock corresponds to 104,167 years and *Homo sapiens* has only been around for about three seconds (Brightmore 2022).

Instead of looking at the past, the rationale of the Deep Time Walk app and the clock face can also be used to look into the future of high-level radioactive waste disposal. Figure 2 shows a twelve-hour clock face in relation to the legal safety requirement of one million years. The figure makes very clear that our scope of action referring to the long-term goal is located only at the very beginning of the period. Even under conservative assumptions, e.g. through delays in the start of storage or in the closure phase, and with the addition of the 500-year recoverability period, we will not get beyond the first minute.

Conclusion: looking towards the future of high-level radioactive waste disposal

In the course of this article, we discussed two challenges for communicating the future of high-level radioactive waste disposal: incorporating the time horizon of 500 years after repository closure and representing one million years in a more meaningful way. For the first challenge, a number of solutions have been proposed or are already under way. Many of these suggestions focus on the transmission of knowledge from one generation to another, be it through the establishment of memory groups and the work of the OPE in France, Bjornerud's intergenerational commons or Magnason's thought-experiment. Concerning the second challenge, conceptualising one million years is likely to require creativity and leaps of imagination. Ultimately, Talasek's (2014, p. 7) proposition to combine "the rational and the intuitive" and the use of more creative visualizations might be a good place to start.

However, as long as people are not aware of the different conceptions and delineations of the time horizons involved in nuclear waste disposal, switches between them (which take place all the time and often unconsciously) can easily produce misunderstandings. 'Time literacy' is therefore essential to help people make meaningful decisions about the future.

By being aware that our genus *Homo* has only been present in the last 2.8 million years and that global climate changes were significant drivers of our evolution, the envisaged one million years of safety can be put into perspective with regard to their direct relevance for our actions today. Through the discovery of physical half-life, we have found a measure that enables us to calculate when the radioactive waste can be considered uncritical for humans in terms of its radiation. This led to the stipulation that the nuclear waste should remain isolated from the biosphere for one million years. Based on the laws of nature, this is a good way to justify the need for long-term final disposal of high-level radioactive waste.

Since we humans must subordinate ourselves to the laws of nature, without

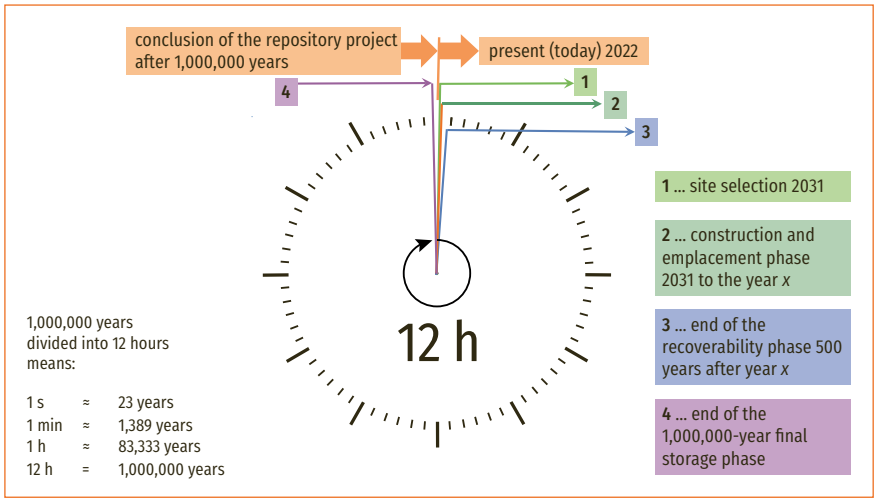

Fig. 2: Transfer of the time horizons of high-level radioactive waste disposal to a period of 12 hours.
Source: authors' own compilation

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representing one ourselves, it is not possible to make valid predictions for events that lie so far in the future, because we often behave arbitrarily and unpredictably even in the near future. Assuming that through delays and complications, the repository might only be closed 150 years from now, the 500-year recoverability phase would extend to 650 years from now. Insofar as one could speak of stability at all, and insofar as these periods until repository closure and the end of the recoverability phase of a repository in Germany could function as a stable phase of human society, we should concentrate (in implementation and communication) on this medium term of nuclear waste disposal. We must then trust that the generations living at that time will be able to live with what we have left behind based on the best possible considerations.

Successful outcomes are likely achieved by proceeding step by step without being blinded or disillusioned by the far-away horizon of one million years or the fast-approaching year 2031. The main task – and already enough of a challenge – is therefore to plan and manage the next 650 years of high-level radioactive waste disposal in an appropriate way. After that point, the manageable historical time of generations can slowly be allowed to phase out into the geological time of deep storage, even though conceptually and imaginatively, it might never be possible to fully bridge the gap between these two time horizons.

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RESEARCH ARTICLE

No time to waste: Exploring timeprints of radioactive waste management options in Belgium

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Abstract • Following the work of Barbara Adam (1998) and Ulrike Felt (2016), we draw particular attention to 'timeprints' in the assessment and selection of radioactive waste management (RWM) options. Using the example of Belgium, we identify four different timeprints mobilized (un)consciously by stakeholders when assessing RWM options, namely trajectorism, promise economy, radioactive waste identity, and multi-situated timeprints. We show that each of these timeprints has a significant impact on the RWM option to be considered and actively determines future radioactive waste management pathways in the form of 'tacit governance'.

***Keine Zeit zu verlieren**: Untersuchung von ‚timeprints' für die Entsorgung radioaktiver Abfälle in Belgien*

Zusammenfassung • *In Anlehnung an die Arbeiten von Barbara Adam (1998) und Ulrike Felt (2016) legen wir besonderes Augenmerk auf die zeitlichen Abläufe bei der Bewertung und Auswahl von Optionen für die Entsorgung radioaktiver Abfälle (radioactive waste management – RWM). Anhand des Beispiels Belgien identifizieren wir vier verschiedene ‚timeprints', die von den Interessenvertretern bei der Bewertung von RWM-Optionen (un)bewusst eingesetzt werden, nämlich ‚trajectorism', wirtschaftliche Versprechen, Identität radioaktiver Abfälle und ‚multi-situated timeprints'. Wir zeigen auf, dass jede dieser ‚timeprints' einen wesentlichen Einfluss auf die in Betracht zu ziehenden RWM-Optionen hat und die zukünftigen Entsorgungswege für solche Abfälle in Form einer ‚tacit governance' aktiv mitbestimmt.*

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Introduction

Time orders human actions and decisions, and is strongly entangled with questions of knowledge and control (Felt 2016). Deeply embedded in individual and collective narratives that give "feelings of stability and belonging" (Felt 2016, p. 2), time is not a straightforward physical entity. It is constructed and reflects clashes and wins that have concrete consequences for both the world we live and wish to live in. Yet, the politics of time is "all-too-easily naturalized and turned in the deep structure of taken-for-granted, unquestioned assumptions" (Felt 2016 b, p. 2).

By bringing time to the forefront of radioactive waste management (RWM) assessment and selection in Belgium, the purpose of this article is twofold. First, based on key analytical assumptions (Adam 1998; Felt 2016), it aims to highlight the framing power of time in RWM. We suggest this can help to understand the lock-in and alternatives of future RWM programs, by highlighting how temporal prints (called 'timeprints') inform the scope and impact of our current choices and designs through time. This paper is an invitation to explore RWM timeprints in different nuclear contexts. The Belgian case aims to pave the way, and, together with the political decision on high-level waste (HLW) management that has been pending for decades, it allows for a broader perspective to examine all RWM options and the potential timeprints they create, without framing the debate exclusively on the nuclear community's preferred option (geological disposal).

Concretely, we ask two questions: (1) How do geological disposal and alternative RWM options carry on and engage a particular temporal regime? (2) How do these competing temporal regimes order RWM? We rely on data collected during two rounds of online structured questionnaire submitted to 580 pre-selected Belgian stakeholders in 2019 (Parotte and Fallon 2020)[1]. We asked them to compare eight RWM options that were still being debated: geological disposal, eternal surface storage, eternal subsurface storage, storage on the site where the waste is produced, storage on the site where some waste is already temporarily stored, storage on a site to be determined, advanced nuclear technologies such as transmutation, and waiting for future generations to find a better solution (ibid., p. 13). We analyzed the implicit and explicit temporal narratives in the reasoning of Belgian respondents by adopting an interpretivist position.

In what follows, section 1 details the conceptual tools and the current state of RWM in Belgium. Section 2 describes the four identified Belgian RWM timeprints in order to highlight how each responds to its own motivations, which significantly change the option(s) to be considered. In the discussion section, we stress that every timeprint actively performs the future pathway(s) to manage HLW as a form of 'tacit governance' (Felt and Fochler 2010), understood as an implicit form of pathway orientation that performs institutions and individuals' reactivity (Espeland and Sauder 2007). We highlight the uneven consequences and conflicts between those RWM timeprints and suggest how they could potentially (re)order the RWM program. We conclude that identifying timeprints of the chosen RWM option (geological disposal or any other alternative) in each management program and considering its consequences could be an element in understanding the implementation (in)actions and their justifications.

Material and methods

To assess the temporal regime of RWM options, we mobilize three theoretical concepts: timescapes, living futures, and timeprints. Each insists on particular issues concerning the politics of time (Felt 2016), namely the situated nature of time, the relative linear sequence of time, and the persistent prints that time produces.

First, decrypting the framing power of time involves analyzing time in its relations with a particular sociotechnical environment. Barbara Adam (1998) combines 'time' with 'scape' to stress the intertwined character of multiple coexisting forms of time and their embodiment in a specific and unique context. In short, the concept of 'timescapes' fights against the universal idea of time to point out the existence of constant and situated 'temporal inconsistencies' – the challenges and tensions resulting from this simultaneous presence of different forms of time (Felt 2016 b).

To assess the temporal regime of radioactive waste management options, we mobilize three theoretical concepts: timescapes, living futures, and timeprints.

Second, Adam and Groves (2007) introduced the concept of 'living future', understood as neither predetermined nor indeterminate but embedded in everyday knowledge practices, to question the linear sequence past – present – future of a timeline. Every action contends 'a not-yet future' and an 'already there'. In this sense, time periods are strongly entangled and fictively sequenced. If the 'not yet' seems to be inaccessible to matter of facts, futures are still currently 'lived' (Adam and Groves 2007).

Finally, every action we take leaves particular prints. Adam and Groves (2007) also proposed the term 'timeprint' to question how far the impact of our present way of life extends space and matter across time. Particular knowledge practices can lead to consumption or appropriation of successors' futures (Adam and Groves 2007): future-making inevitably involves future-taking.

A responsible and ethical approach to the future implies taking this interconnection into account – our actions and their effects extend into the future present of subsequent generations – rather than acting solely from a present future perspective (Adam 2010).

With the illustrative 'temporal landscape' we have chosen, Belgium in 2019, the following sections explain how the study of 'timeprints' highlights contrasting 'living futures'. Belgium has a long history of nuclear power (beginning in the 1920s with the exploitation of uranium mines in Katanga) and with seven pressurized water reactors, the country remains highly dependent on nuclear energy production (49.7 % in 2021). Belgium deals with a relatively large amount of radioactive waste. For low-level waste (LLW), the surface disposal option was validated by the Federal government in 2006 after a participatory process launched in 1998. The long-term management strategy for HLW remains the main challenge, although the National Research Center for Nuclear Energy formally launched the preliminary research and development program on geological dis-

1 This paper focuses on a particular sample of the data collected during the Delphi survey (i.e., the responses to the questions comparing eight RWM options) to which we apply a different theoretical framework. For a full overview of the scientific report, see Parotte and Fallon (2020).

posal in 1974 and built an underground laboratory in 1980 to study this option. Two rounds of national public consultations (in 2009–2010 and in 2020) were organized to discuss the HLW program. Both the long-term waste manager (ONDRAF) and the regulatory body agency (AFCN) acknowledge geological disposal as the reference option, but public consultations and some environmental associations regularly emphasize the need for open debates on RWM (e.g. on options, framing, and the participatory process). Since 2011, successive federal governments have delayed the adoption of national program for HLW until very recently. In April 2022, the Federal Government agreed to pursue R & D activities for deep disposal in Belgium, to explore developing shared disposal facilities with interested countries, and to organize a public debate (Council of Ministers 2022).

Most Belgian stakeholders consider a promising radioactive waste management option to be 'feasible' given a predictable and manageable time horizon.

The data on which this article is based were collected in a Delphi survey that ran from April to November 2019, in a context of no political decision on a HLW program. Here, we exclusively focus on the sample responses of Belgian stakeholders relating to the comparison of eight plausible RWM options (n = 193)[2]. By following the temporal narratives (European Commission 2007) – a tacit way of sharing meaning and constituting a broader sense of direction (making and taking the future) – mobilised by Belgian respondents to compare radioactive waste management options, we identify four timeprints.

Four RWM timeprints in Belgium

Trajectorism

'Trajectorism' narrates an alignment of past, present, and future in a single pathway through which progress and economic success are collectively conceived as achievable (Felt 2016). This timeprint is particularly mobilized to assess geological disposal and future advanced nuclear technology options (e.g. transmutation), two main RWM options that have been studied for decades by the Belgian nuclear scientific communities. More than half of the respondents consider that the option of geological disposal is worth considering. While few justify why, the accumulation of scientific knowledge and the maturity of the option seem important. Respondents argued, for instance, that geological disposal is the *'most realistic' and 'appropriate'* considering knowledge accumulation, *'the only long-term solution'* which is *'permanent'*, and the *'only immediately operational final solution'*. In the more distant future, most of them plan to invest in advanced nuclear technologies. The generation of (future) scientific knowledge also seems to be an essential justification for providing *'newer and better technologies like transmutation'* that *'will provide solutions that do not exist today'*, or that *'will eventually be an alternative to geological disposal, which must be accepted until then'*.

Conversely, other respondents implicitly reject trajectorism, considering that the arguments listed above are not sufficient. They combine RWM options to keep all options open as *'for now, no option offers sufficient safeguard'* or at least they consider them as *'not mutually exclusive'*. For instance, geological disposal and transmutation may be combined due to residual waste; surface or on-site storage *'keeps options open for new technologies'* and are *'temporary solutions before geological disposal is operational in optimal conditions.'*

Both geological disposal and advanced nuclear technologies tacitly support the idea of a 'linear innovation trajectory' (Felt 2016 b), assuming that there is a cumulative path from here to there, specifically from now to tomorrow (Appadurai 2012). Envisioning one (or two) steadily unfolding direction of change, this timeprint relies on a predictable and calculable future through the projection of stabilized and upcoming knowledge (Adam 2010). It already conceives the scientific and economic living futures of RWM options, and how to debate them. For instance, without strongly supporting geological disposal, some stakeholders present it as *'a default choice'*. Trajectorism is driven by a logic of increasing returns (Arthur 1994) and the imperative to remain economically competitive: It affects what most funding is spent on, how research will (not) engage in innovation projects and closes down alternative innovation pathways (Felt 2016). Most Belgian stakeholders are aware of the closing down and monotonic process of this timeprint, and sometimes resist it by refusing the singularity of one particular RWM option.

Promise economy

This timeprint focuses on how (and what) emerging technologies can be seen as promising solutions to RW problems. Such promises work as a speculative bubble (Beckert 2016): despite the future's inescapable uncertainty, their narratives must instill confidence to create a performative fiction that attracts financial, political, and technical resources (European Commission 2007).

2 As the questionnaire was completed anonymously, quotes from respondents will not be referenced but in italics and between inverted commas.

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Hence, most Belgian stakeholders consider a promising RWM option to be *'feasible'* given a predictable and manageable time horizon. Again, geological disposal remains a relevant option in a short temporal frame: *'The problem of any alternative to geological disposal is its lengthy development time.'* In this sense, 'trajectorism' and 'promise economy' are mutually reinforcing, as promises foster a state of necessity and urgency that oppose the freedom to imagine multiple future pathways (Joly 2015). The shared multinational RWM option, which several stakeholders are combining with the geological disposal option, seems to be considered a *'highly desirable'* promise, while acknowledging that it is still in the conditional stage.

Respondents did not mention eternal surface storage or on-site storage options as a promise economy timeprint, but they are clearly divided on the promising option of transmutation. Some of them consider transmutation as a *'serious alternative to geological disposal'* to reduce the lifespan of HLW or to serve as an *'intermediate stage'* before future generations find an *'even better solution'*. The others are not convinced of its *'real added value'* for contrasting reasons that lead to other past and current pathways. One group considers transmutation to be a *'utopia'* that is not mature enough and *'too costly to be implemented as a mass technology'*. Instead, this group suggests reconsidering the reprocessing option legally abandoned in 1993 in Belgium. Another group explicitly refuses 'promise economy', either by arguing that *'we cannot continue to use possible future technological developments as an excuse to delay the decision'* or by considering them as a deferral of responsibility. As they deem that *'no option is convincing for now'*, surface and on-site storage investment should be *'the priority […] set on improving the safety of the option used now as a temporary solution'*.

This timeprint leads to contrasting imaginaries of technological progress: a progressive one based on an optimistic consideration of the role of technology in the future (in favor of different RWM options such as shared geological disposal, transmutation, and reprocessing) versus a precautionary view highlighting a more skeptical position.

Radioactive waste identity

This timeprint explores how the different ways of naming a radioactive object affect which RWM options are preferred in the future. Some respondents emphasize that a distinction should be made between waste, which is considered as *'not retrievable'*, and spent fuel, which may offer *'potential energy resources.'* Others expect that the identity of the radioactive object may change over time, for example when future innovations and knowledge could turn *'old waste into a resource.'*

With regard to the transmutation option, some stakeholders specify that it is potentially a relevant option for future waste but that it *'does not constitute a solution for current vitrified waste'*. What about the final waste that will always remain? They sustain that the leftovers not included in the current classification will influence what to consider *'as a solution in itself.'* For still others, on-site storage and subsurface storage options offer the *'important advantage'* of ensuring easy retrievability of the waste and its future use. Stakeholders in favor of geological disposal face similar debates: some consider *'passive disposal'* as a prerequisite for geological disposal, which closes the debate on the identity of the radioactive object; others argue that it would be *'fair to let future generations judge the attractiveness of waste'*. Besides, the plural identities of radioactive objects in different countries call into question the operationalization of a multinational RWM option. One respondent reminds us that, for the time being, *'there is a diversity of waste to manage but a uniqueness of storage.'*

RWM options are redefined through both temporal and competing imaginaries, as the identity of the radioactive object requires fundamentally opposing strategies in different timescapes: It can be considered either as a resource (actual or potential) that is stored before being reused, or as a byproduct that must be permanently disposed of.

Multi-situated

The multi-situated timeprint addresses the mobility of RWM options and how temporal narratives relate to different sites.

Most Belgian stakeholders strongly support the possibility of a shared multinational option, which is seen as *'technically desirable'* and as a *'potential game changer'* capable of reaching beyond the country's official borders. Some argue that it is particularly relevant for small countries: *'It is irrational to imagine a country the size of Belgium or Luxembourg developing its own program for small waste quantities.'* But for many, it is also a *'utopia'* because of the ethical and legal challenges, such as the waste ownership and responsibility through time, cost sharing between countries and generations, different political and cultural sensitivities, and waste and regulatory management systems. They raise additional concerns about risks and unfair host site selection.

The situatedness (or lack thereof) is a concern for all other RWM options, but is not regularly mentioned. For instance, stakeholders did not distinguish between on-site storage options but expressed concerns about the safety and site exposure (e.g. radiation and external threats) associated with any *of* the on-site, eternal surface storage, and subsurface storage options.

Options are presented as detached from sites, even if any innovation trajectory develops out of a complex entanglement of situated histories (Felt 2016b). They are narrated as generic despite the very situated character of the timeprint.

Discussion

This paper highlighted the RWM timeprints in a particular timescape in Belgium in 2019, and the contrasting living futures in Belgian stakeholders' narratives of long term RWM. Stakeholders mobilize implicit and explicit temporal narratives to justify actions or favor one particular solution.

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Ordering, clashes, and silences of RWM timeprints in Belgium

In this first part of the discussion, we summarize our findings on the Belgian case and underline that a hierarchy is produced among RWM options. Our results support the first of Felt's (2016) arguments about the 'politics of time': The four identified timeprints tacitly order the RWM pathways by reinforcing some and overlooking others. With 'trajectorism', both scientific and economical 'living futures' of RWM options encourage funding for geological disposal and advanced nuclear technologies. The accumulation and promise of scientific knowledge are a central rationale for the future of RWM and are primarily aligned with past and current Belgian R & D projects. Interestingly, Belgian stakeholders (even if they were not all scientists) have assimilated that geological disposal has been presented as the only option (even as a default choice). The 'promise economy' timeprint, strongly associated with a manageable time frame, reinforces an alignment of past, current, and future knowledge to also support the already funded options: geological disposal and transmutation. The radioactive waste identity timeprint emphasizes that today's waste could be tomorrow's resource and that these current uncertainties are mobilized to revive past options (e.g. reprocessing), to avoid more challenging options (e.g. shared multinational option), or to provide retrievability components to any RWM option. Finally, the multi-situated timeprint emphasizes how situatedness (or lack thereof) both supports arguments to justify and challenge a shared multinational solution (primarily associated with the geological disposal option) while it is (un)consciously kept out of the way of current on-site options and alternatives.

Our analysis confirms the second of Felt's statements (2016b): the politics of time is about clashes, inconsistencies, and silences. Aware of the uneven consideration of RWM options, some stakeholders argue, explicitly or tacitly, for control over the framing power of timeprint, and several alternative temporal narratives are proposed. Options should be combined rather than seen as mutually exclusive (e.g. transmutation should be seen as complementary to geological disposal). Improving current surface and on-site storage should be explored, even as a temporary solution before other options are sufficiently mature. The retrievability element of the RWM option should be considered as the primary criterion for eternal storage or as an additional element for geological disposal. Even options presented as 'utopian' (e.g. shared multinational or not-yet-existing technological RWM options) are brought to the fore. We interpret these attempts as a *re*-action to the tacit governance that sustains the two well-known RWM options explored for decades in Belgium: geological disposal and the transmutation option.

Last, we believe that absence of data – the silences – is an outcome in itself. We emphasize how situatedness remains secondary in the RWM timescapes: The (future) multi-situated character of any option is mostly kept out of stakeholder discourses. It is interesting to note how stakeholders silence the operational temporalities – "a nexus of political-economic forces, scheduling and regulatory pressures" (Ialenti 2021, p. 3) – related to current on-site options. The so-called 'temporary' on-site storage options are the most permanent RWM option already built, on distributed sites of nuclearized countries. Similarly, favoring the shared multinational option can be interpreted as another silence to avoid the 'scape' of our nuclear timescapes. Managing our situated waste (where it is produced) to other sites disentangles time and scape.

How to maintain the responsible entanglement of our waste? And how to ensure the reliability of any political organization over such a long-term horizon?

Choreography of RWM timeprints

This second part of the discussion extends the reflection beyond our empirical findings and discusses how this hierarchy among RWM pathways might be challenged in the future. We draw on what Felt (2016b) called 'choreography' of RWM timeprints: they are connected, overlapping, and intersecting. While every timeprint defines engagement in the RWM program and the preferred option(s) differently, they collectively shape it at the same time with uneven connections. This has implications for RWM programs, and for how accountability is addressed.

In our case, the prevalence and combination of temporal timeprints (trajectorism with promise economy) create grooves so deep that they are difficult to break out of. Strongly linked with a vision of 'manageable time for operationalization', these associations of time components mark the 'living future' in an indelible way. RWM alternatives have little space to be considered at present. Thus, it prevents disruptive innovation from occurring, it silences other ways of thinking, and it imposes thinking *with* and *for* the option of geological disposal. It can support the illusion that no further public debate is needed once a technological path is chosen, that 'matters of facts' are apolitical and latent, and thus also matter when it comes to issues of responsibility (Felt 2016b).

However, we argue that some timeprints could potentially change the game in RWM program and stress the need to test this framework in different nuclear contexts. Indeed, we speculate that the identification of timeprints could prove to be a key

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issue in RWM for several countries. First, in countries where waste and spent fuel can still be considered a resource, the identity of radioactive waste coupled with 'promise economy' can produce contrasted living futures: with or without reprocessing (opens up the debate for nuclear energy futures) and with or without retrievability (under what conditions?). Fixing all radioactive objects in waste category organizes the right to forget or to remember and engages a clear "system of *rendez-vous* into legislation; a mutual engagement in time towards the 'fair, accurate and efficient' distribution of financial responsibilities" (Saraç-Lesavre 2020, p. 443). Second, the shared multinational option has attracted more attention in recent years. Indeed, whether to reduce costs, to share knowledge, or to cope with spatial and geological constraints, several countries are willing to jointly explore this option. Eight RW operators (of which Belgium is not part) have recently institutionalized their collaboration in the European Repository Development Organization.

Combined with the trajectorism timeprint, the multi-situated timeprint challenges the 'where' question of RWM programs and reminds us that even a shared multinational option always concentrates RW somewhere. On an ethical level, we can also see it as a way of thinking about our waste located elsewhere: Once the object is removed, the time of the waste can be evacuated. However, negotiations to organize waste mobility will be another challenge. Specifically, how to maintain the responsible entanglement of our waste, how to ensure the reliability of any political organization over such a long-term horizon, and how to cope with emerging geopolitical disorders and with national dissolutions. Being highly dependent on the relationship between countries and its evolution, this challenge raises an important question about the ability of sharing timeprint to invent a collective and legitimate tradition capable of linking multinational pasts and futures.

Conclusion

There is no time to waste. Time, especially in RWM, remains "an invisible infrastructure" (Felt 2016, p. 3) that can no longer be set aside for analysis of RWM options, programs, and actions. Exploring temporal narratives, the produced timeprints and their consequences on RWM program is one way to begin. From our analysis, we draw four systematic questions to assess the framing power of time on any national RWM program: (1) What are the temporal narratives behind the RWM option selected in your country? (2) What kind of timeprints are produced with the selection and implementation of RWM option? (3) Are these RW timeprints mutually exclusive or mutually reinforcing or weakening? (4) What timeprints do we share with other nuclearized countries and how does it open up or close down RWM futures?

The analysis of the framing power of time acts reminds us that our current (non)-actions on RWM are built on a situated temporal and sociotechnical legacy, while generating latent living futures and condemning others. Consideration of the politics of time and the entangled timeprints of RWM options may nuance the nuclear community's common assumption that geological disposal is the only long-term solution because 'there is no alternative'.

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RESEARCH ARTICLE

‚We have a solution': Delivering on the promise to take national responsibility for nuclear waste management

Matti Kojo*[,1], Markku Lehtonen[2], Tapio Litmanen[3], Niina Kiviluoma[3]

Abstract • We examine the realization of the umbrella promise to assume national responsibility for the final disposal of spent nuclear fuel. Three case studies are used to illustrate how Finland delivers on the promise to take care of its own nuclear waste – a promise that has greatly contributed to the legitimacy of nuclear power in Finland. The article shows how this promise is being challenged by new competitors, business visionaries, and the public. The case studies illustrate the tensions between those who made the promise and the actors who interpret and mobilize the promise for varying purposes and under changing circumstances. We investigate techno-scientific promises by looking at debates about (1) the idea of a national solution, (2) the limitations that the promise of a national solution places on international business opportunities in the waste sector, and (3) the challenges related to credibility and spatial requirements in managing waste from small modular reactors.

‚Wir haben eine Lösung': Einlösung des Versprechens zur nationalen Verantwortung für die Entsorgung nuklearer Abfälle

Zusammenfassung • *Wir untersuchen die Umsetzung des Versprechens zur nationalen Verantwortung für die Endlagerung von abgebrannten Kernbrennstoffen. Anhand von drei Fallbeispielen wird gezeigt, wie Finnland das Versprechen umsetzt, sich um seinen eigenen Atommüll zu kümmern – ein Versprechen, das wesentlich zur Legitimität der Kernenergie in Finnland beigetragen hat. Der Artikel zeigt, wie dieses Versprechen durch neue Wettbewerber, unternehmerische Visionäre und die Öffentlichkeit infrage gestellt wird. Die untersuchten Fälle veranschaulichen die Spannungen zwischen denen, die das Versprechen abgegeben haben, und den Akteuren, die das Versprechen für unterschiedliche Zwecke und unter sich ändernden Umständen interpretieren und mobilisieren. Wir untersuchen technisch-wissenschaftliche Versprechen anhand von Debatten über (1) die Idee einer nationalen Lösung, (2) die Einschränkungen, die das Versprechen einer nationalen Lösung für internationale Geschäftsmöglichkeiten im Abfallbereich mit sich bringt, und (3) die Herausforderungen in Bezug auf Glaubwürdigkeit und räumliche Anforderungen bei der Entsorgung von Abfällen aus kleinen modularen Reaktoren.*

Keywords • *promises, nuclear waste, repository, Finland, responsibility*

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Changing context, changing promises

The promise of national responsibility for the management of spent nuclear fuel (SNF) generated in the country has helped to make Finland a forerunner among the developers of deep geological disposal. Posiva[1], the nuclear waste management (NWM) company has proudly announced: "We have a solution" (Posiva Oy 2022). Other Finnish actors have frequently relayed the message. However, back in the early 1980s, the Finnish SNF management policy relied on the exportation of SNF and thus on international (Soviet and Western) nuclear fuel cycles. The policy

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1 The mostly privately owned energy company Teollisuuden Voima (TVO) (60 %) and the mostly state-owned Fortum (formerly fully state-owned Imatran Voima, IVO) (40 %) are the shareholders of Posiva.

changed in 1994. The revised Nuclear Energy Act prohibited the export and import of nuclear waste and stipulated that nuclear waste generated in Finland (with the exception of waste from research reactors) must be permanently disposed of in the country itself (Sandberg 1999). Thus, Finland promised to take responsibility for its own nuclear waste. Eurajoki, the proposed repository siting municipality, also adhered to this idea, announcing in 2000 that it would accept only Finnish SNF for disposal on its territory (Kojo 2009, p. 184).

This article examines the ways in which the promise of national responsibility has been gradually transformed, in response to the changing context and as a result of active promise-construction work by the key actors. Three case studies from the post site selection phase in Finland serve as illustration. Document analysis and opinion surveys are used to illustrate the promises and their consequences, including the implications for the credibility of the promise in the eyes of residents.

The government issued a decision in principle (DiP) in 2000 for the final geological disposal of 4000 tU (from the Olkiluoto 1-2 and Loviisa 1-2 nuclear power plant (NPP) units), and confirmed Olkiluoto, in the municipality of Eurajoki as the site for the repository. In 2002, as part of the DiP for the new Olkiluoto 3 unit, the government approved the expansion of capacity by the 2500 tU that the new reactor was expected to produce. The construction permit for the encapsulation plant and the repository with a capacity of 6500 tU was granted in 2015. In 2021, Posiva submitted its application to operate the repository from 2024 until 2070.

The perspective of techno-scientific promises

The 'success story' of the Finnish nuclear waste management (Lehtonen 2021) can be described as a process of successfully constructing promises that are collectively experienced as credible and legitimate. Promises and expectations are vital to the development and deployment of techno-scientific innovations. They set things in motion by aligning actors, institutions, and capital; they "guide activities, provide structure and legitimation, attract interest and foster investment" (Borup et al. 2006, pp. 285–286; see also Joly 2010; van Lente 2012).

In this article, we focus on the continuous need to reshape and even radically transform the promise to ensure its legitimacy and credibility. We use the term techno-scientific promise to encompass 1. the relatively vague visions ('umbrella promises'), 2. more specific statements about the future of a given technology, and 3. the institutionalization and materialization of promises in policies, laws and regulation, funding decisions, projects, and commercial applications (Parandian et al. 2012). Promises vary in their degree of self-evidence and in their content (e.g., technical, commercial, societal, symbolic, and material aspects). Promises differ from other expectations in that they are, by definition, positive, as well as relational, that is, they entail interaction between 'promise-makers' and 'promise-takers'. The confrontation of promises and counter-narratives in debates between these rival groups can play a constructive role as 'trials of strength' that can strengthen the promise and its social robustness (Alvial-Palavicino 2015, pp. 158–159; Joly 2010).

Van Lente (2012) identified three main positive functions of promises: In particular, broad 'umbrella promises' legitimize investment by referring to a promising future; they provide direction by facilitating choice among options; and they help coordinate action by providing insight into the behavior of other actors in the system. When successful, promises create inescapable 'passage points', a sense that a particular technology is essential to achieving desired societal goals and visions (Joly 2010). More generally, promises link past, present, and future by drawing their power from historical precedents, on the one hand, and positive or negative future scenarios, on the other (Chateauraynaud and Debaz 2017).

The construction of umbrella promises of national responsibility

To explain why the promise of national responsibility for SNF management is crucial to the Finnish nuclear industry, we must first examine the origins and institutionalization of this umbrella promise, which can ultimately be traced back to Finland's accession to the European Union in 1995. The Finnish bedrock was repeatedly portrayed in the public debate as a potential target for imported nuclear waste – the horror picture was a 'graveyard' for foreign nuclear waste in Finland.

The emergence of the promise of national responsibility was also fueled by growing criticism of SNF exports from the Loviisa NPP to Russia. As a result, an amendment to the Nuclear Energy Act banned both exports and imports of nuclear waste. This, in turn, prompted IVO and TVO to establish a joint SNF management company, Posiva, in 1995, to help the companies meet their legal disposal obligation (Darst and Dawson 2010, pp. 67–69; Sandberg 1999; Nikula et al. 2012, pp. 37–39, 71).

Without explicitly using the term, the law essentially defines national responsibility by prohibiting the export and import of nuclear waste. The law states that "nuclear waste generated in connection with or as a result of use of nuclear energy in Finland shall be handled, stored and permanently disposed of in Finland" and that "nuclear waste generated in connection with or as a result of the use of nuclear energy elsewhere than in Finland shall not be handled, stored or permanently disposed of in Finland"[2].

The promise of national responsibility in Finland was further advanced by a change in policy, namely the abandonment of the reprocessing option. Initially, the policy envisioned reliance on the international nuclear fuel cycle, i.e., shipment of SNF abroad for reprocessing. Responsibility for the practical implementation and funding of NWM rests with licensees. No

2 Nuclear Energy Act 990/1987, 6 a, b.

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state nuclear waste agency has ever been established, although this option was included in the Atomic Energy Act in 1978 (Nikula et al. 2012, pp. 58–59, 64).

In 1981–1996, IVO transported SNF from its Soviet Loviisa-type NPP units to the Soviet Union and later to Russia, as agreed by the Finnish and Soviet governments in 1969 (Sandberg 1999, pp. 45–46). TVO also inquired about the availability of reprocessing services in several countries. The situation changed in the mid-1970s when the companies providing reprocessing services changed the terms of the contract and required that waste producers such as TVO commit to taking back and disposing of the remaining high-level waste after reprocessing. TVO also found the contract too expensive (Darst and Dawson 2010, pp. 65–66; Nikula et al. 2012, pp. 58, 79). In 1976, the Ministry of Trade and Industry established a working group to investigate NWM in Finland, and in 1978 and 1983, the government adopted the policy (Suominen 1999, pp. 25–26, 30–31). However, IVO could continue exporting SNF, because the Soviet Union did not require the return of residual waste.

Until the 1994 amendment of the Nuclear Energy Act, reprocessing was the primary objective for licensees, as defined in the 1983 policy decision. In the early 1980s, TVO started planning direct disposal of SNF in Finland, based on the Swedish KBS3 concept (Kojo and Oksa 2014a, pp. 24–25). At that time, the cost of reprocessing was estimated to be twice that of direct geological disposal (Nikula et al. 2012, pp. 77, 88). The import and export ban institutionalized the promise of national responsibility. In the following years, Posiva invoked this promise in its communications by emphasizing that it managed the nuclear waste generated by Finland's NPPs. The company presented itself as guardian of the nation's interests, not just those of its owners (Kojo 2002, p. 41). In addition, the Eurajoki host municipality announced in 2000 that it would only allow SNF from the Finnish NPPs at the Olkiluoto site (Kojo 2009, p. 184).

The case studies

Our first case study examines the transformation work and the dispute over the meaning of the relatively vague and visionary umbrella promise (Parandian et al. 2012). The case shows how this vision of ‚our solution' was first challenged by the Finnish energy companies. It illustrates the difficulties faced by a new entrant that wanted to join Posiva's repository project, and how the views of Posiva's owners about a possible expansion of the Olkiluoto repository underpinned the need for a second repository in Finland. To protect their interests, Posiva and its owners had to specify the umbrella promise.

Specifying the umbrella promise: the dispute over the promise of national responsibility

In 2007, the newly established energy company Fennovoima applied for a permit to build a new NPP and therefore needed to demonstrate that it had a reliable NWM solution. The company announced that it would manage its SNF jointly with Posiva. In doing so, Fennovoima emphasized national responsibility, arguing that Posiva had been established to manage all SNF generated in Finland in a single Finnish repository in Olkiluoto (Fennovoima 2009, p. 11). Posiva, however, developed a counter-narrative by invoking the principle of licensee-specific responsibility – the obligation of each energy company to take care of its own SNF. Posiva also argued that its owners would need the limited space in Olkiluoto for future energy production. It was also unwilling to dig disposal tunnels that would run under the sea or the NPP (Kojo and Oksa 2014b, p. 32.)

The promise of national responsibility has not only underpinned the rejection of reprocessing and long-term interim storage as unacceptable NWM solutions, but also helped to consolidate the position of nuclear power as a cornerstone of Finnish energy and climate policy. In its DiP application, Fennovoima (2009, p. 11) announced that it would develop and implement SNF disposal together with other Finnish utilities bound by the nuclear waste management obligations, to improve operational safety and reduce costs. Fennovoima further noted that the state could require licensees to cooperate if necessary to ensure the general welfare of society, as stipulated in the Nuclear Energy Act.

Parliament ratified the DiP for Olkiluoto 3 in 2002 and for Olkiluoto 4 and Fennovoima's Hanhikivi 1 in 2010. At the same time, the government approved Posiva's application to expand the final disposal capacity to accommodate SNF from Olkiluoto 3 and 4. The government gave Fennovoima six years to either agree on final disposal of SNF with TVO and Fortum or launch an Environmental Impact Assessment (EIA) procedure for its own repository (Finnish Government 2010, p. 16). Fennovoima's EIA program (Fennovoima 2016, pp. 16–17) indicated Eurajoki, albeit excluding the Olkiluoto site, as the first choice for repository, and the municipality of Pyhäjoki – the host of its planned new NPP – as the second option.

The promise of national responsibility failed to coordinate actions when a new player appeared on the scene. Posiva's shareholders, TVO and Fortum, repeatedly indicated that they were not interested in discussing final disposal with Fennovoima. They described Posiva as 'our solution', and the repository as designed to receive waste only from its owners' plants, including the possible new Olkiluoto 3 and 4 units – although the state is the majority owner of Fortum, it did not exercise its steering power on this issue (Kojo and Oksa 2014b, p. 18). Posiva explicitly ruled out nationalization and sought to strengthen its image as a private company accountable solely to its owners.

The ministry struggled to force the companies to cooperate on NWM. Cooperation in the form of know-how and provision of services came about only after the ministry established a joint working group with the companies in 2012 (Kojo and Oksa 2014b, pp. 33–38). Later, in 2016, Posiva's subsidiary Posiva Solutions signed an agreement with Fennovoima on technical expert services related to site selection (Lehtonen et al. 2021, p. 135), but Fennovoima was never allowed to participate in Posiva's SNF repository project.

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Stretching the national responsibility to create business opportunities

Our second case study describes another shift in promise, provoked by recent initiatives that propose to turn NWM into a major business opportunity, building on Finland's reputation as a pioneer. For example, the former deputy director general of the International Atomic Energy Agency, Olli Heinonen, proposed building a few additional repositories in Finland for waste from abroad to make the country a model for others and reduce the risks of terrorism and proliferation (Heinonen 2012). To make this promise a reality, economic visionaries sought to extend the scope of the promise from national to international responsibility. This, in turn, would require lifting or softening the ban on waste imports.

Two recent corporate initiatives illustrate the transformation: One launched by the start-up Avalon Energia established in 2017, and another by the Ecomodernist Society of Finland (ESF), a pro-nuclear NGO founded in 2015. To legitimize the promise, which he described in his LinkedIn-profile as safely disposing of "global high-level nuclear waste in a network of deep geological repositories in the bedrock of Finland", Robert Nemlander argued this would bring economic benefits to the host municipalities, the company, the government, and society at large, but would also help to create a better world for our children by combating climate change via greater use of nuclear power (Nemlander 2019, pp. 36–37). Importing waste would generate profits of some ten billion euros per year, that is, one trillion euros over the hundred years of the repository operation; enough to allow Finland to introduce universal basic income. If reprocessed, Nemlander argued on LinkedIn, the imported SNF could "power the entire planet with clean energy for over 70 years". Avalon's action plan highlights gaining public support and identifying repository sites as important steps on the path to Finnish NWM business.

In 2021, the ESF suggested legislation and research and development as tools for advancing Finnish NWM exports. The ESF proposed amending the Nuclear Energy Act to allow trade in SNF, as this would remove barriers to rational climate solutions and vast export opportunities for Finland in technologies such as nuclear-powered district heating. In addition, the amendment would help other countries to clean their energy systems, consolidate Finland's reputation as a low-carbon country, and enable Finland to export service packages for the entire nuclear energy life cycle including the handling of nuclear waste. Given Finland's pioneering role in responsible nuclear waste management, the change would also be ethically justified (ESF 2021 a).

For Avalon Energia, a network of repositories would pave the way for further construction of nuclear power. It predicted that "public support for nuclear energy skyrockets if the waste issue is solved" (Nemlander 2019, p. 22). Avalon described Finland as "the best chance for international HLW [high-level waste] repositories due to politics, geology, tech and limited time" (Nemlander 2019, p. 22) but saw permanent geological disposal only as a step towards the ultimate goal of recycling of HLW, once the technology would become available.

Like Avalon Energia, the ESF stressed the importance of waste management in the nuclear technology service packages (ESF 2021 b). The Society's suggestions aligned with calls from Finnish Energy, the Finnish energy-sector advocacy group, for a market-based and technology-neutral approach to NWM from small modular reactors (SMRs) to keep the door open for various disposal options, including reprocessing and SNF export. "The regulation should enable business in new areas of nuclear energy" and "guide solutions only to the extent necessary to ensure safety, security, and non-proliferation" (Finnish Energy 2021, p. 5).

Nearly half (43 %) opposed final disposal, and 46 % opposed long-term storage in their neighborhoods.

Credibility of the promise: NWM of small modular reactors

A third challenge for the initial promise of national responsibility stems from the planned SMRs, and local residents' views on the options for managing SNF from such reactors. A positive expectation of citizens regarding SMR waste would be an indication that promise-building has succeeded in convincing a stakeholder group that is important for the development of the technology. Crucially, the decentralized nuclear power production model entailed in the SMR vision questions the promise of national responsibility. As nuclear power is increasingly framed as a key contributor to energy security and combat against climate change, SMRs have been suggested as a means of decarbonizing district heating, necessary for the cities in the Helsinki Metropolitan area to reach its CO_2 emission reduction targets. However, little attention has been paid to the management of nuclear waste from SMRs – a potential obstacle to the fulfilment of the SMR promise. Crucially, the option of siting the waste locally challenges the vision of a centralized national solution. Results from a resident survey conducted in the Helsinki metropolitan area in November 2021 reflect the ambiguities, hesitations and contradictions involved. Indeed, citizen's opinions were divided, both on the possible construction of SMRs and on the associated waste management options (Kojo et al. 2022).

Most respondents expressed reluctance to the idea that SNF accruing in SMRs should be handled at the local level. Nearly

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half (43 %) opposed final disposal, and 46 % opposed long-term storage in their neighborhoods.

However, in apparent contradiction with this reluctance to accept local solutions, 57 % of the respondents agreed that transporting waste generated by SMRs would be dangerous. The possibility of transnational waste trade faced mixed views: 45 % opposed the idea of disposing of imported nuclear waste at the Eurajoki site, while 48 % held a neutral opinion regarding a possible amendment to the Nuclear Energy Act that would allow SMR waste to be returned to the producer abroad.[3] Most respondents (60 %) favored a centralized solution to the final disposal of SMR waste. However, the preferred location of SMR waste management remained unclear, as half of the residents were neither clearly in favor nor against disposing of the waste in Eurajoki, the site of the original ‚national solution'.

Conclusions

In the past decades, the promise of national responsibility was a political statement used to allay fears that nuclear waste would be imported to Finland (after the country joined the European Union) and to demonstrate that nuclear waste from new NPP units would be managed responsibly. In the 1990s, the nuclear industry still believed that the construction of multinational repositories would conflict with the national disposal plan (Nikula et al. 2012, p. 92). Since then, the situation has changed. Some actors have suggested legislative changes that would allow imports and exports of nuclear waste, generate business opportunities, and diversify the options for managing waste from possible SMRs.

This article described the gradual transformation, in reaction to changing circumstances, of the umbrella promise that has underpinned the continuity and legitimacy of nuclear power in Finland, namely that the country takes care of its own nuclear waste. Changing policy circumstances and pressure from diverse involved actors have led to further specification and continuous disputes over the very nature of the promise of national responsibility, with attempts to redefine this responsibility in international rather than national terms. This promise-transformation work involved, first, the entry of a new player in the field. The incumbent players were unwilling to accept the new entrant, and prioritized licensee responsibility for SNF management over a national centralized repository solution. Second, the transformation of the business landscape further spurred a move away from the narrative of a centralized national solution, as the energy industry, start-ups, and ecomodernists brought to the table visions in which waste trade and SMRs would open lucrative new business opportunities, in the spirit of national interest. Third, the incipient efforts to bolster the legitimacy and credibility of the SMR vision in the eyes of the public are reflected in the relatively positive views among local residents concerning possible SMRs. However, the unresolved issue of how to deal with the waste from a possible decentralized SMR fleet divides residents' opinions and forces further changes to the initial version of the national responsibility promise, built on the vision of centralized waste management.

Earlier research on techno-scientific promises have often either stressed the role of hype-disappointment cycles (Parandian et al. 2012) or analyzed the various functions of promises (Van Lente 2012). Our case studies highlight the need to complement such analysis of the performative power of a given promise with more fine-grained studies of the ways in which the initial promise gets transformed through active transformation work undertaken by the involved actors, and how policy, innovation, promises as well as actor behavior and preferences co-evolve. In current Finnish NWM policy, such transformation efforts imply pressures towards more market-oriented policy approaches.

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3 In 2016, almost three out of four of Finns disagreed with the statement "I accept the final disposal of nuclear waste generated abroad in Olkiluoto, if it is found to be safe", Aarnio et al. 2017, p. 19

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RESEARCH ARTICLE

Intergenerational justice starts now: Recognizing future generations in nuclear waste management

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Abstract • Intergenerational justice is an inherent component of nuclear waste management. By looking at challenges of intergenerational justice at various stages of the repository siting process, the following thesis is discussed: Current generations can anticipate notions of intergenerational justice by applying high procedural standards to enable equitable distribution between generations and thus adequately recognize the needs of future generations. Applying high standards in this context means a constantly critical, reflexive, and open process, without bias or selfishness. This requires representative bodies such as the German Council of the Young Generation ('Rat der jungen Generation') that act as a bridge to future generations.

Intergenerationale Gerechtigkeit beginnt jetzt:
Anerkennung künftiger Generationen bei der Entsorgung radioaktiver Abfälle

Zusammenfassung • *Intergenerationale Gerechtigkeit ist ein wesentlicher Bestandteil der nuklearen Abfallentsorgung. Anhand von Herausforderungen der intergenerationalen Gerechtigkeit während verschiedener Phasen des Standortauswahlverfahrens und der Endlagerung wird die folgende These diskutiert: Heutige Generationen können Vorstellungen von intergenerationaler Gerechtigkeit durch die Anwendung hoher Verfahrensstandards antizipieren, um eine gerechte Verteilung zwischen den Generationen zu ermöglichen und damit Bedürfnisse künftiger Generationen angemessen zu berücksichtigen. Die Anwendung hoher Standards bedeutet dabei einen konstant kritischen, reflexiven und offenen Prozess, ohne Voreingenommenheit und Eigennutz. Dies erfordert, dass repräsentative Gremien wie der ‚Rat der jungen Generation' als Brücke zu künftigen Generationen fungieren.*

Keywords • *nuclear waste, justice, repository, environmental justice, representatives*

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On the importance of intergenerational justice

Notions of intergenerational justice are inherent to discussions about nuclear waste management. In Germany, the site selection process for a high-level nuclear waste (HLW) repository is ongoing. The target of the process is to find a geological formation that can guarantee the best possible safety for the disposal of nuclear waste for one million years. Additionally, the retrievability of nuclear waste shall be possible for 500 years after the initial deposit.[1] In comparison: The industrial revolution, which can be regarded as the foundation of modern-day Europe, took place around 250 years ago – this societal transformation is unmatched to this day. Social change takes place in shorter periods than the decay of nuclear material.

Current generations have to deal with a burden that was imposed on them by past generations and find themselves exposed to past decisions, that they could not (dis)approve. The legal basis for the site selection process in Germany, the 'Repository Site

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1 In German legislation there is a difference between reversibility and retrievability. Reversibility comprises the planned technical possibility to retrieve HLW during the operating phase, while retrievability refers to unplanned retrieval of HLW from a repository, Standortauswahlgesetz (RSS-Act), § 2.

Selection Act' (RSS-Act, StandAG) determines the "avoidance of unreasonable burdens and obligations for future generations"[2]. Choi and Matsuoka (2020) note that the forwarding of burdens (and benefits) from generation to generation is unavoidable. Current decisions will affect future generations: In the case of nuclear waste, this means that current generations will need to find a suitable repository site and future generations will bear the risk of a nuclear waste repository, without benefiting, e.g. via 'cheap' energy (Shrader-Frechette 2000). As decisions on energy infrastructure are often determined in a 'moral vacuum' (Jenkins et al. 2018), the inclusion of intergenerational justice requires serious and sincere consideration. Warren (2002) describes, that democratic inclusion relies on the opportunity of affected actors to influence a decision. Reciprocity is not achievable, as future generations cannot represent themselves personally, but rely on current generations to anticipate their needs: A dilemma arises that needs to be resolved for a nuclear waste repository site to be perceived as just from an intergenerational point of view.

The inclusion of intergenerational justice requires serious and sincere consideration.

The following thesis will be discussed: Intergenerational justice can be enabled by setting high standards in the procedure, distribution, and recognition within the current site selection process. The qualifier high describes that standards need to be critical, reflexive, and open for adaptation without bias or selfishness. Hence, justice for future generations is intrinsically linked to justice in current generations. Additionally, I provide challenges and opportunities for the long-term perspective of intergenerational justice.

State of research

Questions of intergenerational justice typically revolve around the extent of current generations' responsibilities (Blowers 2010), whether it is fair to deprive future generations of their flexibility (Leigh and Dotson 2011), or whether an inclusive discourse with future generations is possible. Spaemann (2003) states that merely a fictional dialogue is possible. Hocke (2021) complements that such a discourse is entirely in the hand of current generations, thus revealing a power asymmetry between current and future generations. Even in current generations, many different approaches fit the idea of acting responsibly towards future generations by either granting flexibility or freedom. This translates into the debate around reversibility and enclosure for an HLW repository (Ott and Semper 2017).

Gosseries (2008) states that intergenerational justice is achievable if the needs of future generations are not compromised upon by current generations. He argues that the capital (in its broadest sense; not narrowed down to a purely economic capital) that a current generation forwards to a future generation, should not be smaller than the capital that it received from a past generation. For nuclear waste, current generations have to deal with a legacy that was inherited from past generations. Additionally, future generations have to deal with possible consequences of decisions that will (not) be made by current generations. As current generations are future generations to past generations, and the nuclear waste legacy was forwarded, the inherent challenge of nuclear waste to notions of justice becomes apparent.

Liebig and Scheller (2007) attest that not only goods but also burdens need distribution and that the perception of justice of such distributions is based on different ideals of justice. Nonetheless, unequal distributions between people and generations require reasoning and explanation (Berger 2004). This is necessary for the repository, as all German HLW shall be stored in a central repository.

Tremmel (2021) describes two major concerns of intergenerational justice as the contradiction between (forgone) welfare and sovereignty. This is transferable to nuclear waste management: Kermisch (2016) provides an overview of different disposal options and differentiates between close and remote future generations. She concludes that "non-retrievable geological disposal appears to be the most favorable option for remote future generations" (p. 1809), but shows simultaneously that close and remote future generations might have different needs for a repository. The assessment between generations on how to interact with nuclear waste is therefore subject to temporal change (Kasperski and Storm 2020). Tremmel (2021) argues in favor of 'institutions for future generations.' This can be enabled by improving the political representation of children as links to future generations (Campos 2021). This representation needs to be understood as a representation of claim rights (Campos 2019).

Reversibility enables future generations to act flexibly regarding nuclear waste management thus granting them sovereignty over HLW, whereas enclosure grants a higher degree of freedom, without the obligation to act and thus to focus on then prevailing challenges. From another perspective reversibility can be regarded as a burden, as future generations might have to deal with HLW; while enclosure can be regarded as an obsta-

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.

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cle to correcting past decisions. The contradiction between reversibility and enclosure requires constant evaluation at fixed times and flexibility regarding the outcome (Tremmel 2017). From a critical perspective, Okrent (1999, p. 878) raises the question of whether "millions of dollars spent today to save a relatively few statistical lives thousands of years in the future," although this money could be used to save more lives in the present, can be regarded as intergenerationally just. While this question is fundamental, it is equally difficult to answer and will therefore be put aside.

From an environmental justice perspective, Schlosberg (2004) argues that justice is generally made up of three dimensions, namely procedure, distribution, and recognition. Against this background, intergenerational justice can be regarded as a part of recognition, with direct implications for procedure and distribution. In the following, I discuss that intergenerational justice can be enabled by setting high standards for procedure, distribution, and recognition within the current site selection process.

Aspect	Item	Reference
Recognition	Future generations have to be considered in the siting procedure for a repository.	Gosseries 2008; Hocke 2021
Reversibility	For the sake of future generations, the repository should be kept open.	Kermisch 2016; Tremmel 2021
Enclosure	For the sake of future generations, the repository should be immediately sealed.	Kermisch 2016; Tremmel 2021
Timely solution	A repository must be found quickly, to not burden future generations.	Röhlig et al. 2017
Time delays	The process may take longer than planned (a) for scientific reasons; (b) for participatory reasons.	RSS-Act 2017*; Leigh and Dotson 2011
Young generation	Intergenerational justice comprises the inclusion of the young generation.	Campos 2021, Tremmel 2021
Compensation	The repository community is entitled to generous financial compensation.	Kunreuther et al. 1990; Blowers 2010

* Repository Site Selection Act of 5th of May 2017 (BGBl I, p. 1074), as last amended by Art. 1 of the Act of 7th of December 2020 (BGBl I, p. 2760)

Tab. 1: Survey items. *Source: author's own compilation*

Intergenerational justice research often thematizes the dilemma or the challenge of reciprocity, representation, or hypothetical wants and needs of future generations. Especially in the case of nuclear waste management, there is a lack of empirical insights to assess how claims of intergenerational justice are manifested. By conducting a quantitative survey that is complemented by qualitative observations, this contribution provides exploratory insights into how intergenerational justice is perceived in the German site selection process.

Methods

This contribution draws on a quantitative survey carried out among interested citizens in Germany. The presented notions of justice were assessed in a survey that was carried out in the context of the German repository site selection process. 716 respondents were acquired via networking platforms from the ongoing site selection process, political working groups on environmental and energy politics, civil society organizations, as well as interested groups (via Facebook). The respondents were invited via mail or group post and two reminders to participate were sent. Additionally, in online events of the German site selection process, respondents were invited via public chat messages. The anonymous survey covered three dimensions of justice (procedure, distribution, recognition); adjacent factors such as trust, power, and emotions; and personal constituents, e.g. spatial proximity, experiences, and socio-demographics. Notions of intergenerational justice were part of six questions (Table 1). All items were formulated as statements. Respondents had to assess on a scale from 0 (low) to 10 (high) how strongly they (dis)approve of a statement. Each item is derived from the indicated sources.

Additionally, qualitative observations (systematic protocols with categories; Lamnek 2010, pp. 564–565) were carried out to gain additional insights. The categories for observations were derived from the RSS-Act. Justice was formulated as an open category. Observations of intergenerational justice were collected within this category. It was captured how actors in the site selection process refer to notions of (intergenerational) justice and future generations. 71 events were observed using systematic protocols, such as the sub-areas conference, (organizational) meetings between the events of the sub-areas conference, and thematic workshops as well as informational events organized by the German Federal Company for the Disposal of Nuclear Waste ('Bundesgesellschaft für Endlagerung') or by the Federal Office for the Safety of Nuclear Waste Management ('Bundesamt für die Sicherheit der nuklearen Entsorgung'). The findings of the observations were used in addition to the quantitative survey results, thus providing an empirical base for interpretation.

Results and discussion

As the meaning of intergenerational justice varies over time and the progress of nuclear waste disposal, the following section is structured chronologically: pre-siting decision, siting decision, and post-siting decision.

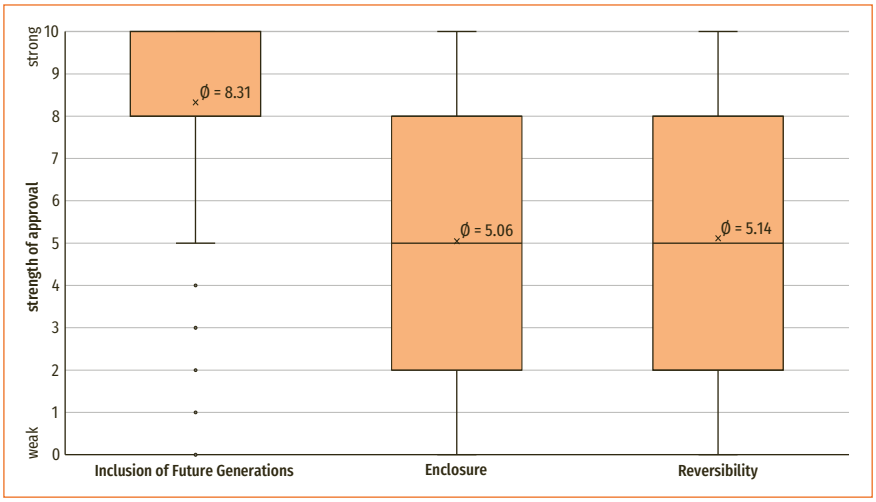

Fig. 1: Statements regarding future generations. *Source: author's own compilation*

Pre-siting decision

The consideration of future generations is apparent since the initiation of the current site selection process: The 'Repository Commission' wanted to achieve the least possible burden for future generations but at the same time to enable reversibility and retrievability (Röhlig et al. 2017). In the RSS-Act three time horizons are defined: (1) a repository site shall be found by 2031; (2) retrievability shall be possible for up to 500 years after enclosure; (3) nuclear waste has to be safely encapsulated for one million years[3]. Most actors assume that the first date is utopian and lately the Federal Company for the Disposal of Nuclear Waste has issued a statement that the repository will probably be found between 2046 and 2068 at the earliest.[4] Usually, discussions revolve around the 'one million years,' a humanly unimaginable time. The second period of 500 years is rarely thematized. Most actors focus on contemporary events, such as the conflict in Ukraine that strongly influences how people perceive the necessity to deal with nuclear waste (Brunnengräber 2022). Some actors call for a faster process while others emphasize the short-termism of societal events and insist on a solid scientific base for the site selection. Röhlig and Eckhardt (2017) insist that such ephemeral trends should not influence the safety or scientific base of the site selection.

Generally, the respondents approve that the wants and needs of future generations have to be considered in the site selection process (*Ø = 8.31, SD = 2.71*). This general approval is manifold in its implications. There is no clear tendency whether enclosure (*Ø = 5.06, SD = 3.42*) or reversibility (*Ø = 5.14, SD = 3.39*) is regarded as intergenerationally just. For both options all assessments were chosen by the respondents, thus showing that the actual path to achieve justice for future generations in this aspect is unclear.

The respondents do not attach any particular importance to a timely site decision (*Ø = 6.45, SD = 2.99*). Delays due to scientific reasons (*Ø = 8.34, SD = 2.20*) are more strongly approved, than delays due to participatory reasons (*Ø = 7.77, SD = 2.58*). This result is observable in the site selection process as well: Whereas in the 'Sub-areas Conference' (February-August 2021) many discussions revolved around how and when citizens can participate in the process, the last participatory conference – the 'Repository Siting Forum' (May 2022) – strongly revolved around methodological questions. An important development regarding intergenerational justice is the (bottom-up) foundation of the 'Council of the Young Generation' which aims to involve young participants in the site selection process. The council members argue that young people will actually experience the implementation of the repository and are therefore affected more strongly. Such institutions can help to build a bridge to the next generations if carried out constantly throughout the process (Campos 2021). This development provides an example of how procedural justice in the current process contributes to intergenerational justice in the future. The inclusion of younger generations is assessed positively by the respondents (*Ø = 7.28, SD = 3.12*). Such developments aim at long-term inclusion.

Through the establishment of the 'Council of the Young Generation', procedural justice has the potential to keep the procedure on a just path, exemplarily against short-termism or societal shocks. By applying high procedural (and scientific) standards, if society is accepted as a corrective of the site selection process, a responsible foundation for future generations can be laid. This requires continuity, as well as a flat (non-hierarchical) power relation between all involved actors (Schwarz et al. 2021).

Siting decision

The siting decision in Germany will be accompanied by a site agreement that comprises the definition of compensation for the affected host community. Kunreuther et al. (1990) have shown in the case of the U.S. that compensations can only work when the affected population has been able to convince itself that compensations do not function as bribes and that the process has a scientific basis. Lehtonen (2021) describes the kind of compensations that were carried out in the Finnish case; e.g. a senior residence, credits for an ice stadium, and economic development. In Switzerland, compensations are intended for the sustainable development of the host region and comprise 500 million CHF for a high-level waste repository site (Steinebrunner 2019).

3 StandAG, § 1 (2,4,5).

4 The statement is available here: https://www.base.bund.de/SharedDocs/Kurzmeldungen/BASE/DE/2022/zeitplan-endlagersuche.html;jsessionid=3EF4AD06D83CCD5356C3AF7FD3457A8C.2_cid382 or here https://www.bge.de/de/aktuelles/meldungen-und-pressemitteilungen/meldung/news/2022/11/bge-tritt-in-die-diskussion-ueber-den-zeitplan-bei-der-endlagersuche-ein/.

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Compensations can be designed differently, which directly influences intergenerational justice. The need to compensate the host community is slightly approved (*Ø = 6.99, SD = 3.00*), but its implementation is contested: According to observational insights, actors of the anti-nuclear movement argue that compensations are necessary, but timing is crucial to avoid misuse of the mechanism. Compensations shall function as a mechanism to additionally develop a region that took responsibility for a national task. The height and mode of compensation cannot be part of the discussion before the site decision but only after the decision has been made. This only works if the participatory process is regarded as trustworthy (Seidl et al. 2013) and if compensations are not used as an incentive for structurally or financially weaker municipalities. Distributive justice for future generations can be achieved if externalities do not influence the siting decision. Exemplarily, the East German politician Kai Emanuel argues that structural change cannot end in a final repository in the East of Germany (NSDO 2020). A citizen forum on compensation might help to include the needs of future generations by including the Council of the Young Generation.

Post-siting decision

Most currently living generations will not live to see the German repository. Scholars and state actors deal with the heritage of a nuclear waste repository. Heritage research deals with how people in the future can be warned of a repository site when the memory of its location will be lost. Kermisch (2016) estimates that such memory loss will happen approximately 500 years after closure. Questions of responsibility during this phase are rarely discussed in the ongoing site selection process. In contrast to this, different risks of accidentally causing damage to the repository have been discussed, such as accidents while drilling for geothermal energy or salt caverns. Such risks are – again – hypothetical, but taking precautions today is one way of considering the needs of future generations. One component of intergenerational justice is the safety of the repository from geological and human activities. While geological dangers will be addressed within the site selection process, human intrusion "poses the only real danger to [a] site's integrity" (Bryan-Wilson 2002, p. N/A). To communicate with future generations, different semiotic warning signs are considered.

Figure 2 symbolizes ideas to mark the repository site by repelling instead of attracting. The most prominent example is the 'Landscape of Thornes' (E) which "conveys a menacing aura of danger through its stylized inelegance and a repudiation of high-tech origins" (Bryan-Wilson 2002, p. N/A). Although the repository is a deep-geological structure, such a monument would be above-ground, thus effectively changing a landscape for the duration of its existence.

From an intergenerational perspective, such measures are imaginable, but their assessment of justice is ambiguous. The 'Landscape of Thorns' can be compared to ancient (from a current perspective) burial places that were intruded upon by Westerners. Danesi (2022) describes that warning signs change over time. They should therefore be re-designed constantly to ensure the repository's integrity from human intrusion. This constant attention poses challenges to intergenerational justice, nuclear waste knowledge preservation, e.g. by an atomic order or priesthood, seems necessary, but any entity made up of people can potentially be corrupted or destroyed. Such a project is already imagined in fictional novels (Hug 2021).

A monument is neutral but since there is no immediate threat from a repository, the question remains whether it only burns entire landscapes and creates emotional relations. Such questions can be answered by current generations, but need re-evaluation by future generations to guarantee future applicability. Therefore, intergenerational justice is – again – intertwined with jus-

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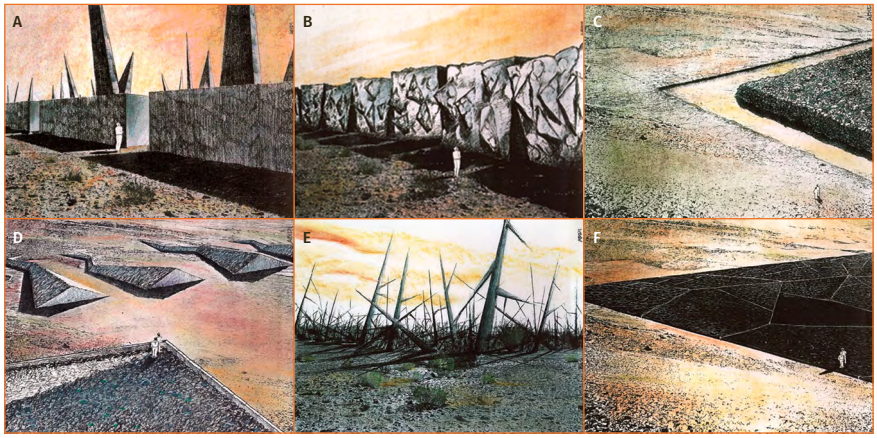

Fig. 2: Monuments to prevent human intrusion into the repository. *Source: Bryan-Wilson 2002*

tice in current generations. As potential problems do not need to stem directly from the deep-geological repository site the questions of the monument's location additionally requires consideration – alongside its implications for distributive justice in current and future generations.

Conclusion

The contradiction between enclosure and reversibility or phrased differently between (forgone) welfare and sovereignty (Tremmel 2021) is at the core of intergenerational justice for an HLW repository. The survey has shown that the respondents generally approve of including the needs of future generations in the site selection, but the actual implementation is contested. Following the findings of Campos (2021), first positive developments regarding intergenerational justice are observable in Germany, especially by the foundation of the Council of the Young Generation. Such an institution can help bridge the gap between current and future generations but requires constant participation and interest from young(er) participants. This is important as the council can embody a proxy for the abstract concept of future generations. By installing such a representative body, reasoning and explanations for unequal burdens can be critically discussed and improved (Berger 2004).

Bridging mechanisms and institutions are necessary: as Kermisch (2016) described how distant future generations might favor a certain type of repository, her assessment is based on certain assumptions made from a current point of view. Re-evaluation is necessary until a final decision needs to be made. Some paternalism of then-current generations toward future generations is inevitable, as future generations are affected by both indecision and actual decisions. By setting high standards for the site selection procedure, distribution, and recognition, current generations can enable a solid basis for future generations. As high standards comprise criticalness, reflexiveness, and openness for adaptation without bias or selfishness (derived from justice literature), they are subject to constant evaluation throughout the site selection process.

In this context, it is necessary to establish the Council of the Young Generation as a constant part of the site selection procedure. This council can act as a corrective and a reminder of the impact on and needs of future generations, as well as a proxy for their sovereignty in the site selection process for an HLW repository. This is necessary as current generations cannot solve this challenge alone, due to the longevity of HLW.

Whenever intergenerational justice is envisioned, it lays the groundwork for how other dimensions of justice will be approached in the future by people who have never benefited from nuclear energy but may have to deal with nuclear waste decisions. Such decisions will have to be made, especially if a flexible solution for a nuclear waste repository is chosen in the coming years (e.g., repository with retrievability or aboveground long-term storage). To achieve intergenerational justice, current generations must lay the groundwork by implementing a procedurally fair process with an equitable distributional outcome by recognizing the potential needs of future generations.

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RESEARCH ARTICLE

Citizen participation in the long-term process of high-level radioactive waste disposal: Future tasks and adequate forms of participation

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Abstract • The central importance of public participation in the search for a repository site for high-level radioactive waste is already recognized both in Germany and in other countries. In this paper, we argue that public participation will have to play a role after site selection as well, especially in the political and sociotechnical decisions in the next stages of the final disposal process. The form of citizen participation should correspond to the specific tasks and follow the principles of safety and justice. In order to show in which cases these principles apply and which form of participation would then be appropriate, we analyze three aspects of participation (co-determination, co-design, and involvement) and look at two cases: the decision on the sealing of the repository and the design of compensations.

Bürgerbeteiligung im langfristigen Endlagerungsprozess:* *Künftige Aufgaben und angemessene Beteiligungsformen

Zusammenfassung • *Die zentrale Bedeutung der Öffentlichkeitsbeteiligung bei der Standortsuche für ein Endlager für hochradioaktive Abfälle ist sowohl in Deutschland als auch in anderen Ländern bereits anerkannt. Wir vertreten in diesem Beitrag die These, dass Bürgerbeteiligung auch nach der Standortentscheidung eine Rolle spielen sollte, insbesondere bei den politischen und soziotechnischen Entscheidungen in den nächsten Etappen des Endlagerungsprozesses. Die Form der Bürgerbeteiligung sollte den konkreten Aufgaben entsprechen und auf den Prinzipien Sicherheit und Gerechtigkeit beruhen. Um zu zeigen, in welchen Fällen diese Prinzipien Anwendung finden und welche Beteiligungsform dann angemessen ist, analysieren wir drei Aspekte von Beteiligung (Mitbestimmung, Mitgestaltung und Mitwirkung) und betrachten dazu zwei Fälle: die Entscheidung über den Verschluss des Endlagerbergwerks und die Kompensationsmaßnahmen.*

Keywords • *participation, high-level radioactive waste, compensation, justice, safety*

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On the adequacy of participation techniques

Public participation in the long-term process of final disposal of high-level radioactive waste (HLW) has been already explored: concerning its type and extent in accordance to the purpose of the involvement and the stage in the decision-making process (Krütli et al. 2010), exploring the requirement of a learning process and its implications for the institutional actors involved (Brohmann et al. 2021) and considering particular requirements for a successful long-term governance, like place-attachment of the people at the repository site (Mbah and Kuppler 2021). In order to assess the role and modes of participation in the stages of the process after the site selection, our analysis mainly relies on the challenges posed by the characteristics of the problem itself. As Kamlage et al. (2019) argue, the ambitious participatory approach in the current search for a repository site in Germany emerged as a response to challenges posed not only by the failed attempt at Gorleben, but also due to the characteristics of the problem of radioactive waste disposal and its governance system.

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The final disposal of radioactive waste is a complex and highly contested sociotechnical problem (Brunnengräber 2016; Ramana 2019). Its solution does not arise from a scientific or technical point of view alone. It also requires the involvement of different societal actors (Röhlig 2022; Brunnengräber and Di Nucci 2019; see also Skorupinski and Ott 2000) whose knowledge, interests and values are at stake. It also involves a political decision-making process since science alone cannot identify the single very best site. Political decisions in a democratic system, on its turn, require citizen participation at different levels if citizens are expected to endorse them and to identify with corresponding policies (Lafont 2020).

It is easy to claim and hard to refute that participation is inadequate if the underlying concept of adequacy remains undefined.

Under the general agreement that there should be public participation, there still may be disagreement between participants and process-owners (Krütli et al. 2010, p. 863) about the modes and forms that are (in)adequate at different stages of the disposal process. In the present stage, strong disagreement has led to protest and withdrawal from the process in Germany (Boettcher et al. 2021; Themann et al. 2021). To determine which form is 'adequate' is, however, wicked; it is easy to claim and hard to refute that participation is inadequate if the underlying concept of adequacy remains undefined.

The dynamic-functional approach assesses the adequacy of participation techniques based on a typology of participation forms and the requirements at different stages of the decision-making process (Krütli et al. 2010). In our contribution, we consider that additionally the adequacy-relation should be specified as well. To that end, we first examine different aspects of participation and then illustrate the idea of adequacy on the basis of two future tasks within the process of final disposal.

Three forms of participation

Our approach to participation follows a theory of deliberative democracy (Habermas 1992) as it has been specified in the concept of "environmental deliberative democracy" (Ott 2014, p. 291) and the "participatory conception of deliberative democracy" (Lafont 2020, p. 7). Both concepts offer important distinctions for situating the kind of participation that we want to stress in democratic decision-making processes.

Following Habermas, the concept of environmental deliberative democracy distinguishes between a) the core of the political system that has sufficient democratic input-legitimacy to make collective decisions with long-term consequences, b) a reasoning civil society, and c) an intermediate deliberative zone. Within this zone, committees, boards, academies, state authorities, think tanks, and representatives from science, trade-unions, churches etc. are involved in deliberative settings (Ott 2014, p. 225). Through participatory formats, citizens can take an active role within this intermediate zone. Such role is additional to the formally regulated options of political engagement either in civil society or by voting at elections. It is also additional to the governance processes within the core of the political system that involve local and federal authorities. This additionality must be taken into account when considering the appropriateness of formats. Participation enriches the role of citizenship in the intermediate zone, apart from the role of citizenship in civil society and as a voting electorate. Furthermore, participation may have some intrinsic value, but it has to be embedded in democratic ways of problem solving and not just be 'maximized' without further considerations.

From the point of view of participatory deliberative democracy, participation in decision-making processes corresponds to the capacity of citizens to effectively shape the policies to which they are subject so they can endorse them as their own (Lafont 2020, p. 2). The key aspect of participation is its contribution to the "macro-deliberative processes of opinion- and will-formation in the broader public sphere" (Lafont 2020, p. 31). The distinction between deliberation processes at the macro level, on the one hand, and deliberation at the micro and local levels, on the other hand, characterizes the concept of participation: Public participation in macro-deliberative processes is an essential component of the democratic ideal of self-government, the idea that citizens shape the policies to which they are subject. The aim at this level is maximal inclusion in deliberation. Approaches to participation at the other two levels have other purposes in mind: Improving the quality of micro-level deliberations, e.g., through participation in mini-publics, and strengthening problem-solving capacity at the local level through citizen participation (Lafont 2020, pp. 31–32).

In an analysis of fair democratic processes, two aspects of participation have been distinguished: participation as the greatest possible involvement of affected parties in a discussion and participation as the possibility of contesting and shaping the discussion agenda (Benhabib 2016, p. 213). If participation is a necessary condition for a fair process in the siting of radioactive and other types of repositories (Young 1983; English 1991), then Benhabib's distinction applies: One should have broad participation and participants should be entitled to shape the agenda. Sometimes it has been claimed that participation also should include final decision and veto power. Research on site selection processes shows, however, that participation as decision power is not seen by stakeholders as a necessary condition

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for a fair procedure. Decision-making power is less important than transparency and access to information, as the selection process for a repository in Switzerland shows (Krütli et al. 2015, pp. 135–136). In the broader context of procedural justice, participation has been understood as "voice," i. e. as the possibility of presenting one's point of view within a decision-making process (Meyerson et al. 2021, p. 5) sometimes with the expectation of influencing the outcome (Schmidt 2018, p. 175). This last aspect is also stressed in the participatory approach of deliberative democracy (Lafont 2020, p. 32).

We want to complement the previous outline with a result from an interdisciplinary discussion on participatory aspects of procedural justice held at the workshop 'Ein faires und inklusives Verfahren?'. The workshop is part of the project Transdisciplinary Research on High-Level Radioactive Waste Management in Germany (TRANSENS) and took place at the University of Kiel in November 2021. The discussion on procedural justice was structured through the dialogue method 'Open Space Dialogue'. In the discussion, three German terms were associated with the meaning of participation. The result was the specification of the terms with reference to three elements in decision-making: preparation, process and outcome. However, unlike the 'ladder' conception of citizen participation (Arnstein 1969), the specification does not stress the higher or lesser degree of participants' decision power, but rather point out their involvement with respect to the (decision-making) *process*, its *outcome* and its *preparation*. This specification allows us to link the definitions presented above with those elements, making the following distinctions more suitable for our analysis of adequate participation forms in decision-making in the German final disposal process:

‚To have a say' ('mitbestimmen') is ambiguous, as it might refer to having real decision and veto power or just having the entitlement to present arguments in order to create an influence on the decision. In German language 'bestimmen' implies a capacity to decide as in, e.g., 'Hier bestimme ich!'. A way to resolve this semantic ambiguity is by drawing a distinction between a strong and a weak version. In the strong version, 'having a say' refers to the decision outcome and implies decision power (Young 1983, English 1991). In the weak version, it refers to the decision-making process and just means a real chance to present one's arguments in a deliberative setting, being close to the conception of participation as 'voice' (Meyerson et al. 2021).

‚To jointly shape' ('mitgestalten') refers to the deliberative decision-making process and not to the decision outcome, like in the weak sense of 'having a say'. It can be defined as taking up a point (an opinion, a statement or an argument) and reflecting upon it, in order to obtain something shared from it. Jointly shape means, thus, to reflect upon arguments being made in order to proceed to a commonly shared decision. In its deliberative sense, to jointly shape is similar to the understanding of participation in participatory deliberative democracy (Lafont 2021). Going beyond this understanding, it entails formal involvement in the decision-making process, not only the deliberation processes in the public sphere.

‚Being involved' ('mitwirken') refers, as in the case of jointly shaping, to the deliberations within the intermediate zone prior to the decision-making process and not to the decision outcome. Unlike jointly shaping, it does not entail formal involvement in decision-making, but rather involvement in the preparation of the decision-making process in formal and informal deliberation processes ("Entscheidungsvorbereitung"; Ott 2014, p. 296). It is discursive involvement in processes of finding solutions within the intermediate zone.

Participation in the stages after the site selection: two future tasks

As mentioned earlier, there are several approaches to evaluating the role and form of citizen participation in the long-term process of radioactive waste disposal. We agree with Krütli et al. (2010, pp. 863, 865) on the importance of examining the adequate 'type and extent' of participation for each stage of a decision-making process and considering the 'issue at hand', instead of just aiming for maximum inclusion. The modes of participation in future stages of the final disposal in Germany (KLA 2016, p. 252) will thus correspond to the particular tasks in a given stage. We now explore the task of compensating for possible harms and burdens during construction and operation (stages two and three) and the task of sealing the repository (stage five).

Decision on compensatory measures

After deciding on the location, the host community is selected as the one that lives at the site with the "best possible safety"[1]. If an adverse impact would affect the safety of the repository, immediate action would be taken to restore a safe condition. The case for compensation, however, remains even if the site is safe in technical terms. It supposes that local people are negatively affected by the overall process of constructing and governing a repository, or by its mere presence. This includes, e.g., noise, property damage, all kinds of political trouble, or bad reputation for the host community. Thus, the damages and burdens to be compensated do not include the risks of radioactive contamination, but only noise and property issues in terms of civil law and property law.

Negative impacts on the economy, the development perspectives and the quality of life of the population will be also compensated. In the siting process in Switzerland compensations ('Kompensationen') are carefully distinguished from payments ('Abgeltungen') that will be negotiated between the repository host community and the responsible for waste disposal as recognition for contributing to solve a national problem (BFE 2017, p. 3).

1 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. Cited below as StandAG.

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In the German case, such a distinction is implied, but there is not yet a defined term for the benefits that will be part of the Site Agreement. In the ongoing search for the repository site, it is planned to analyze which impacts a repository could have in the potential host communities that will be proposed in phase three of stage one for underground exploration. The socioeconomic potentials analysis will then offer a basis for the Site Agreement[2]. There, a plan for regional development to offset possible negative impacts on the host community should be already included.

A series of questions have to be specified concerning compensation measures, e.g., what exactly will be offered to whom and for how long. Defining which persons exactly count as being affected is not a simple matter since any definition will be arbitrary. Shall only persons in the host community count as being affected or also those in its surroundings? Should political units or mere distance to site be decisive? However this might be decided, the appropriate form of citizen participation in the case of determining what will be offered and how it will be used is the granting of decision power to those being affected. The argument relies on the notion of fair compensation itself. If a claim for compensation has been accepted, and if there are different options to fulfill this claim (money, resettlement, infrastructures etc.), and if the general principles of participation and deliberative setting ('jointly shape') are taken seriously in cases of compensatory justice, then it follows that the burden bearers should decide which compensation they prefer. If a burden X shall be compensated by either A, B, or C, and if A, B, and C are equally costly for the compensatory agency, and if the burden bearer prefers A over B and C, there are no reasons why the agency which takes the responsibility for the burden, should be entitled to decide against the preference of the burden bearer. From the perspective of the burden bearers, B and C would count as 'under-compensation.' For political reasons, there could be protests if a non-preferred option is forced on people affected by the burden.

At the transdisciplinary workshop 'Finanzieller Ausgleich für ein Atommüll-Endlager', held in Karlsruhe, Germany from 06 to 08 May 2022, we have proposed to engage citizens in discussions concerning compensations by means of the evaluation of compensation models and the development of new models on this basis. Beside the traditional models of direct payments or infrastructure development, the models of social or community benefits (Richardson 2010, p. 5; Lehtonen and Kojo 2019), the added value approach (NEA 2015, Kojo and Richardson 2019) and "postmaterialistic offers" (Ott and Riemann 2018, p. 54) appear as more suitable for developed regions. Compensation measures refer, in this sense, to novel kinds of prosperity and quality of lives at a site. At the workshop we took a first step towards developing compensation models: Two separate groups worked on basic aspects of compensations using the first two steps of 'Soft Systems Methodology'. Both groups included researchers, stakeholders and citizens. The results are still being assessed, but we want to stress here the relevance of the exercise: through work group, participants gained a more differentiated insight on basic aspects besides the type of burdens, e.g., the affected parties, the responsible parties, the possible ways of offsetting the burdens as well as possible limits or restrictions to this offsetting. Preliminary results show that from the participant perspective the concept of 'offsetting' and its possible limits need special attention. Compensation measures that really improve the situation in the host community of a repository have thus to include the perspective of that community.

The damages and burdens to be compensated include not only the risks of radioactive contamination, but also noise and property issues.

Repository sealing

Once the radioactive waste has been stored in a geological formation, a decision should be made among finally sealing the repository, keeping it accessible, or retrieving the waste. Although we cannot foresee how future generations will decide at the turn to the next century, a basic combination of positions can be outlined. We simplify the case by taking only the option 'sealing,' and the positions 'in favor' or 'against'. We further consider three groups of actors: people living in the host community, the nation-wide population, and the Parliament. Of the three possible scenarios, 1. a consensus (or broad majority) in favor of sealing the repository, 2. a consensus (or broad majority) against sealing, or 3. no consensus, i. e., disagreement on the matter, we assume that 3. is likely. Thus, we assume that the details of repositories will be as contentious in the future as they are today.

Similar to Eckhardt (2021, p. 22), we assume in our analysis that predominant values in present day Germany will not be fundamentally different in the long-term. For sure, a weakening of the democratic system cannot be fully excluded, but if a functioning democracy still exists in Germany in the moment of the decision to sealing or not, it can be assumed that learning institutions could adapt or be transformed according to changing values, which could be still negotiated in democratic processes of public opinion and will formation and transformation. Thus, assuming that there will be democratic structures in situation 3, the question will be who gets the authority to decide and who should take costs and liability to govern an un-sealed repository. In its final report, the commission states that, from today's point of view, the decision cannot be in the hands of the operator and the licensing authority, but must again be taken by Par-

2 StandAG § 16, see also § 10 (4).

liament, as is the case in the present siting decision (KLA 2016, p. 270). The issue at stake speaks in favor of this assessment: In the case of repository sealing, considerations about safety and justice are both relevant. Assuming that the future world could be full of problems (the effects of climate change, a war near the repository site), it seems imperative to free future people from the risks and burdens of managing an accessible repository (Ott 2020, pp. 180–181). At the same time, making the repository inaccessible seems to violate their right to decide, i. e., would impose the decision of the then-living over future people and restrict their freedom of action (Ott 2020, p. 183; Riemann 2017, p. 164). The decision-making power should then be entrusted to an institution that is capable of legitimately balancing the various interests. Assuming democratic nation states in the future, we cannot envisage a better institution than freely elected parliaments. Local actors will not be able to decide on behalf of the entire citizenry, and a nationwide plebiscite in its present form is not compatible with the basic law.

Nation-wide, the public should be involved in the deliberative preparation of the decision-making process. For this purpose, they could profit from an ongoing discourse on HLW management if the knowledge base is maintained (for a present example see Röhlig 2022). In this way, the tasks and responsibilities, advantages and disadvantages of an open repository can be part of the public opinion formation. The mode of participation for the local citizens should be, however, more than just being involved. Local authorities at the host community should have formal access to the hearings concerning the sealing, giving the local citizens the possibility of shaping the decision-making process. Local interests/values must be considered not only in the search for a site but also in the case of sealing because they would probably change after the repository is built. In both cases, local interests and public interests should be balanced, and local authorities can be a "connecting link" between the national authorities and the local citizens (Mbah and Kuppler 2021, pp. 433–435).

The adequacy-relation between tasks and participation forms

Citizen participation will have to play a central role in further stages of the process after the site selection. In addition to 'voice' and 'vote,' a participatory interpretation of deliberative democracy stresses the importance of involving citizens in deliberative settings within the intermediate zone between political power and civil society. This holds true for the complex and highly contested process of HLW disposal in particular. Relying on the two cases above, we can now specify the idea of adequacy of participation forms according to the principles of justice and safety:

For a task or problem that implies only or primarily justice aspects, like compensation of negative impacts, the adequate form of participation is granting the affected parties real decision power. Different actors, including scientists and stakeholders, may jointly work on novel compensatory models, but affected parties should finally decide which compensatory options they prefer and how to spend the means.

For a task or problem that concerns both safety and justice aspects, in which safety and security are given priority, citizen participation without decision power is appropriate. This holds true for the case of sealing the repository. The extent of influence should be greater than mere 'involvement,' but not so strong as veto-power, especially if this is granted to particular groups, e.g., some minority groups in the future favoring a 'rolling stewardship' concept of long-term governance. Citizen participation in the form of 'jointly shaping' the decision-making process is, in this case, the adequate form.

Cases that concern primarily safety issues, e.g., container technologies, need to be analyzed in order to assess the appropriate participation mode. According to Krütli et al. (2010, pp. 870–871), decisions on safety issues would rely on experts and allow a lesser degree of public participation, although some 'active' forms of participation as 'public reviewing' could still prove fruitful. The peculiar societal dialectics between 'risk' and 'danger' (Luhmann 1991) give a strong risk-theoretical reason why persons who feel endangered should not decide if stakes are high, but should put pressure on experts that safety and security be optimized in given safety cases. To do that, the intermediate deliberative zone and thus the mode of 'being involved without decision power' would be the appropriate one. It is also probable that concepts of safety change over time. For integration of new concepts in long-term final disposal governance (Mbah and Kupler 2021, pp. 417–418), citizen involvement in the intermediate zone would be adequate.

Further elaboration should also allow to identify demands for participation which are inadequate. Making the adequacy-relation between participation modes and tasks more transparent is important for two reasons: first, a missing or unclearly defined adequacy-relation could be a source for many kinds of criticism, protest, and failure. Second, and more important, a clear adequacy-relation might be an alternative to mere demands for 'more participation'. Maximizing participation might come at the expense of legitimate state's power to act and to find a solution being acceptable to the entire citizenry.

Even with a transparent adequacy condition there still are other risks within participation that emerge if agents adopt a strategic attitude within deliberative settings. Participation can be strategically misused by groups which take a primary interest in de-legitimizing the state. There can be hidden agendas being pursued in participatory formats. There might be kinds of excessive participation with much political rhetoric, but without deliberative content. We regard it important to mention these risks of failure, but it would take another article to analyze them in detail from a discourse-ethical perspective. Making adequacy-relations between tasks and formats more transparent might still improve participation policies in general and, hopefully, even within the site selection process in particular and specifically after site selection in Germany.

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RESEARCH ARTICLE

Commoning in der Standortsuche für ein Endlager?: Neue Wege kollektiven Handelns

Dörte Themann*,[1]

Zusammenfassung • Der Beitrag setzt sich mit der Frage auseinander, ob die Forschung von Elinor Ostrom zur Commons Governance neue Deutungsmöglichkeiten in Bezug auf derzeitige Institutionalisierungsprozesse im Verfahren der Standortsuche und generell für den Umgang mit hochradioaktiven Abfällen eröffnen kann. Basierend auf teilnehmenden Beobachtungen werden Hypothesen entwickelt, inwieweit dabei Logiken des Commoning verfolgt werden und erste Ergebnisse präsentiert.

Commoning in the search for a repository site?: New ways of collective action

Abstract • *This article addresses the question of whether Elinor Ostrom's research on commons governance can open up new interpretive possibilities with regard to current institutionalization processes in the site selection process and for dealing with high-level radioactive waste in general. Based on participatory observations, hypotheses are developed as to what extent logics of commoning are pursued, and preliminary results are presented.*

Keywords • *nuclear waste governance, commoning, collective action, self-organization*

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Einleitung

Hochradioaktive Abfälle stellen eine Ewigkeitslast dar (Brunnengräber 2019). Eine solche Last verbleibt oftmals als eine Art „unbeabsichtigte Öffentlichkeit" (inadvertent publicness) (Kaul 2012, S. 49) in staatlicher Verantwortung. Die Privatwirtschaft hat hohe Gewinne mit der Kernenergie erwirtschaftet, doch die Risiken und unbeantworteten Fragen des Umgangs mit den Abfällen wurden an den Staat und damit die Öffentlichkeit übergeben. Sie können als „negatives Gut" (Ott 2020, S. 174) oder ‚public bad' (Schulz 2016; Brunnengräber und Mez 2014) betrachtet werden, also eine Art öffentliches ‚Ungut'. Diese Konzipierung weist auf ein Governance-Konzept hin, das bisher kaum Eingang in die Debatte des Umgangs mit hochradioaktiven Abfällen gefunden hat, dessen Potenzial aber für die angesprochenen ‚Ungüter' zu ergründen ist: die *Commons Governance* (Ostrom 2013). Diese beschreibt Wege kollektiven Handelns jenseits rein staatlicher Verwaltung oder marktwirtschaftlicher Zugänge, um Gemeingüter oder öffentliche Güter zu produzieren und zu verwalten.

Risiken und unbeantwortete Fragen des Umgangs mit den Abfällen wurden an den Staat und damit die Öffentlichkeit übergeben.

Das Standortsuchverfahren für ein Endlager für hochradioaktive Abfälle in Deutschland stellt in diesem Zusammenhang eine aufschlussreiche Fallstudie dar, weil mit dem Standortauswahlgesetz (StandAG) und dem Neustart des Verfahrens eine neue Institutionenarchitektur etabliert wurde. Der vorliegende Beitrag geht der Frage nach, inwiefern im Prozess Logiken des *Commoning* verfolgt werden. Hierzu wurden die Fachkonferenz Teil-

1. Klare Grenzen	Es ist definiert, welche Stakeholder bzw. Gruppen zur Nutzung des Commons berechtigt sind und auch die Grenzen des gemeinsam hergestellten oder zur Verfügung stehenden Gutes sind klar umrissen.
2. Regeln bzgl. Bereitstellung und Nutzung einer Ressource sind verhältnismäßig	Regeln in Bezug auf die Nutzung eines Commons müssen im ausgewogenen Verhältnis zu den Bereitstellungsregeln stehen, die Zeit, Arbeit, Geld oder anderweitige Ressourcen erfordern sowie auch den lokalen Bedingungen entsprechen. Bei Unverhältnismäßigkeit kann dies zu Inakzeptabilität der Regeln führen.
3. Gemeinschaftliche Entscheidungen	Personen, die von den operativen Regeln bzgl. des gemeinsamen Gutes betroffen sind, sollen an deren Entwicklung und Änderungen mitwirken können.
4. Monitoring bzw. Kontrolle	Kontrolle zum Zustand des Gutes sowie zur Einhaltung der Regeln und Verhalten der Nutzer*innen durch „Überwacher*innen". Diese Überwacher*innen können laut Ostrom die Nutzer*innen selber sein oder rechenschaftspflichtige Dritte. So wird Vertrauen in Kooperation ermöglicht.
5. Abgestufte Sanktionen	Abgestufte Sanktionen kommen zum Einsatz, falls Nutzer*innen die vereinbarten operativen Regeln verletzen. Außergewöhnliche Umstände oder Missverständnisse werden berücksichtigt und erlauben eine Fehlerkultur, die Personen ermutigt, die gegen Regeln verstoßen haben, sich wieder an diese zu halten.
6. Konfliktlösungsmechanismen	Es gibt schnelle und leicht zugängliche Arenen sowie einfache Mechanismen zur Konfliktlösung zwischen Nutzer*innen oder zwischen Nutzer*innen und ihren Bevollmächtigten.
7. Anerkennung des Organisationsrechts	Anerkennung des Organisationsrechts und des Rechtes der Nutzer*innen eigene Institutionen auszubilden durch staatliche Behörden und entsprechende Regierungsebenen.
8. Polyzentrische Governance	Verschachtelte Institutionen und Einbettung unterschiedlicher Organisationseinheiten in verschiedenen Ebenen, wenn das Common Teil eines komplexeren Systems ist. Umfangreiche Institutionen sind notwendig, um eingebettete Organisationseinheiten zu verbinden.

Tab. 1: Design-Prinzipien nach Ostrom.
Quelle: eigene Darstellung basierend auf Ostrom 2013; Poteete et al. 2010

gebiete sowie weitere Veranstaltungen, die in diesem Rahmen stattfanden, mittels teilnehmender Beobachtung wissenschaftlich begleitet. Der nachfolgende Text bietet einen Einblick in erste Auswertungen des Datenmaterials, aus denen Hypothesen für die vertiefende Analyse abgeleitet werden. Am Ende steht ein Ausblick, welche Impulse für die Standortsuche und darüber hinaus von der Commons Governance ausgehen können.

Commoning

Selbstverwaltete Institutionen und polyzentrische Systeme wurden „in Zeiten voranschreitender Demokratisierung" laut Ostrom zu lange übersehen und deren Bedeutung falsch eingeschätzt (Ostrom 2009, S. 222). Obwohl in der Commons Governance Prinzipien für erfolgreiches, langfristiges, selbstorganisiertes, kollektives Handeln identifiziert wurden, spielt sie in der Auseinandersetzung um die Ausgestaltung demokratischer Prozesse und politischer Ordnung angesichts zunehmender Risikoentscheidungen bisher kaum eine Rolle. Dabei hat die Forschung um Commons und Praktiken des Commoning in den letzten Jahren auch Einzug in gesellschaftstheoretische Debatten gehalten (Euler 2020; Helfrich 2012, 2009). Darüber hinaus gibt es vereinzelte Arbeiten, die sich mit der Übertragung dieses Konzeptes auf den Umgang mit langfristigen technologischen Effekten beschäftigen (Stern 2011). Neben den klassischen „common-pool resources", die Ostrom (2013, S. XVII) betrachtete, lässt sich der Blick auch erweitern auf „common-pool hazards" (Stern 2011, S. 225).

Logik des Commoning

Laut Quilligan sind Commons „Dinge, die Menschen gemeinsam nutzen und verwalten, indem sie, basierend auf Traditionen oder sozialen Normen und Praktiken, ihre eigenen Regeln aushandeln" (Quilligan 2012, S. 99). Ein Gut wird somit nicht nur durch seine materielle oder immaterielle Natur zum Commons, sondern vor allem durch die soziale Praxis und Strukturen, die Menschen ihm gegenüber gemeinschaftlich entwickeln und organisieren – genannt „Commoning". Commoning umfasst dabei ein gemeinsames Tun, mit dem Ziel, Regeln und Praktiken zur Nutzung und Bereitstellung eines Gemeingutes zu vereinbaren (Linebaugh 2008; Euler 2018; Meretz 2012). Sehr unterschiedliche Güter, wie etwa auch Wissen, können somit zu Commons werden, weil diese Charakterisierung von den jeweiligen sozialen Praktiken abhängt.

Wesentliche Dimension von Commoning ist die Institutionalisierung einer Form von Selbstorganisation. McGinnis (2011, S. 6) definiert Selbstorganisation bzw. „Self-governance" als "the capacity of any group of individuals to work together to resolve common problems and realize shared aspirations. Ideally, members of a self-governing community organize themselves so they can actively participate in all (or at least the most important) decision processes relating to their own governance". Selbstorganisation ist stark auf das zu erhaltende oder zu produzierende Common gerichtet und mit der Autonomie der Beteiligten oder Betroffenen verbunden, Ziele, Regeln und Organisationsformen in Bezug auf das Common bewusst selbst festzulegen.

Ostrom hat durch die Analyse hunderter Fallstudien acht Design-Prinzipien einer erfolgreichen und langlebigen Commons Governance identifiziert (Tab. 1). Sie bieten weitere Anhaltspunkte, um Logiken des Commoning in der Standortsuche zu erkennen, sowie gegenwärtige Problemlagen zu analysieren.

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Methodisches Vorgehen

Der Handlungszusammenhang, der im Folgenden genauer betrachtet wird, ist die Fachkonferenz Teilgebiete, also das erste gesetzlich festgelegte Beteiligungsformat im Standortauswahlverfahren, deren drei Beratungstermine zwischen Februar 2021 und August 2021 stattfanden, sowie das Folgeformat Forum Endlagersuche im Mai 2022. Die Fachkonferenz Teilgebiete war die erste formelle Öffentlichkeitsbeteiligung laut Deutschem Standortauswahlgesetz[1] (StandAG) und hat den Zwischenbericht Teilgebiete, den die Bundesgesellschaft für Endlagerung im September 2020 vorlegte, öffentlich beraten. Das Forum Endlagersuche hingegen ist ein informelles Beteiligungsformat, das aus der Fachkonferenz Teilgebiete hervorging und als Brückenformat bis zu den Regionalkonferenzen (StandAG § 10) dienen soll. Die drei Beratungstermine der Fachkonferenz Teilgebiete, das Forum Endlagersuche sowie die öffentlichen Sitzungen der jeweils vorbereitenden Gruppen wurden von der Autorin mittels teilnehmender Beobachtung (Thierbach und Petschick 2019) wissenschaftlich begleitet (Abb. 1). Hierzu wurde ein Beobachtungsbogen mit Kategorien angelegt, die Interaktionen und Prozesse aber auch Äußerungen zu bestimmten Inhalten u. a. Konfliktgegenstände, Äußerung von Werten oder Rollenzuweisungen abdeckten. Der Bogen war aber nur teilweise vorstrukturiert, um offen für das Geschehen zu sein. Die nachfolgenden Aussagen basieren auf einer ersten explorativen Analyse des Materials, aus der heraus Hypothesen und vorläufige Ergebnisse abgeleitet werden, die im Verlauf einer noch folgenden vertieften Analyse mittels Grounded Theory (Glaser und Strauss 1979) weiter untersucht werden. Weitere Beobachtungen sowie Interviews sind geplant, um die Datengrundlage zu verbreitern. Wo möglich, werden die nachfolgenden Aussagen um Statements aus den Wortprotokollen oder Sekundärliteratur ergänzt, um die Ableitung entsprechender Hypothesen zu untermauern.

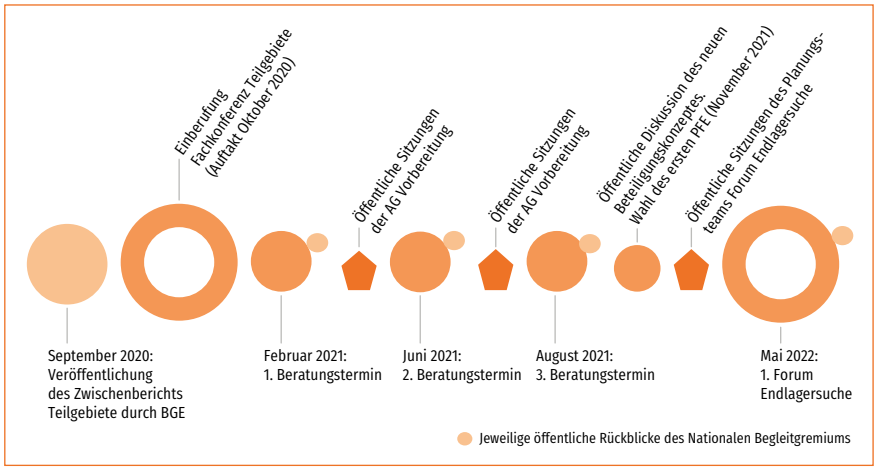

Abb. 1: Zeitlicher Verlauf der wesentlichen öffentlichen Veranstaltungen im Rahmen der Fachkonferenz Teilgebiete und des Forum Endlagersuche. *Quelle: eigene Darstellung*

Standortauswahlverfahren – neue Wege kollektiven Handelns?

Wunsch nach Selbstorganisation

Mit Veröffentlichung des Teilgebieteberichtes im September 2020 durch die Bundesgesellschaft für Endlagerung – die Vorhabenträgerin – und der daraufhin einberufenen Fachkonferenz Teilgebiete hat das Verfahren der Standortsuche in Deutschland eine neue Dynamik erfahren. Es kam während der Fachkonferenz Teilgebiete zu einer starken Auseinandersetzung um geeignete Organisationsformen der Beteiligung, die in Konflikten um die Mitgestaltungsmöglichkeiten der Öffentlichkeit sowie um die Selbstorganisationsform und Rollenverständnisse mündete (Themann, Di Nucci und Brunnengräber 2021; Themann, Schwarz et al. 2021; Schwarz et al. 2021 a, 2021 b). Während der Fachkonferenz Teilgebiete wurden die Teilnehmer*innen aus den laut StandAG zu beteiligenden Teilöffentlichkeiten (Bürger*innen, gesellschaftliche Organisationen, Wissenschaft, Gebietskörperschaften) zusammenfassend als „Zivilgesellschaft" bezeichnet. In diesem Text wird diese Zusammenkunft innerhalb der Fachkonferenz Teilgebiete als ‚erweiterte Zivilgesellschaft' bezeichnet und in Abgrenzung dazu Organisationen wie der Bund für Umwelt und Naturschutz Deutschland e. V. als ‚organisierte Zivilgesellschaft'. Die organisierte Zivilgesellschaft, und im Verlauf der Fachkonferenz Teilgebiete auch große Teile der erweiterten Zivilgesellschaft, argumentierten für eine kontinuierliche Selbstorganisationsmöglichkeit der Öffentlichkeit bis zu den Regionalkonferenzen (§ 10 StandAG) mit dem Bundesamt für die Sicherheit der nuklearen Entsorgung (BASE) in einer operativ unterstützenden Rolle. Exemplarisch wird die Aussage eines Teilnehmers während des zweiten Beratungstermins der Fachkonferenz Teilgebiete angeführt:

> „[…], weil der Zwischenbericht Teilgebiete weit hinter den Erwartungen zurückgeblieben ist, beginnt man jetzt zu improvisieren. Das bedarf der genauen Beobachtung. Gerade deswegen ist jetzt in den nächsten Jahren weiterhin eine selbstorganisierte Begleitung dieses Verfahrens durch die Zivilgesellschaft unerlässlich." (BASE 2021 a, S. 37)

Dieser Wunsch nach zivilgesellschaftlichen Beobachtungsmöglichkeiten innerhalb des Prozesses gegenüber der Bundesgesell-

1 Standortauswahlgesetz vom 05. 05. 2017 (BGBl. I S. 1074), das zuletzt durch Artikel 1 des Gesetzes vom 07. 12. 2020 (BGBl. I S. 2760) geändert worden ist. Online verfügbar unter https://www.gesetze-im-internet.de/standag_2017/StandAG.pdf, zuletzt geprüft am 17. 10. 2022.

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schaft für Endlagerung (BGE) wird mit dem Ziel des bestmöglich sicheren Standortes verbunden. Dem liegt die Annahme zugrunde, dass durch eine zusätzliche Arena des kritischen Hinterfragens mögliche Fehlentwicklungen oder Lücken entdeckt werden und so das Verfahren gestärkt wird. Daraus entwickelte sich in der Themen-AG ‚Beteiligung und Transparenz' der Fachkonferenz Teilgebiete ein Antrag für ein Anschlussformat, das die Beteiligungslücke bis zu den Regionalkonferenzen schließen und in selbstorganisierter Form die Arbeiten der Bundesgesellschaft für Endlagerung weiter begleiten und hinterfragen soll. Um diese Selbstorganisationsmöglichkeit zu schaffen, wurde ein Forum als Raum angedacht, aus dem heraus sich die Zivilgesellschaft konstituieren und organisieren kann (Gaßner 2021). Dieser Antrag wurde mittels Abstimmung mehrheitlich durch die Teilnehmer*innen der Fachkonferenz Teilgebiete angenommen (BASE 2021 c). In den Worten der Commons Governance haben die ‚Nutzer*innen' der Beteiligungsstrukturen, also die erweiterte Zivilgesellschaft, damit einen ersten Schritt getan, um neue kollektive Arenen zu etablieren und Formen der Selbstorganisation zu verstetigen.

Das BASE hat diesem Organisationsvorschlag beim dritten Beratungstermin eine Form kollaborativer Governance gegenübergestellt, in der das Bundesamt stärker in Strukturen rund um das Folgeformat involviert ist und dieses gemeinsam mit Vertreter*innen der erweiterten Zivilgesellschaft bereitstellen möchte. Eine Selbstorganisation, wie von der Fachkonferenz Teilgebiete angedacht, wurde von Seiten des BASE eher kritisch gesehen (BASE 2021 b), wobei es eine Begründung schuldig blieb.

Nach der Fachkonferenz Teilgebiete folgten, unter Begleitung des Partizipationsbeauftragten, Beratungen zu einem neuen Beteiligungskonzept für den Zeitraum zwischen Fachkonferenz Teilgebiete und Regionalkonferenzen. Diese Beratungen fanden statt zwischen dafür mandatierten Vertreter*innen der Fachkonferenz Teilgebiete, dem BASE, der Bundesgesellschaft für Endlagerung sowie dem Nationalen Begleitgremium. Die Ergebnisse wurden im November 2021 öffentlich für alle Interessierten zur Diskussion gestellt und mündeten in das Forum Endlagersuche sowie das Planungsteam Forum Endlagersuche.

Bereits im Laufe der Fachkonferenz Teilgebiete haben etliche Akteure der organisierten Zivilgesellschaft das Beteiligungsverfahren verlassen (Schwarz et al. 2021 a). Die noch verbleibenden Teile der organisierten Zivilgesellschaft im Verfahren konnten sich der Organisationsform für das Forum Endlagersuche und das Planungsteam Forum Endlagersuche nicht anschließen, da sie den Anspruch der Selbstorganisation der Öffentlichkeit durch die aktive Rolle des BASE mit seinem Stimmrecht im Planungsteam Forum Endlagersuche unterlaufen sahen. Die Distanzierung organisierter Zivilgesellschaft vom Verfahren wurde zuletzt offenkundig durch die geringe Teilnehmer*innenzahl aus der Gruppe gesellschaftlicher Organisationen auf dem ersten Forum Endlagersuche im Mai von nur sechs bis neun aktiv teilnehmenden Personen, sowie durch nur eine vorhandene Kandidatur für das neue Planungsteam Forum Endlagersuche (PFE), das zur Vorbereitung des nächsten Forum Endlagersuche neu gewählt wird. Konstitutionell ist diese Form kollektiven Handelns also nicht durch alle zu beteiligenden Gruppen legitimiert. Und auch innerhalb des Planungsteam Forum Endlagersuche ist zu beobachten, dass die Rollen der verschiedenen Akteure sowie die Art der Zusammenarbeit weiterhin Gegenstand von Konflikten sind.

Prinzipien der Commons Governance: Reflexionspunkte im Standortsuchprozess

Diese Beobachtungen legen nahe, dass Beteiligung als gemeinsames Gut verstanden wird mit dem Ziel, den „Standort mit der bestmöglichen Sicherheit" (StandAG § 1 (2)) zu finden. Mittels Selbstorganisation der Beteiligung will die erweiterte Zivilgesellschaft eine zusätzliche Instanz schaffen, um das Verfahren von außen begleiten und hinterfragen zu können. ‚Sicherheit' wird somit als ein gemeinsames und nicht allein durch staatliche Organisationen zu gewährleistendes Gut konstruiert. In dem Wunsch nach kritischer Begleitung der Arbeit der Bundesgesellschaft für Endlagerung verdeutlicht sich das Ostromsche Prinzip von Kontrolle, die mit einer gewissen Autonomie gegenüber den staatlichen Organisationen ausgeübt werden soll. Die Sicherheit des Standortes als etwas gemeinsam zu produzierendes, sowie eine eigene Arena der Kontrolle, sind vor dem Hintergrund bisheriger sozialwissenschaftlicher Analysen plausibel – etwa zur Anwendung der Decide-Announce-Defend-Strategie in der Vergangenheit (Kamlage et al. 2019) sowie zum verlorenen Vertrauen in die staatlichen Organisationen im Umgang mit hochradioaktiven Abfällen (Di Nucci et al. 2021; KLHRA 2016).

‚Sicherheit' wird als ein gemeinsames und nicht allein durch staatliche Organisationen zu gewährleistendes Gut konstruiert.

Eine besondere institutionelle Position als „unabhängige Begleitung" (StandAG § 8 (1)) des Verfahrens und speziell der Öffentlichkeitsbeteiligung hat dabei das Nationale Begleitgremium. Es füllt womöglich eine Art ‚überwachende' Rolle aus, wie Ostrom sie für das Prinzip 4 identifizierte. Das Zusammenspiel zwischen den Nutzer*innen der Beteiligungsstrukturen und dem Nationalen Begleitgremium in seiner Wächterrolle mit seinen diversen Kompetenzen scheint dabei ein wichtiger Punkt für die vertiefte Analyse.

Ebenfalls in Zusammenhang mit Prinzip 4 betonen die organisierte wie auch erweiterte Zivilgesellschaft, dass sie Ressourcen für die Einbindung von wissenschaftlicher Expertise benötigten, um überhaupt eine Kontrollfunktion bzgl. der Arbeits-

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schritte der Bundesgesellschaft für Endlagerung wahrnehmen zu können. Der Wunsch nach Zugang zu unabhängigem fachlichen Wissen, um den Zustand der Sicherheit eigenständig beurteilen zu können, so die Hypothese, konstruiert fachliche Expertise somit als ein Gemeingut. Zumal sich, entgegen dem immateriellen Charakter von Wissen, Rivalitäten entwickeln können: „Der Markt ist leergefegt. BASE und Bundesgesellschaft für Endlagerung haben bereits alles an Expertise beauftragt. Wir finden kaum noch Leute, die für uns ein Gutachten unabhängig übernehmen können" äußerten Vertreter*innen organisierter Zivilgesellschaft während einer Veranstaltung der Evangelischen Akademie Loccum im Jahr 2021. Rivalität um Fachwissen entsteht hier dadurch, dass die Zivilgesellschaft Expert*innen beauftragen möchte, die nicht bereits in Auftragsverhältnissen zum Operator oder Regulator stehen, wodurch eine Knappheit wahrgenommen wird.

Prinzip 3 scheint zunächst erfüllt. Nicht nur betont das StandAG (§ 5 (1)) explizit die Mitgestaltungsmöglichkeit der Öffentlichkeit, die Fachkonferenz Teilgebiete sollte auch einen Raum eröffnen, in dem die Beteiligten selbst Regeln der Zusammenarbeit vereinbaren. In der weiteren Analyse ist jedoch zu betrachten, wie sich Machtwirkungen und Dominanzen von Akteuren auf das Prinzip ausgewirkt haben. Machtanalytische Betrachtungen der Fachkonferenz Teilgebiete weisen durchaus auf entsprechende Effekte hin, die die institutionelle Entwicklung der Fachkonferenz Teilgebiete beeinflusst haben (Themann, Di Nucci und Brunnengräber 2021; Themann, Schwarz et al. 2021; Schwarz et al. 2021 a, 2021 b). Auch das Forum Endlagersuche sowie die Arbeit des Planungsteam Forum Endlagersuche und deren Austausch mit der interessierten Öffentlichkeit ist vor dem Hintergrund dieses Prinzips zu reflektieren.

Ein weiteres erfülltes Prinzip, so die Hypothese, ist eine Form polyzentrischer Governance. Obwohl sie keine Entscheidungskompetenzen im Standortsuchverfahren haben, richteten einige Bundesländer oder Regionen eigeninitiativ Foren ein, um die Standortsuche zu begleiten und den Kommunen und Bürger*innen Hilfestellungen im Verfahren zu ermöglichen. So hat z. B. Niedersachsen ein ‚Begleitforum' für die Standortsuche eingerichtet. Dieses umfasst u. a. die Bereitstellung finanzieller Mittel, die Kommunen abrufen können, um etwa Gutachten in Auftrag zu geben, und so auf Fachwissen zuzugreifen. In Bayern wurde in der Region Oberfranken eine ‚Regionale Koordinierungsstelle für das Verfahren der Endlagersuche' eingerichtet. Diese Entwicklung, in der Länder, Regionen und Bürger*innen eigenständig Räume und Ressourcen schaffen, um das Verfahren kritisch zu begleiten, kann als eine Form polyzentrischer Governance interpretiert werden.

Mit Blick auf Prinzip 2 weist die Verhältnismäßigkeit der Bereitstellung und Nutzung einer selbstorganisierten Beteiligung kritische Aspekte auf, wie etwa der erhebliche zeitliche Aufwand für die ehrenamtliche Arbeitsgruppe Vorbereitung (AG V) der Fachkonferenz Teilgebiete sowie für das Planungsteam Forum Endlagersuche. Zusätzlich konstatierte das Nationale Begleitgremium eine „schleichende Zermürbung der hoch engagierten zivilgesellschaftlichen Vertreter*innen" (NBG 2022, S. 4). Grund seien mit Blick auf die Zusammenarbeit innerhalb des Planungsteam Forum Endlagersuche komplizierte Abstimmungsbedarfe im Bundesamt, die Prozesse verlangsamen sowie hierarchische Strukturen, die eigenverantwortliches Handeln behindern. Hier treffen unterschiedliche institutionelle Logiken innerhalb des Planungsteam Forum Endlagersuche aufeinander, die die Arbeit auf operativer Ebene erschweren.

Der vorläufige Ausstieg etlicher zivilgesellschaftlicher Akteure weist auf noch unausgereifte Konfliktlösungsmechanismen hin.

Prinzip 6 zu Konfliktlösungsmechanismen sowie Prinzip 7 zur Anerkennung von Selbstorganisation durch staatliche Behörden wären gemäß obiger Schilderungen wichtig für die Standortsuche, sind aber nicht erfüllt. Der vorläufige Ausstieg etlicher zivilgesellschaftlicher Akteure weist auf noch unausgereifte Konfliktlösungsmechanismen hin, obwohl durch die Rolle des Partizipationsbeauftragten (StandAG § 8 (5)) eine entsprechende Instanz bereits institutionell verankert ist. Die Beobachtungen verdeutlichen zudem, dass staatliche Akteure Vorbehalte gegenüber einer Selbstorganisation im Bereich der Beteiligung haben.

Ausblick

Erste Auswertungen des Datenmaterials aus den Beobachtungen weisen darauf hin, dass zivilgesellschaftliche Handlungen im Rahmen der Fachkonferenz Teilgebiete (§ 9) über den ‚participatory turn' (Bergmans et al. 2015) hinausweisen und eine Anwendung des Konzeptes der Commons Governance wichtige Einsichten für die Standortsuche bergen kann. Vor allem das Verständnis von einer kollektiven Verfügung über Fachwissen, der Wunsch nach anerkannter Selbstorganisation innerhalb der Beteiligungsstruktur, die sich ausbildenden polyzentrischen Strukturen sowie das Ziel der bestmöglichen Sicherheit als ein gemeinsam zu schaffendes Gut deuten auf Logiken des Commoning hin. Daneben bietet die Auseinandersetzung mit den Prinzipien aufschlussreiche Analysepunkte entlang gegenwärtiger Herausforderungen und Konflikte der Standortsuche, die in der vertieften Analyse weiter betrachtet werden sollten.

Angesichts der beschriebenen Konfliktlagen stellt sich die Frage, welche Impulse von der Commons Governance für die jetzige Situation ausgehen können. Ostrom schreibt hierzu: „In

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jeder konkreten Situation muss aufs Neue darum gestritten werden, dass staatliche Institutionen ihrer Rolle als Treuhänder überregionaler Ressourcensysteme, als Ermöglicher für gemeingütersensitives Handeln, als Konfliktschlichter bei Nutzungskonflikten, als Unterstützer für Selbstorganisation und als aktive Förderer der Commons und der „Commoners gerecht werden" (Ostrom 2012, S. 107). Statt zu steuern, so eine mögliche Überlegung, könnte das BASE sich eher als Ermöglicher und Unterstützer einer zusätzlichen größtenteils selbstorganisierten zivilgesellschaftlichen Arena verstehen. Das Nationale Begleitgremium wiederum könnte seine ihm gesetzlich zugeschriebene Wächterfunktion ebenfalls gegenüber einer solchen Arena ausüben, um sowohl auf mögliche Fehlentwicklungen hinzuweisen als auch die Berücksichtigung der Ergebnisse durch BASE und Bundesgesellschaft für Endlagerung zu prüfen.

Mit Blick auf den langen Zeithorizont der Endlagerung erscheint es insgesamt lohnend, Organisationsformen und Governance-Konzepte zu betrachten, deren Prinzipien auf Langlebigkeit, Wissensweitergabe, Vertrauensaufbau und Adaptivität ausgelegt sind. Die Commons Governance kann hier womöglich wichtige institutionelle Impulse für den weiteren Standortsuchprozess als auch anschließende Phasen der Endlagerung setzen. Überlegungen betreffen etwa die zukünftigen Betroffenheitsräume (Steinebrunner 2021) durch den Endlagerstandort. Heute geht es um die Sicherheit als gemeinsam zu schaffendes Gut, doch je weiter das Verfahren voranschreitet und mit Errichtung des Endlagers wird die Last räumlich konzentriert und ein ‚Gemein(un)gut' oder „common pool hazard" (Stern 2011, S. 225) entsteht.

Welche Impulse die Commons Governance hier setzen kann – auch über den Fall der Endlagerung hinaus – sowie welche Ergänzungspotenziale der Fall der Standortsuche und der Blick auf öffentliche Ungüter für die Commons-Forschung bereithält, muss durch weitere Forschungsarbeiten ermittelt werden. Insbesondere im Zusammenhang mit risikoreichen Technologien und Großinfrastrukturprojekten sind auch die Verbindungslinien zwischen Risiko Governance (Renn 2008) und Commons Governance aufzuarbeiten (Stern 2011), sowie deren demokratietheoretische Implikationen.

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