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Governing Nuclear Waste in the Long Term: On the Role of Place

Melanie Mbah & Sophie Kuppler *

Abstract: *»Langfristige Regelung der nuklearen Abfälle: Über die Rolle des Ortes«.* A major challenge in building and securing a repository for high-level waste is the long-time spans needed for site selection, construction, storage, and closure. Depending on the type of site selection procedure and the chosen repository concept, this can take decades or even more than a century. Even today, this applies to many places in all countries that have or are operating nuclear power plants. These include the sites for interim or final storage or reprocessing. Over time, other places will also be affected during the site selection procedure and afterwards during construction and disposal. The processes will cause landscape transformations to a greater or lesser extent, to allow for activities including transportation and excavation. Nuclear waste governance is an extremely challenging and contested issue, starting with site selection, because nobody wants nuclear waste close by. Technologies and societies can change considerably over time. How this influences a repository may vary from place to place depending on context factors. Thus, we argue that realizing a nuclear waste governance that is oriented toward public welfare in the long term requires consideration of place. Based on empirical material collected in three regional workshops and nine qualitative interviews on the meaning of place and transformations caused by infrastructure projects, we discuss the relevance of those findings for a place-sensitive long-term governance framework.

Keywords: Spatial identity, place attachment, governance, disposal, site selection, participation.

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1. Introduction

1.1 Why Place-Sensitive Long-Term Governance?

The disposal of nuclear waste, in particular high-level waste from the use of nuclear energy, has been an unsolved and highly controversial dilemma in Germany for decades. The challenge lies in the fact that the high-level wastes are hazardous for an extremely long time because of the sometimes very long half-lives[1] of radionuclides, which necessitates safe storage out of human reach and shielded from the living environment. Nowadays, storage in a geological repository is the favoured option in most countries.[2] Long-term storage on the surface involves risks, as political and social changes can jeopardize safety. Changes that may threaten safety range from a simple loss of interest with an accompanying lack of human and financial resources, to serious disruptions, such as social unrest or even war, as the example of the current war in Ukraine and the occupation and bombardment of the Zaporizhzhya nuclear power plant illustrates (cf. Herviou et al. 2022; Smeddinck, Eckhardt, and Kuppler 2022; Ustohalova and Englert 2017). Additionally, the lifetime of structural facilities above ground is limited and requires continuous life-cycle management, as the combination of materials needs to withstand the heat radiation of the waste (cf. Köhnke 2017; Rahman and Ojovan 2021). Even with a final repository planned underground, such a facility influences the local site. In some countries, such as Finland, Germany, and Switzerland, this effect was or is to be evaluated in socio-economic impact studies (e.g., Lehtonen, Kojo, and Litmanen 2017; BFE 2018). Not only do the facilities influence the site, but place also plays a role in participating in environmental risk governance, as was shown for the case of West Cumbria (UK) (Landström and Kemp 2020). Lehtonen, Kojo, and Litmanen (2017) describe how during the socio-economic impact study it became clear that the municipalities involved had a different view on nuclear facilities based on past experiences with such and future development plans and visions for the municipality: While Eurajoki, for example, identified as a "nuclear community" and was favourable towards the endeavour, Kuhmo, in contrast, wanted to become a municipality that is viewed as "natural" in people's minds. In

[1] The time until half of the radioactivity has decayed. The important gamma emitters with long half-lives are: carbon14 with a half-life of more than 5,700 years, plutonium239 with more than 24,100 years, and uranium235 with 704 million years. Gamma emitters are comparable to light; they are composed entirely of energy and can even penetrate the body. For this reason, they pose the greatest danger to the environment and to health; https://www.epa.gov/radiation/radionuclides (Accessed 30 November 2022).

[2] Numerous so-called "exotic" options for the final disposal of the waste had to be rejected due to technical risks or uncertainties and the associated dangers for humans and the environment, such as transport into space or subduction zones (Röhlig 2022).

Sweden, too, "familiarity with nuclear activities" was identified as an important factor in the results of the feasibility studies conducted in several communities between 1993 and 2000 (Sundqvist 2002, 205). In Switzerland, "regional attachment" is one reason for including in the site selection procedure municipalities that will not be affected directly but might feel concerned (Scherer and Zwicker-Schwarm 2022). Furthermore, regional participation in the placement of above-ground facilities of a future waste repository resulted in a proposal to separate the facility for repacking the waste from the disposal site (cf. Neles 2022). For the US, Endres (2009) argues that the term "wasteland" has served to uphold, but also resist, nuclear waste facility siting that was planned on Native American lands. Similarly, in Canada, nuclear siting is focused on First Nations land, associated with settler colonialism, and while the siting process is considered exemplary by some, epistemic tensions arise regarding the inclusion of indigenous knowledges (Runyan 2018; Bell 2022).

These experiences of other countries can be interpreted from the perspective of social geographic and environmental psychology theory (cf. Bailey, Devine-Wright, and Batel 2021; Manzo et al. 2023) as expressions of place attachment that are or are thought to be affected by the emplacement of a nuclear waste repository in the community. Place attachment stands for the value people attach to a ("their") place and the factors that influence it (see figure 3). While the administrative boundaries of a host community are clear, the boundaries of the community whose place attachment is touched are less clear, as affectedness can be located at many different scales (Brunnengräber and Schwarz 2023) and is thus subject to deliberation. Yet, place attachment as a theoretical concept has not been addressed or systematically analysed in nuclear waste governance. What could be a potential role for place attachment in the governance of nuclear waste? As place attachment refers to people's relations to and their wishes and visions regarding the future of a place, its consideration in governance processes could contribute to addressing local and regional concerns. Furthermore, local and regional requirements for participation and regional development could be integrated. In this way, it could contribute to an acceptability of a site selection procedure and beyond.

Nuclear waste governance literature often argues that disposal is a problem that requires a socio-technical approach to ensure safety and security (cf. Landström and Bergmans 2015; Brohmann et al. 2021). In this sense, it is necessary to understand how social and political processes shape technical aspects of nuclear waste management and how technical approaches influence the social and the political (cf. Lösch 2021; Hietala and Geysmans 2022). A peculiarity of nuclear waste is the long-time spans. In some countries, a licence for repository construction has already been issued (Finland and Sweden); in others, this will probably happen within the next decade (Switzerland) or is still several decades away (Germany, see figure 2). In any case, final

disposal is a project that occupies more than one or two generations and therefore qualifies as a long-term problem (Sprinz 2014). The working generation that is primarily concerned with the process now may possibly no longer actively participate in the siting decision and subsequent phases of disposal. It follows that many different stakeholders will be involved in the selection process, and that social and political changes can be expected as well as economic, demographic, and environmental changes. What is more, the degree of involvement will vary over time. The longer the time scale, the more demanding aspects of long-term governance become, such as knowledge transfer, vigilance, adherence to the goal of a safe and secure disposal for a common good, and the availability of financial and human resources, but also technical aspects such as knowledge about the waste inventory (cf. Kuppler and Hocke 2019). Different interests will clash, and tensions may arise over time, which is why a shared vision that is continuously maintained is key, as well as a learning system with actors who have the ability to evaluate knowledge and make decisions (cf. Hakkarainen et al. 2022; Mbah and Kuppler 2021). Ideally, all of this should take place in a governance system with functioning checks and balances (cf. Kuppler and Hocke 2019). In this article, we argue that place attachment needs to be taken into consideration as a factor that can influence the safety of a repository in the long term.

1.2 The German Case

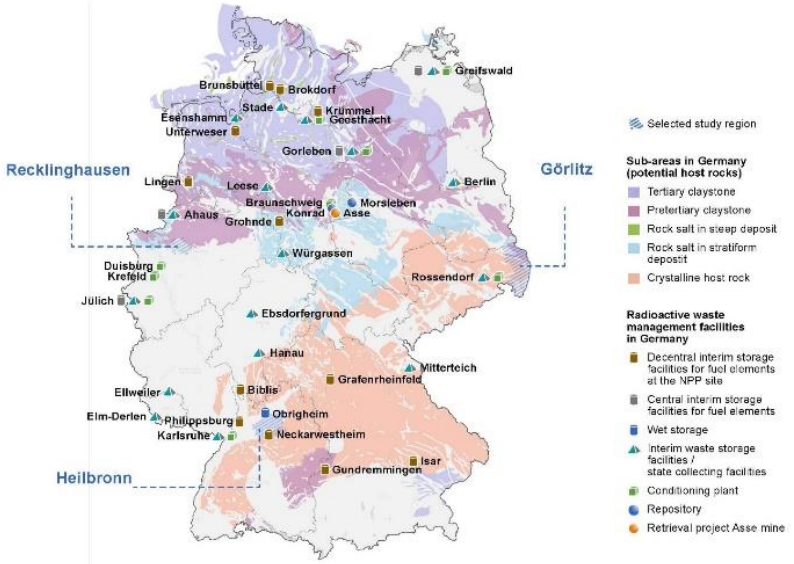
Here, we focus on Germany.[3] If – as Hietala and Geysmans (2022) argue – nuclear waste governance is understood not only as the mere disposal of the waste, but as the endeavour to manage it safely and securely over its entire lifespan, various communities are concerned at different points of time, to different degrees and with different possibilities for involvement (see figure 1).

In Germany, 74 sub-areas covering 54% of the total area of Germany are currently listed as potential siting regions (BGE 2020; Hoyer et al. 2021, see figure 1). Historically, siting attempts started back in the 1970s, when a first attempt to politically determine a site top-down – an underground salt dome in the town of Gorleben – failed. The political decision in favour of Gorleben led to decades of protests, whose actors found support and networked widely throughout Germany (cf. Hocke and Kallenbach 2015; Grunwald 2022). It was not until the Fukushima accident in 2011 and the change of government from a conservative to a green social-democratic alliance that a window of opportunity opened for an innovative law on the search and selection of a site for a

[3] Germany was selected for two main reasons: (1) The project within which the empirical data were generated focuses on the German case, (2) while factors of place attachment have been identified retrospectively in other countries (see above), we would like to show why a place-sensitive long-term governance in Germany is needed.

repository for high-level radioactive waste (Site Selection Act[4]) (cf. Bernardi et al. 2018; Schreurs 2012). In the Site Selection Act, the siting decision is "aimed for the year 2031" (§ 1(5)) – a schedule that has since been corrected by the operator BGE[5] to sometime between 2046 and 2068, depending on the underlying scenario (BGE 2022; BASE 2022). It may even take more than 100 years before safe storage is possible (Blattmann et al. 2023). Furthermore, the retrievability or salvageability of the waste must be ensured over a period of 500 years after closure of the repository, which puts high demands on monitoring and institutional capabilities to fulfil those tasks (cf. Aparicio 2010; Mbah et al. 2021; Hocke et al. 2022).

Figure 1 Regions in Germany Currently or Potentially Affected by Radioactive Waste Facilities



Source: Sub-areas by BGE mbH, other information by GEOBASIS-DE BKG 2020, Oeko-Institut 2023.

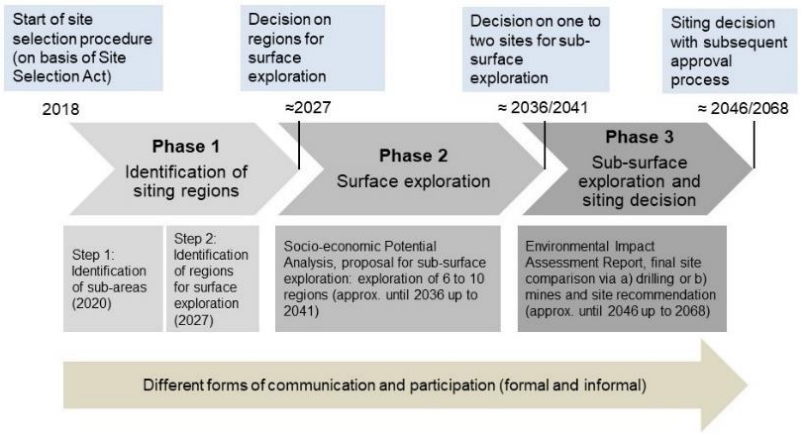
The site selection procedure itself is divided into three phases: first, the phase of identifying possible siting regions; second, surface exploration; and third, underground exploration and the siting decision (see figure 2). Once a decision has been made on the site, the next steps are the approval process and construction of the mine and surface facilities, which includes diverse infrastructures, e.g., for transport. Current interim storage facilities will have to

[4] In German: Standortauswahlgesetz – StandAG (Site Selection Act), first version passed in 2013; with updates in 2017 and 2020.

[5] BGE is the federal company for radioactive waste disposal, in German: Bundesgesellschaft für Endlagerung, cf. https://www.bge.de/en/.

be upgraded as they were approved for only 40 years (cf. Spieth-Achtnich et al. 2022). Their repackaging from transport into storage containers and their transfer to the final storage facility will take up to a few decades. After closure of the repository, the surface facilities that are no longer required will be dismantled and the area renaturalised (cf. Kuppler and Hocke 2019; Mbah and Kuppler 2021). People living at those sites and interacting with the technologies could actively contribute to a nuclear cultural heritage, which "is a process during which social values and knowledges are shaped and transmitted to the future" (Rindzevičiūtė, 2019, 7). An active nuclear cultural heritage is thought to serve the prevention of loss of knowledge and can help to make better decisions with regard to nuclear sites (Rindzevičiūtė, 2019). In this understanding, nuclear cultural heritage encompasses all technical and social knowledge, artefacts, and practices related to nuclear technologies. We understand it as an intrinsic part of long-term governance, although it is not yet clear how nuclear cultural heritages will develop over time. However, practices of dealing with the waste, which are developed in interaction with the repository at a particular site, influence the way long-term governance is enacted at the local level.

Figure 2 Phases of Site Selection Procedure in Germany



Source: Own depiction based on Mbah and Kuppler 2021 and BGE 2023.[6]

1.3 Aim of This Article

Nuclear waste disposal is a long-term infrastructural procedure, which includes or causes transformations at specific sites as well (cf. Mbah and

[6] Online access: https://www.bge.de/fileadmin/user_upload/Standortsuche/Wesentliche_Unterlagen/07_-_Vortraege/Vortraege_Politische_Gremien/20230113_Praesentation_PFE_Workshop_Zeitplan_barrierefrei.pdf (Accessed 26 January 2023).

Brohmann 2021). Infrastructures are designed to be long lasting; they impact space and thus change landscapes as well as socio-economic practices, i.e., through the creation or loss of jobs, and are seen as characteristic of path dependencies that last for decades (cf. Abassiharofteh et al. 2022; Isidoro Losada 2021).

Our working hypothesis is that, in addition to spatial changes, numerous contextual factors will change over time, such as political and social conditions, which include preferences regarding participation in the disposal process, and perhaps the understanding of safety (cf. Mbah 2022).

Therefore, in this article we aim to explore the role of place attachment in the long-term governance of nuclear waste, which we assume from a theoretical point of view and from findings in the literature. In order to provide some insights into the question of the role place attachment can potentially play in addressing people's affectedness, its influence on acceptability, and its potential contribution to safety and security in the long-term governance of nuclear waste, we draw on workshops and interviews that were conducted as part of a transdisciplinary case study within the research project TRANSENS.[7] The case study regions selected were explicitly chosen to be located only partly inside of the identified sub-areas (see figure 1): first, for the practical reason that communities would be more reluctant to participate if they thought the research could contribute to their becoming a siting region; and second, to allow participants to freely debate their ideas of place attachment without feeling the need to relate them to (potential) nuclear sites.

The theoretical idea of place-sensitive long-term governance will be introduced in the following section. We will then highlight the different manifestations of place attachment that can be found in different regions in Germany and discuss possible conclusions that can be drawn from these different manifestations of place attachment for long-term governance.

2. Place-Sensitive Long-Term Governance of Nuclear Waste – An Introduction

Definitions of governance are manifold. In our understanding, in nuclear waste governance the term stands for widening the perspective from policy-making by government to decision-making processes involving a variety of actors that cooperate in networks with varying power relations (Chhotray and Stoker 2009; Kuppler and Hocke 2019, based on Benz 2004). In contrast to

[7] TRANSENS is a joint project funded by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), and by the Lower Saxony Ministry of Science and Culture as part of the "Niedersächsisches Vorab" funded by the Volkswagen Foundation, which aims to conduct transdisciplinary research on nuclear waste disposal in Germany.

other societal problems, nuclear waste requires resources and responsibility. Therefore, state actors strongly control the governance network but give power to the people in the form of "power to" and "power with," meaning that people are granted the opportunity to resist certain solutions or to co-produce them (cf. Themann et al. 2021). On the institutional side, long-term governance refers to the institutional setup capable of handling those tasks, as well as the necessary tasks that need to be carried out today to prepare for tomorrow's decisions and necessary actions (Kuppler and Hocke 2019; Hocke et al. 2022). The responsible institutions need to be able to adapt to changing requirements, which necessitates learning capacities. Learning in this context refers to a high degree of responsiveness and a positive error culture (cf. Mbah and Brohmann 2021; Smeddinck 2021; Smeddinck, Eckhardt, and Kuppler 2022; Sträter 2022). For a public task such as the safe and secure disposal of nuclear waste, those processes should always be oriented toward public welfare. To achieve this, the institutional design needs a system of checks and balances, including participation, that increases the likelihood that decisions are taken in such a way. This also includes aspects of taking common responsibility for a "public bad" (Themann 2022). Even with the decision to store waste in an underground repository, many different paths can be taken depending on the strategy chosen (Spieth-Achtnich et al. 2022). Long-term governance links an existing problem to a possible future solution that involves complexity, uncertainty, and ambiguity. Such governance processes involve a constant formulation and reformulation of ideas of what members of society expect from their government, and of what is considered a "good" outcome of policymaking (Haus 2010). The definition of a "good" outcome in the context of long-term nuclear waste governance depends on the place where a repository is to be located (Mbah and Kuppler 2021). In this case, place is understood as the physical environment surrounding a site.[8] The boundaries of the place are not clearly defined and depend in part on affectedness at different scales (Brunnengräber and Schwarz 2023). Differences in the definition of a "good" outcome originate in people's "place identity," which is formed through psychological identity processes (Proshansky, Kaminoff, and Fabian 1983). Thus, people living in a place develop individual and collective "place attachments" (Low and Altman 1992), which include socio-emotional bindings to material objects of a place (Brown, Raymond, and Corcoran 2015), making it "their own" (cf. Noka 2017). Place attachment is formed and articulated by memories, wishes, emotions, and personal relations (cf. Kienast, Buchecker, and Hunziker 2018; van Veelen and Hagget 2017). It includes aspects at different levels: the actor, the spatial, and the processual level (Scannell and Gifford 2010, 2). The actor level includes individual and collective attachments. The spatial level refers to social imprints and the

[8] For further reading about understandings of place, see also Massey 2005; Raymond, et al. 2021; Watkins 2015.

physical environment. The processual level includes aspects of behaviour, perceptions, and emotions to spatial settings. In this understanding, place attachment stands for everything that people emotionally relate with a certain place. Changes in the place caused by a nuclear waste installation (in future) may influence such emotions. The meaning people attach to those potential changes can differ depending on the aspects that form the current place attachment. For example, in Finland, communities attached quite different meanings to the planned repository, leading to their rejection of a disposal site on their grounds, or a favourable vote, respectively (Lehtonen, Kojo, and Litmanen 2017).[9] If governance is understood as encompassing not only governmental action, but also bottom-up initiatives and everyday practices related to a certain task, then the way people perceive the repository; the expectations they have towards siting, operation, and closure; and regarding governance aspects, co-produce long-term governance arrangements at the local scale. As experiences show, this can include expectations regarding transparency and inclusion, for example, or the right to renegotiate the boundaries of responsibility drawn by decision-makers and the operator (cf. Kuppler, Eckhardt, and Hocke 2023). In the current siting phase in Germany, procedural aspects of siting might differ depending on the place-based context. In the long term, it can be expected that place attachments and related expectations regarding the governance of the waste will co-evolve with the actual governance of the nuclear waste installation (cf. van Assche, Gruezmacher, and Beunen 2022).

The personal significance of a place shapes the extent to which people feel threatened (cf. Manzo and Devine-Wright 2014). Individuals with a powerful place attachment react more to spatial change – both positively and negatively (cf. Carrus et al. 2014; Lewicka 2011). Mihaylov and Perkins (2014) developed a model of "community/social action" which accounts for eight aspects of place attachment that influence social actions or perceptions of landscape change (see table 1). Since the factors may vary among the residents in a region, different place attachments may occur at the same time in one place. Mining experiences or a collective identity such as a nuclear identity can also shape place attachment (cf. Llewellyn et al. 2017). Furthermore, place attachment seems to be more pronounced when governance is perceived as inadequate (Clarke, Murphy, and Lorenzoni 2018). Consequently, dissent and political conflicts can arise due to different perceptions, expectations, and opportunities for participation, which can escalate into massive disputes – depending on how one's own power to act is assessed in each case

[9] That place attachment can influence and be influenced by the siting of energy-related infrastructure has been shown in the literature. It also influences the acceptability of energy-system transformations by local and regional imaginaries (cf. Gailing et al. 2020; Levenda et al. 2019) and participation (Süsser, Döring, and Ratter 2017), and changes itself due to landscape and socio-economic transformations (Llewelyn et al. 2017).

and which opportunities for participation are granted during the procedure and in the entire governance process (Gailing and Leibenath 2017). If such processes are neglected in the long-term governance of nuclear waste, conflicts can escalate and produce stalemates in decision-making that might impede a safe disposal (cf. Hocke and Renn 2009).

In Mbah and Kuppler (2021) we argue that, based on the literature, the local community should play a role in this governance system in the long term as it is affected in different ways over the lifespan of a nuclear repository:

(1) In the beginning, the existing place attachments will influence the way potential host communities act in the site selection procedure, e.g., regarding participation or resistance. Place attachments will form people's interpretations and meanings of a potential repository as well as narratives and visions of "their" place. Neglecting those place attachments in the beginning could mean that local knowledge is not incorporated in repository planning and local fears are not addressed.

(2) During construction and waste emplacement, policies might need to be adapted according to changing context conditions, e.g., new technological options for disposal or political changes. In a deliberative understanding of democracy, policies should not only be oriented toward public welfare, but also negotiated in a participatory manner. This necessitates a debate involving the local community, concerning the issue of what public welfare can be under unpredictable future circumstances (cf. Sierra and Ott 2022). This needs to be a continuous process.

(3) After closure of the repository, it becomes more and more likely that interest in the repository will decrease, as will resources to maintain it. To fulfil the requirement of retrievability for 500 years after closure, an active nuclear heritage could be of advantage. This involves the formation of a local nuclear memory, which could be considered as being linked to local place attachments (Mbah and Kuppler 2021).

To date, these ideas about the role of place attachment in long-term governance remain theoretical, as the role of place attachment in the governances of final disposal has never before been analysed.

3. Methodology

3.1 Methodological Reasoning

As we are particularly interested in reactions to spatial transformations regarding a nuclear waste repository, we are interested in models that help to

analyse different factors of place attachments in terms of the actions to be expected from local inhabitants. For this reason, we would like to focus on place attachment with regard to potential future change and base our analysis on the model of Mihaylov and Perkins (2014). The model shows the importance of place attachments regarding the residents' evaluation of spatial change. If all factors are strongly pronounced, a reaction is likely. How exactly the influencing factors are weighted, however, remains open. Likewise, this model does not make it possible to determine which reaction of the residents is to be expected when (cf. Mihaylov and Perkins 2014, 63 cont.). Here, we would like to point out that empirical research and models of behaviour and reactions are always reductions of reality and can therefore only be taken as frameworks for a flexible interpretation of place attachment (Devine-Wright 2014, 171). Nevertheless, the model offers a useful approach to differentiate between different factors of place attachment that play a role in inducing the reactions to landscape changes to be expected in, i.e., siting a nuclear waste repository. With that, we follow those strands in the literature that focus on emotional aspects of place attachment, such as people's networks and ties to a certain place or their use or memories of it (e.g., Süsser, Döring, and Ratter 2017; van Veelen and Hagget 2017; Knaps, Herrmann, and Mölders 2022). Still, we keep material factors of place attachment in mind, mainly through the selection of the regions we analysed, but also in questioning the participants in our empirical study on material objects in space. For this, we use an explorative qualitative and transdisciplinary approach, meaning that we aim not at representativeness, but at exploring how place attachment can be characterized in different regions that have either mining experiences or experiences with a nuclear facility. Qualitative studies on place attachment generally use semi-structured interviews to explore certain aspects of place attachment, such as the role of shared place meanings in the adoption or rejection of renewables (Süsser, Döring, and Ratter 2017).[10] We use a slightly different research approach by organizing our research in a transdisciplinary way,[11] which means we aimed at working closely with actors rather than just exploring them as research subjects. Before we set up our research design, we conducted five expert interviews with scientists from various disciplines[12] in order to validate and adapt our research design.

Our approach is to use the results of this explorative approach to discuss the potential role of place attachment regarding a possible repository site for nuclear waste in the future with the objective of deriving recommendations

[10] We decided not to do quantitative research as, e.g., Devine-Wright and Batel 2017, or Clark, Murphy, and Lorenzoni 2018 did, but to use a transdisciplinary approach.

[11] For further reading, see Bergmann et al. 2012; Lam et al. 2021; Lang et al. 2012; Lawrence et al. 2022.

[12] Our experts were: Prof. Lenelis Kruse-Graumann (environmental psychology), Prof. Tatjana Schneider (architecture), Prof. Stefan Siedentop (spatial planning), Dr. Markus Egermann (transition governance), and Prof. Ludger Gailing (regional planning).

for long-term governance. We are aware of the difficulty and restrictions involved in researching place attachment and then trying to relate it to a possible future infrastructure. We assume that mining is generally accompanied by specific cultural characteristics, like the existence of communities of assistance with a high degree of social cohesion (cf. Llewellyn et al. 2017). As Germany aspires to deep geological disposal, we assume a certain transferability of results. Furthermore, we assumed that currently existing nuclear facilities in a region would influence place attachments in a way similar to a potential future nuclear waste facility.

In our research design, we decided to focus on three different regions of Germany, which were selected based on seven characteristics. These characteristics were: experience with nuclear facilities or mining, experience with structural change, geographical distinction, cultural specificities and religious affiliation, rural/urban context, socio-economic structure, and positive or negative net migration, and whether part of the sub-area has been reported as a potential host for a disposal site (BGE 2020, see figure 1). The study regions were selected with the intention of considering study regions that differ from each other as much as possible, so that the aspect of structural change could serve as the focus for analysing the associated changes in place attachment during different phases of transformation in three regional contexts. The aim of this was to enable the investigation of place attachments as they might occur in relation to a nuclear waste repository in a variety of settings, rather than a comparison between the regions. Two of the selected districts (Recklinghausen and Görlitz) are experiencing or have experienced pronounced structural change and differ greatly in terms of population density and cultural characteristics; both have mining experiences but no experience with nuclear facilities. Regarding the potential of being selected in the siting procedure, most parts of the Recklinghausen district are not part of potential sub-areas (see figure 1).[13] In contrast, large parts of Görlitz district are potential sub-areas. The third district (Heilbronn) was selected as a comparative region that has not undergone any specific structural change, has a more representative population density and socioeconomic structure as well as positive net migration, and is neither too urban nor too rural as compared to an average German region. Nevertheless, it has somewhat similar characteristics, such as mining experience, albeit not in the same dimension as the other two regions, and parts of it are potential sub-areas. Furthermore, the Heilbronn district has experience with a nuclear facility, the Neckarwestheim nuclear power plant.[14]

[13] For a closer look on the map of potential sub-areas, have a look at the interactive map of the BGE: https://www.bge.de/en/sitesearch/sub-areas-interim-report/ (Accessed 26 July 2023).

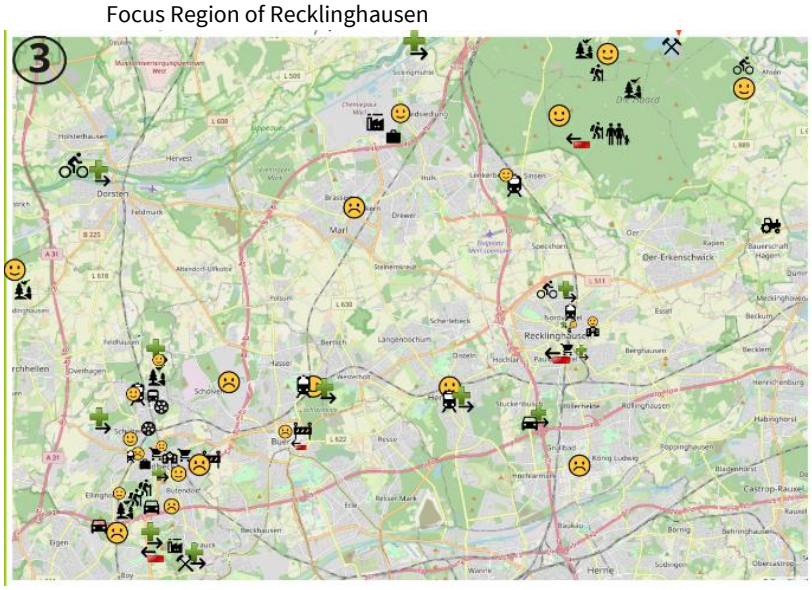
[14] With the nuclear phase-out in Germany, the second reactor of the Neckarwestheim power plant has been undergoing decommissioning since 15 April 2023, whereas the first reactor was decommissioned in 2011 and is currently being dismantled. See also https://www.enbw.com/

For operationalization, smaller units of all three regions, consisting of four to eight municipalities, were selected as "focus" regions. Actors[15] from each region were invited to take part in a regional online workshop called "What is special about my place of residence?" The workshop design draws on an adapted emo/action-mapping method for collaboratively mapping significant places and spaces, based on West and Kück (2019). Figure 2 gives an example of the empirical co-mapping of important places we did together with the participants of the workshop in Recklinghausen. It illustrates which places are regarded relevant from the participants' points of view, and for which reason these places are considered as important, e.g., as recreation areas (marked with a bicycle, hiker, family, or trees), as working places (marked with buildings, e.g., industries), or in terms of transportation (marked with a train or car). The happy or sad smiley faces indicate whether participants like or dislike places. The participants also indicated whether there had been positive or negative transformations in the last five to ten years (indicated by the green plus and the red minus).

unternehmen/konzern/energieerzeugung/kernenergie/standorte/standort-neckarwestheim.html (Accessed 26 July 2023).

[15] The actors were selected by screening according to the following characteristics: membership in cultural and heritage associations, environmental protection and professional associations, or citizens' initiatives; representatives of municipal administration, politics, tourism, or students' associations; and representatives of churches.

Figure 3 Example for Co-mapping with a Range of Places of Meaning in the Focus Region of Recklinghausen



Source: Own depiction as collaborative working output of the regional online workshop conducted in February 2022.

Table 1 Number of Workshop Participants (abbr. "WP") and Interviews (abbr. "ID") per Region and their Affiliation to Selected Actor Groups

Actor groups/regions	Görlitz	Heilbronn	Recklinghausen
Cultural and heritage associations	-	ID 1, 1 WP	1 WP
Environmental protection and professional associations (entrepreneurs)	ID 1	1 WP	1 WP
Citizens' initiatives (civil society)	ID 2	-	1 WP
Representatives of municipal administration	ID 3	ID 2	ID 1, ID 2, ID 3, 1 WP
Representatives of politics	ID 4	2 WP	2 WP
Tourism and students' associations	-	-	1 WP
Representatives of churches	-	-	-

Source: Own compilation.

Regarding the analysis of place attachment, we conceptualized our empirical material considering the model of place attachment and social actions by Mihaylov and Perkins (2014). In our analysis we assigned statements from the interviewees[16] or content summaries of the statements of interviewees or workshop participants to the eight factors of the model and supplemented them with publicly available information gathered via desk research. We

[16] Exact quotes of interviewees are marked with IDs assigning the regional backgrounds of interviewees.

assigned various aspects to the factors, as shown in table 2. If all eight factors are addressed in one region, then the strength of place attachment among the study participants can be considered rather high. If only some of the factors are addressed, then the strength of place attachment is medium. We would assume a low strength of place attachment if only up to three factors were addressed, which was not the case for our study.

3.2 Core Characteristics of the Selected Districts

Here, we would like to give an overview of some key characteristics of the regions, based on desk research and statements from interviewees and participants of the workshops in order to better understand the place attachments identified in the next chapter.

Recklinghausen

The district of Recklinghausen is in the northwest of North Rhine-Westphalia. The focus region within the district of Recklinghausen includes the municipalities of Recklinghausen, Herten, Marl, and Gladbeck. It has a population density of about 1,032 inhabitants per km² and is therefore one of the most densely populated regions in Germany.[17]

The region forms the transition zone from the highly dense Ruhr region in the south and the rural Münsterland region in the north. The cities are characterised by a high building and population density and have traditionally been the focus of industry and commerce in the region: "[…] the transition from one settlement structure to the next is fluid" [Recklinghausen_ID1]. The landscape is therefore characterized by transportation lines, built-up areas and cultivated land, and to a lesser extent by woods. Historical mining experience is particularly pronounced and still of importance for identity formation.

For a long time, coal mines and their suppliers (construction, timber industry, etc.) spawned a wide variety of industries. Whereas industry provided more than 53 % of the region's jobs in 1990, today it provides only 28%,[18] making it one of the areas in Germany with above-average unemployment (about

[17] It has a population density of about 1,032 inhabitants per km² https://www.regioplaner.de/statistik/bevoelkerungsstatistik (Accessed 08 January 2024). On average, the calculated population density for Germany is 232 inhabitants per km² (see also the map of population density on this website: https://www.demografie-portal.de/DE/Fakten/bevoelkerungsdichte.html (Accessed 15 July 2022).

[18] http://masterplan-bildung.ruhr/wp-content/uploads/2019/05/5.2-Integriertes_Handlungskonzept_fu%CC%88r-die-ELR_Dachkonzept-fu%CC%88r-den-Umbau-21.pdf (Accessed 15 July 2022).

10%).[19] The rapid and ongoing change has shaped the region and its people and led to a culture of openness.[20]

Heilbronn

Heilbronn district is in the north of Baden-Württemberg and has a population density of approx. 313 inhabitants per km². Thus, it is slightly over the average population density of Germany[21] and continues to record an increase in population. The focus region covers eight municipalities, namely Beilheim, Abstatt, Neckarwestheim, Talheim, Untergruppenbach, Lauffen am Neckar, Flein, and Ilsfeld. The unemployment rate is 3.5%.[22] Traditionally, the district has been characterized by agriculture (including viticulture); today, the manufacturing industry is of great importance.[23]

The district of Heilbronn is a quite rural and at the same time rather densely populated hilly region with lots of cultivated land. The interviewees and workshop participants describe it as a scenic wine-growing area with steep slopes, many castles, and the Neckar River, and with beautiful historical buildings in general.

The district is also home to the Neckarwestheim nuclear power plant[24] and to an underground disposal site for hazardous waste. Currently, a further underground landfill in the Heilbronn district is being planned, as the existing landfills are reaching their capacity.[25] However, there are doubts regarding its safety.[26]

Görlitz

The district of Görlitz is in Saxony, in south-eastern Germany. It has a population density of approx. 121 inhabitants per km²,[27] which means it is sparsely populated and quite rural. Our focus region covers six municipalities, namely Hohendubrau, Kreba-Neudorf, Vierkirchen, Niesky, Quitzdorf am See, and Rietschen. Upper Lusatia, as the region is also called, experienced a particularly sharp decline in population after the reunification of Eastern and

[19] https://www.regioplaner.de/statistik/arbeitsmarkt (Accessed 08 January 2024).
[20] http://masterplan-bildung.ruhr/wp-content/uploads/2019/05/5.2-Integriertes_Handlungskonzept_fu%CC%88r-die-ELR_Dachkonzept-fu%CC%88r-den-Umbau-21.pdf (Accessed 15 July 2022).
[21] See footnote 14.
[22] https://statistik.arbeitsagentur.de/Auswahl/raeumlicher-Geltungsbereich/Politische-Gebietsstruktur/Kreise/Baden-Wuerttemberg/08125-Heilbronn.html (Accessed 15 July 2022).
[23] https://www.landkreis-heilbronn.de/der-landkreis-in-zahlen.1102.htm (Accessed 15 July 2022).
[24] Unit I is being decommissioned/removed, Unit II was shut down in mid-April 2023.
[25] https://www.euwid-recycling.de/news/politik/einzelansicht/Artikel/planungen-fuer-neue-untertagedeponie-in-heilbronn.html (Accessed 15 July 2022).
[26] https://www.stuttgarter-zeitung.de/inhalt.untertagedeponie-in-heilbronn-giftmuell-statt-salz-bis-mindestens-2028.e748c01a-c956-4e2a-afb2-8914a262f8e1.html (Accessed 15 July 2022).
[27] https://www.kreis-goerlitz.de/city_info/webaccessibility/index.cfm?item_id=852639&waid=393 (Accessed 15 July 2022).

Western Germany and the structural change in the region following the decline of lignite mining. The unemployment rate is 7.1%.[28]

Mining goes back to the 18th century, and the opencast mines have greatly changed the natural and cultural landscape. Due to the phase-out of lignite mining, the region is experiencing not only a socio-economic structural change, but also a change to the natural and cultural landscape. The large opencast mining "holes," for example, are (supposed to be) filled with water, creating a lake district. The economy has traditionally been characterised by lignite mining, steel and wagon construction in Niesky,[29] and agriculture. Nowadays, tourism and renewable energies are gaining in importance.

4. Expressions of Place Attachments in Districts

In the following chapter, we draw on our empirical findings, primarily from statements made by the interviewees, but also statements and conclusions from the mappings in the workshops we conducted. We either quote statements and then mark them as quotations or sum up different statements from interviewees and workshop participants without marking them as quotations. In addition, we attempt to assign the statements and conclusions to the various factors of place attachment according to the model by Mihaylov and Perkins (2014), as shown in table 2, with the aim of figuring out which factors might be important in each region (see table 2). We assume that the more factors are identified as relevant in a region, the greater the strength of place attachment. We highlight the factors of place attachment and the linking quotes or elements of our conclusions drawn from the mappings or interviewees' statements by underlining them to show what makes us claim a factor. Because of our limited empirical research, our findings are far from being representative and must be regarded as explorative in linking the field of nuclear waste governance to the concept of place attachment.

4.1 Recklinghausen

Landscape changes induced by structural change have high relevance for the workshop participants and interviewees, so the factor environmental disruption is very important. The landscape changed considerably over the last decades, especially from open pit mines to newly built recreation sites. One interviewee summarises this as follows: "The transformation process is almost

[28] https://www.saechsische.de/arbeit/arbeitsmarkt-agentur-fuer-arbeit-arbeitslos-corona-kurzarbeit-februar-2021-5390548.html (Accessed 15 July 2022).

[29] https://www.saechsische.de/niesky/lokales/waggonbau-niesky-mit-voller-fahrt-durch-die-krise-auch-stahl-technologie-industriebetriebe-in-niesky-5403416-plus.html (Accessed 15 July 2022).

complete, or has been completed, as colliery wastelands have acquired new functions, production sites have gained new uses, and landscape reclamation for residents has been achieved" [Recklinghausen_ID1]. In terms of landscape and quality of life, the region is characterised by multiple loads like traffic, building density, and small recreation areas which are important aspects of the factor place dependence. Land scarcity and emissions with related high rates of air pollution are seen as the greatest challenge.

The Recklinghausen district was formerly dominated by Catholics, but nowadays it is characterised by high cultural diversity with a variety of minority groups. This diversity is also addressed by interviewees and hints at a decreasing importance of religion as an aspect of place identity: "The Ruhr region is a melting pot of many cultures, but it is also characterized by the integration achievements and the special abilities and the will to change of its inhabitants" [Recklinghausen_ID1]. Place identity is grounded and shaped by the fact that the region has a long history of immigration. Therefore, belonging is not defined by local ancestors in the sense of generational history or Catholic affiliation. Moreover, manifold norms and traditions were mixed, changed, and transcended into a culture of openness and flexibility.

Further, its mining experience is an identity-forming factor, especially in terms of social cohesion and assistance structures as important aspects to cope with daily life in mining, as the following quote emphasizes: "Being underground together left its mark; it was about being able to rely on each other and deal with each other, regardless of origin or culture" [Recklinghausen_ID_3]. This generated communities of support. Therefore, we assume the factor sense of community to be important.

The positive value of the region is seen in its people and cultural identity. "It's not about a certain circle of friends and acquaintances, but actually the type of persons in the region that has evolved over the last 100-200 years" [Recklinghausen_ID3]. The people of the region are described as open and direct, with solidarity with each other and little superficiality, which can be seen as aspects of either the factor place identity or place bonding. They have their "heart on the tongue, but when it comes down to it, they are there" and stand together [Recklinghausen_ID1].

4.2 Heilbronn

In the district of Heilbronn, the preservation of village structures and nature are important to the interviewees and participants of the workshop. As these are landscape-related factors linked to home, they are part of the factor place definition. The district is characterised by agriculture on the one hand, and on the other by technology research and manufacturing, e.g., engineering companies like Bosch and Magna. Workshop participants and interviewees consider local recreational areas to be very important for the inhabitants,

including restaurants, wineries, and a rich cultural programme (concerts, choirs, etc.), which are all important aspects of recreation, meeting, and networking points, emphasizing the quality of this region. One interviewee summarised this as "living where it's nice and the big cities are not far away" [Heilbronn_ID2], meaning that there nothing is lacking and at the same time you live in a quiet and rather rural area. With this, both job opportunities and daily needs are fulfilled, which are aspects of place-based social interactions and place dependence.

Regarding cultural backgrounds, the Swabian dialect is perceived as a linking element, as for example one interviewee quoted a German proverb: "One likes to speak as one's beak has grown" [Heilbronn_ID1]. This quote shows that the dialect and common mentality are important aspects of creating a sense of community. Here, again, the interviewees and participants of the workshop highlighted that networks, friends, sports, and cultural associations are important for belonging and feeling at home. Some also have family history in the region going back for some generations. Those are aspects of the factor collective efficacy, and family bonds are mainly aspects of the factors place bonding and place identity.

Regarding infrastructural changes, it is expected that they would hardly change the landscape if possible. If they do, participants expect changes to be developed carefully and that they represent an added value for the region: "People must be involved and identify with the project. In principle, there should only be cautious changes, i.e., not overly large projects, but rather small-scale changes" [Heilbronn_ID2]. This can be assigned as aspects of the factor place dependence. The Neckarwestheim nuclear power plant is an example of this, because the interviewees and participants of the workshop emphasised here that it is quite well embedded in the landscape, as it is located in a former quarry and therefore hardly noticeable except for the steam clouds and the chimney. Furthermore, the added value for the region in terms of jobs, financial assets via taxes, and low energy costs were important aspects for the region to accept such an industry, as this quote also shows: "[…] you have to live with it as you got cheap energy from it" [Heilbronn_ID1]. Another example stated was that an earth dump is inconceivable, but a new railroad line would be considered acceptable if it brought a positive traffic development and would thus cover current and future needs.

4.3 Görlitz

The district of Görlitz enjoys a quite marked communal affiliation linked to local politics, sports associations, and agriculture, which are aspects of the factors place definition, place-based social interactions, and collective efficacy. Especially associations and the vivid participation in them seem to be very pronounced. People appreciate the close network of relationships, as

this interviewee described it: “You stand outside the bakery in the morning and meet numerous acquaintances and friends and are so engrossed in conversation until the baker comes out and asks if you don’t wanna come in and buy some bread (laughs)” [Görlitz_ID_2]. This is an example for the factor place bonding. The interviewees describe the inhabitants of Görlitz as generally oriented toward rather traditional norms that are expressed in traditional local community festivals like the “Cherry Blossom Festival or the Bus House Festival” [Görlitz_ID3]. These are aspects of the factor place identity. At the same time, interviewees feel so rooted and responsible for the region’s development that they emphasised how their own actions to contribute to it, e.g., with an initiative to design urban green spaces for all generations. This can be seen as an aspect for the factor sense of community.

Place attachment is strongly linked to the landscape and the inhabitants, so place definition is an important factor, as the following quote underpins: “Home is a feeling when you see the familiar surroundings, and you feel, ‘here you are at home, here you have arrived’” [Görlitz_ID2]. Görlitz is currently experiencing a landscape transformation from open-pit mines to new open-air landscapes with lakes and green nature for recreation and tourism. Lignite mining is not perceived as a burden which causes negative changes. Instead, it is stressed that the open-pit mines last for only 30 to 40 years, after which they are renaturalised, creating beautiful lake landscapes that are attractive for tourists. Therefore, the factor environmental disruption is both negatively and positively connoted. The former because previously open-cast mining had been important for income generation, which is now lost or coming to an end, but the latter due to the emergence of a new income generation branch – tourism. Furthermore, the negative net migration trend, which has been underway for decades, the loss of jobs due to the structural transformation from traditional lignite mining and agriculture into as yet undefined sectors and the feeling of being left behind was stressed by the interviewees. Many challenges go hand in hand with the transformation process, e.g., a low number of industries, a growing vacancy rate in city centres and commercial areas, the increasing residential vacancy rate, and the deterioration of buildings worth preserving.

Table 2 Summarised Expressions of the Eight Factors of Place Attachment in the three Study Regions

Factors of place attachment	Examples of aspects or expressions of factors	Recklinghausen	Heilbronn	Görlitz
Place-based social interactions	Working place, living place, shopping, recreation, etc.	Urbanised region, many jobs and shopping possibilities	High-quality jobs with modern technology firms, Heilbronn as a larger city	All sites of daily activities at short distances (work, shopping, recreation)
Place definition	Definition as home with reference to landscape characteristics	-	*Beautiful landscape, viticulture, wineries*	Landscape for recreational activities with many ponds, lakes, and forests
Environmental disruption	Transformations in terms of infrastructure or socio-economic (structural) change	*Transformation experience from industrialisation with positive net migration to deindustrialisation with a negative migration trend*	-	*Vivid transformation experience with many challenges (unemployment, negative net migration, vacancies in city and commercial centres), and on the other hand new recreation areas and a developing tourism sector*
Place dependence	Residential/population density, green spaces, accessibility, etc., so aspects which refer to the quality of place in comparison to others	Accessibility and simultaneously multiple burdens (e.g., air pollution, noise)	*Nature, and accessibility of cities important ("living where it's nice and the big cities are not far away")*	-
Place identity	Norms and traditions going back to e.g., religious affiliation, cultural traditions; dialects, etc.	*Open and direct mentality, cultural melting pot*	*Swabian dialect*	e.g., the "Cherry Blossom festival," Sorbian culture and borderland region
Collective efficacy	Participant in associations, clubs, or NGOs	-	Many associations (sports, choirs, etc.)	Importance of associations (sports, senior citizens, youth, fire brigade, etc.)
Place bonding	Family networks, friends	Friendships, family, and openness of the people	Friendships, and even family structures extending far back into the past	*Family networks and friendships, neighbourhood*
Sense of community	Traditional or modern structures of social cohesion in terms of specific needs to help each other	*Reliability on miners underground*	-	Initiatives for shaping positive regional development

Aspects identified as particularly important in italics.
Source: Own compilation drawing on Alrobaee and Al-Kinani 2019, Michalos 2014, and Mihaylov and Perkins 2014, and the empirical findings.

5. Discussion of Findings

In all three regions, different factors of place attachment could be identified based on the interviews and workshops, albeit with different characteristics (see table 2). The diversity of the regions is also reflected in their place attachments. In Recklinghausen, six out of eight factors were identified, with place identity, sense of community, and environmental disruption being particularly pronounced. One reason for this can be seen in the region's early industrialisation, which led to high immigration rates and intensive mining experience. Highlighted in this context is the importance of being able to rely on each other during the hard work underground (in mines), which is why religion or origin were not significant for identification. The formation of communities of need and support had more significance (cf. Llewellyn et al. 2017). At the same time, encounters among different cultures in the course of various transformation experiences (e.g., industrialisation, de-industrialisation, and an awaited transformation in the course of the energy transition) shaped and possibly still shapes the Recklinghausen region in that a welcoming culture and a culture of openness developed. The interviewees and workshop participants understand the transformation of the landscape from open-pit mining and quarries to spaces for leisure, culture, and tourism to be complete. Still, efforts must be made to (re)establish economic prosperity in the present and in the future considering the high unemployment rate of 10%. We would assume a medium to high strength of place attachment for Recklinghausen.

In Heilbronn, the interview partners and workshop participants emphasised the special features of the region's landscape even more, with viticulture playing a particularly important role. Here, six out of the eight factors of place attachment could be identified as important. Besides the factor place definition, the interviewees and participants particularly emphasised aspects of the factors place dependence and place identity. Regarding the factor place dependence, it was emphasised that although it is a rural region, it has very good connections and accessibility to larger cities (like Heilbronn and Stuttgart). The Swabian dialect is addressed as significant for place attachment. Here, landscape-related factors of place attachment with a positive connotation are of particular importance. At the same time, the rather positive perception of the now shutdown Neckarwestheim nuclear power plant shows that a regional added value of infrastructures plays a role. Neckarwestheim was not only associated with jobs, but also with cheap energy for the region (cf. Kramer 2019). For the district of Heilbronn, we assume a medium to high strength of place attachment.

In Görlitz, this seems to be rather different. Lignite is still mined here, although many open-pit mines have already been renaturalised. Regarding the expression of place attachments, seven out of eight factors could be identified here, with aspects of place bonding due to private networks (family, friends), environmental disruption and sense of community being mentioned frequently by the interview partners. The interviewees emphasised the importance of rural areas and village structures. Structures and aspects of village community and cohesion seem to be significant. At the same time, aspects of environmental disruption were described rather ambivalently: on the one hand, as landscape gain in terms of new recreational spaces, which are also important for tourism; on the other, as negative experience of job losses and migration. Here, community factors of place attachment seem to be very important. Therefore, we would assume a high strength of place attachment for Görlitz.

In conclusion, place attachment in all three regions is rather high, with a slightly more pronounced expression in the district of Görlitz. The reason for this might be the current and ongoing transformation experience, which is less pronounced in the other two regions, where it is also understood to be a new beginning (cf. Manzo et al. 2023). At the same time, our explorative study hints at very different expressions of place attachments in the three regions. Whereas in Recklinghausen the factors environmental disruption, place identity, and sense of community seem to be particularly pronounced, in Görlitz, besides environmental disruption and sense of community, aspects of place bonding seem to be especially important. This shows that mining is an important aspect for place attachment if many people work there and develop a strong sense of community linked with the experience of environmental disruption. In Heilbronn, in contrast, aspects of the factors place definition, place dependence, and place identity seem to play a major role.

The main difference between Recklinghausen and Görlitz counties, on the one hand, and Heilbronn district, on the other hand, seems to be the stronger pronunciation of social factors of place attachment which foster social cohesion due to experienced environmental disruptions. In Recklinghausen, this is linked to the memory and heritage of people with different backgrounds working together in the mines: “Local places like the power plants and the mines are embedded in regional images, networks, and discourses that are influenced or even created by national and global objectives and policies” (Gailing et al. 2020, 1123). With this, Gailing et al. (2020) point out that there are bidirectional flows of information which implicitly influence local, regional, and national governance referring to the Ruhr region. In Görlitz, the phase-out of lignite mining with its effects on employment seems to have had a major impact on the remaining people’s identification with their region and the felt need to preserve the existing social structures and natural landscapes. At the same time, the remains of the lignite mines are viewed as something

positive, bringing recreational value to the area. Whereas for Heilbronn, landscape factors of place attachment seem to be stronger. Reasons for this can be found in the long tradition of landscape conservation and landscape-bound income generation (viticulture) combined with cultural practices (wineries, restaurants). Here, the focus lies on preservation of landscape, with the wish for only slight changes and expectations of participation in projects which implicate wider landscape changes.

As mentioned above, the technical implementation of a disposal pathway will imply a change of landscape in several regions. As far as long-term governance is concerned, strong place attachments point out the need to know the regional contexts and its peculiarities well so that they can be sufficiently included in infrastructure planning and implementation and thus enable "place-embedded agency" and learning, as Hakkarainen et al. (2022) pointed out. Süsser, Döring, and Ratter (2017) highlight the importance of participation, which is at the same time influenced by specific manifestations of place attachment. Depending on how one's own power to act is assessed in each case and which opportunities for participation are given during the procedure and in the entire governance process, dissent and political conflicts may emerge (Gailing and Leibenath 2017). As social cohesion, which is expressed by the factors place identity, collective efficacy, place bonding, and sense of community, seems to be a strong factor in all three regions, it can be assumed that a strong reaction towards landscape transformation via infrastructure planning is to be expected. Our empirical findings show that concrete places play a major role, as the interviewees focused more on the nearby surroundings of their places of residence and only references a few places further away (e.g., famous places of interest such as castles or important recreation areas). Especially when we asked for possible landscape changes by infrastructural planning in the future and what should be considered from their points of view, the participants and interviewees highlighted nearby surroundings of their places of residence and emphasised their wish to be engaged in decision-making. Governance should refer to place attachment through regional and local participation, e.g., in terms of experimental settings and networks, which may be a starting point for upscaling on national or international levels (cf. Gailing et al. 2020). Based on this and the experiences made in other countries regarding place attachment and nuclear waste repositories (see introduction), we conclude that place attachment plays an important role in the interaction between a nuclear waste repository and the host community, too. The public needs to be involved in planning, implementation, and operation of a radioactive waste disposal facility.

This is particularly true when "natural," "green" places of recreation are perceived as limited or particularly important to inhabitants. As is emphasized in the literature, a strong expression of place attachment is often linked to a sense of loss (cf. Manzo et al. 2023). This might also be true for a potential

loss in future, so past, present, and potential future losses can lead to social actions. Therefore, participation is always needed, especially when landscape-related factors of place attachment are strong. At the same time, the pronunciation of social factors of place attachment might foster (re)actions to potential changes.

The examples of Recklinghausen and Görlitz, furthermore, show that strong bonds to industrial landscapes are possible, which could also be important in terms of nuclear waste governance. Based on the observations on how mining shaped place attachment, particularly in Recklinghausen but in Görlitz as well, it seems likely that a nuclear waste repository will influence place attachment. Certainly, not as many people will work underground and it will be different from traditional mining. Still, the creation of jobs in the region will be important. Of course, job opportunities will vary along the different phases of nuclear waste disposal, with a high creation of jobs in the early stages of site selection, construction, and emplacement – also through the need for downstream services (cf. Rütter et al. 2006). This might induce added value at the selected repository site and its surrounding region and population growth, which might last for only a certain period. At the same time, a nuclear waste repository might induce opposite developments in close-by regions that are not the host communities and might not benefit in the same way, but would rather be concerned by, e.g., a potentially negative image, leading to less tourism, lower property values, and therefore a negative population trend (cf. BFE 2021; Lehtonen, Kojo, and Litmanen 2017). This means that the type of influence will be different regarding both the perceived benefit and the potential negative impacts for the region. It can be assumed that the close-by "invisible hazard" and the "everlasting" construction area (from the point of view of one generation) influence the way a local community perceives and interacts with the repository. The social practices that develop in the interaction with the repository might be part of the professional handling of the waste, of protest activities by local citizens' initiatives, or maintenance and marketing to frame the nuclear waste repository and the region more positively. In summary, these activities are part of or might create a local nuclear cultural heritage that contributes to a safe storage of the waste in the long term and thus contribute to long-term governance.

In our understanding of place-sensitive long-term governance, safe disposal is enacted at every moment in time over a very long period. Each decision now, each cultural practice formed, and every bit of knowledge and memory related to nuclear waste form the way the waste is handled tomorrow, and every idea of tomorrow shapes the way the waste is handled today (Frey et al. 2022). Just as the miners' experience of working together underground still lives on in the social self-conception in Recklinghausen, the experience of building a nuclear waste repository could contribute to the transmission of knowledge into the future. This idea that knowledge is transmitted

not only through the communication of knowledge in the form of written testimonies has been developed in the international debate on communicating nuclear knowledge:

> Based on "mechanisms" such as culture, education, knowledge management, but also on regulation and surveillance, etc., the first mode of transmission aims to reinforce the permanence of an "indirect", "mediated" link between generations, in cultural, economic, and political contexts likely to change over time. (Calla et al. 2023, 4)

Therefore, long-term governance includes the participatory development of regional energy futures that are part of socio-technical and spatial imaginaries, which is also a way of reducing uncertainty (cf. Chateau, Devine-Wright, and Wills 2021; Gürtler and Herberg 2021; Levenda et al. 2019; Reimer and Rusche 2019).

It has been suggested in the literature that nuclear waste governance could be a form of commons governance (Themann 2022, based on Ostrom 2013). This would mean that people take collective responsibility for safely disposing waste by taking decisions jointly. A possible risk of such polycentric governance is that decisions cannot be taken because of dissent. Therefore, this requires strong conflict-resolution mechanisms (Themann 2022, 52). It could be observed in Gorleben and Wendland that the planned repository led to a breaking up of families there, while at the same time strong social cohesion was created among protestors (cf. Blowers 2018; Kirchhof 2021). If this were to happen at a future repository site, it could counteract any efforts made towards creating safety through long-term governance aimed at public welfare using principles like those developed in the framework of commons governance. Therefore, Gorleben and Wendland can be used as examples for reactions and actions elicited by planning, which can be traced back to strong place attachment, although no concrete studies on place attachment in this context are available to date. However, the construction of the Wendland concept reveals a place attachment that is characterized by a strong sense of community and a high degree of networking and integration (expert interview with Tatjana Schneider[30]). As Knaps and Herrmann (2018), Knaps, Herrmann, and Mölders (2022), and Gailing et al. (2020) indicate the importance of place attachments for planning and governance, we conclude that such contextual knowledge and networks must be a basis for regional participation forms and the development of a place-sensitive long-term governance.

[30] Prof. Tatjana Schneider, see https://www.gtas-braunschweig.de/introducing/detail/tatjana-schneider (Accessed 17 February 2023).

6. Conclusion

"Place is space made personal" (Noka 2017). Presumably, nobody would like people entering their home and altering it without asking. The routes our children walk to school every day, our favourite bakery, that spot where we go in summer to relax. All of this makes us feel at home and turns a general space into a personal place. Place can be formed by different objects, meanings, and emotions for different people at the same time, and its collective meaning becomes established over time and several generations. In Recklinghausen, people report that they feel that they must stick together no matter where a single person comes from – just as previous generations worked together in the mines, where everyone depended on each other. In Görlitz, many people move away, which has created a feeling of loss and the need to preserve what is there. In Heilbronn, people are happy to live in a rural area with easy access to urban areas and perceive the region as of great personal value and with no need for transformation.

When a repository for high-level nuclear waste is built, filled, and closed, it becomes a task that will occupy various generations. Doing this in an area where many people oppose this alteration of their place seems like a bad idea for an endeavour that should ensure safe and secure disposal of the waste and its active monitoring and control for centuries. Organizing such control and the ability to act at every moment during the process, always with a view to the potential challenges and tasks yet to come, requires a high degree of vigilance and openness to learn. A destructive conflict in a hosting region with families breaking apart, as happened in the Gorleben area, is not very likely to support such vigilance over the long-time spans needed. This does not mean that opposition and conflict should not be welcomed – they can give important indications of where things go wrong. Rather, our findings from the workshops and interviews suggest that it is necessary to give people a chance to make the repository part of their place. Particularly for long-term communication and knowledge preservation, a long-term repository governance that considers local place attachment – a place-sensitive long-term governance – would be an asset. Far from persuading or bribing people into accepting such a repository, it would contribute to a governance in which responsibility is taken together.

With this article we intended to show the importance of place attachment for planning and long-term governance. There are still open research questions, i.e., how exactly place attachment needs to and can be addressed in long-term governance, what kind of institutions and formats are appropriate, and how they develop over time.

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