

Insights into the acceptance of a deep geothermal energy project in Germany through the co-design of scenarios[☆]

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HIGHLIGHTS

- DGE is less popular than other renewables due to seismic and environmental risks.
- Concerns and expectations of stakeholders must be taken seriously.
- Mitigating seismic risk and sharing energy with communities can foster acceptance.
- Co-design scenarios can promote procedural and distributive justice in a DGE project.
- Acceptance is related to the trustworthiness of DGE developers and expert's credibility.

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ABSTRACT

Unlike solar and wind energy, which have grown significantly over the past decade, the use of deep geothermal energy (DGE) has stagnated in Germany and worldwide. This is despite DGE's significant potential as a reliable, weather-independent source of decarbonised electricity and heat, and despite its political support. However, the high upfront costs, exploration risks, complex permitting processes, environmental concerns, and lack of social acceptance, particularly with regard to the risk of induced seismicity, have hindered its development. This study addresses the prerequisites for the acceptance of DGE by analysing the needs, concerns and expectations of stakeholders regarding its use, based on the principles of procedural and distributive justice. To this end, we developed a co-design method to analyse stakeholders' evaluation criteria and, based on these, design scenarios to identify conditions for success. The results revealed several key findings that are prerequisites for accepting a DGE project. These include the importance of trustworthiness and regional roots of project developers, as well as reliable seismic risk mitigation strategies and energy sharing with local municipalities, for example, through the decarbonisation of district heating. The findings emphasise the importance of procedural and distributive justice, a shared vision and co-designed scenarios for the use of DGE resources and open communication on the feasibility of deep geothermal energy sharing. These findings, along with the co-design method, can be applied beyond the context of Germany's energy transition to other regulatory and cultural frameworks. The authors recommend that developers of DGE projects tailor their projects to the needs, concerns, and expectations of municipalities and their stakeholders and integrate them into the local energy transition context to improve the conditions for acceptance.

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1. Introduction

In pursuit of climate neutrality by 2045, Germany has set the overarching target of raising the share of renewable energy sources to 80% of gross final energy consumption by 2040. Within the electricity sector specifically, the Renewable Energy Sources Act (EEG) establishes more ambitious intermediate targets, mandating that renewables account for at least 80% of gross electricity consumption by 2030 and 100% by 2035 (Jan et al., 2024). Progress toward these goals has been substantial in recent years, with the share of renewables in gross electricity consumption increasing up to over 55% in 2025 (Umweltbundesamt, 2026a). The share of renewable energy in Germany's heat supply lags significantly behind that of the electricity sector, although the heating sector accounts for more than 50% of Germany's total final energy consumption (Umweltbundesamt, 2026b). According to the municipal heat planning in Germany, this will change in the future as heat pumps and district heating networks are expected to supply about four-fifths of the heat demand by 2045 (around 42% and 37%, respectively) and the share of heat delivered via networks is projected to grow from roughly 15% today to 38% by 2045 (Stobbe et al., 2026). Yet more than half of the plans lack details on future heat generation for these networks, and where specified, the most common mix combines heat pumps and biogenic fuels, complemented by site-specific options such as industrial waste heat and geothermal energy, with local resources, existing infrastructure, settlement density, and strategic choices determining the most suitable solutions.

Deep geothermal energy (DGE) is a reliable, weather-independent, low-carbon energy source that can provide a consistent energy supply around the clock. However, its deployment lags behind that of solar and wind power (Li et al., 2015a), due to capital-intensive projects and rising costs worldwide (Mueller et al., 2026), project risks specific to the site and context (Liu et al., 2025), and opposition from local communities delaying, altering, or in some cases contributing to the cancellation of DGE projects (Soltani et al., 2021; Bonciani et al., 2024). The strongest driver of these concerns is the risk of induced seismicity. A study analysing eight countries, including Germany, found that 26% of DGE projects had failed due to a combination of hydrogeological, financial and technical factors (Brémaud et al., 2025).

Despite favourable geological conditions in several regions – particularly the South German Molasse Basin, the Upper Rhine Graben and the North German Basin – and its political positioning as a key decarbonisation option for a largely fossil-based heat supply, geothermal energy still plays a minor role in Germany compared to wind, solar and bioenergy (Leiss et al., 2021). It provides roughly 0.1% of renewable electricity, and just 1.3% of district heating stems from shallow geothermal systems, a significantly lower share than that provided by bioenergy and solar thermal energy, which together contribute 18.7% of renewable district heat (EEG, 2023; Grotelüschen, 2022). By exploiting thermal waters (~400–5000 m; $\leq 180^\circ\text{C}$), DGE could supply ~25% of district heat in Germany if ~10% of resources are utilised (Die Bundesregierung, 2023), with lithium and copper co-production offering additional strategic value (Sanjuan et al., 2022). The limited exploitation of this potential contrasts with the common perception that the technology's main advantage is its contribution to district heating (Wolf et al., 2025) and that the base-load capability of DGE can compensate for temporal fluctuations in wind and solar power (Tester et al., 2021). In view of the potential and advantages of geothermal energy, several EU countries have created national geothermal roadmaps with ambitious targets (including Ireland, Poland, Croatia, France, and Germany) to make investment in geothermal projects more attractive and to encourage their development. (European Commission, 2026). Another boost came in the form of the German Geothermal Acceleration Act (GeoBG), which was adopted in December 2025 (Bundesministerium der Justiz und für Verbraucherschutz, 2025). The Act streamlines the permitting process, drastically shortening the planning and approval phases for geothermal energy projects. It does this by

classifying such projects as being of overriding public interest until the country achieves climate neutrality in 2045. This simplifies and shortens the planning and approval phases, which could previously take years, thus accelerating the process and ensuring the completion of at least 100 of the planned 150 projects by 2030.

Despite its significant potential and political support at the European and global levels (Tester et al., 2021; Weber et al., 2020; Hirschberg et al., 2014), geothermal energy accounts for only a small share of the energy transition (Li et al., 2025; Younger, 2015; Agemar et al., 2014). Geothermal energy reached a total installed capacity of 14.85 GW in 2023, accounting for 0.384% of global renewable energy capacity (Fogha et al., 2026) and 0.2% and 0.7% of EU electricity and heat production, respectively (Nkinyam et al., 2025; Taylor et al., 2025). No further increase is expected, given declining growth rates and costs higher than those of wind and solar power (Fogha et al., 2026). This is primarily due to high upfront capital costs and geological exploration risks specific to the site (Agemar et al., 2014; Kassem et al., 2025). These factors limit its competitiveness and hinder cost reductions, unlike wind and solar power (Yao et al., 2021). Other factors include financial constraints, complex regulatory frameworks, lengthy permitting processes, environmental concerns, and a lack of social acceptance (Daniilidis et al., 2017; Meirbekova et al., 2024; Kunze et al., 2017), which is shaped by perceived risks, particularly those related to induced seismicity. Such risks can trigger local protest movements and cause significant delays to, or even prevent, the implementation of DGE projects (Edwards et al., 2015; Cousse et al., 2021; Knoblauch et al., 2018). However, risk perceptions are not static; they are socially constructed and shaped by cultural, political, spatial, and temporal contexts, as well as by trust in the institutions and companies and individuals responsible (Wüstenhagen et al., 2007; Batel et al., 2015; Benighaus et al., 2019; Carrera et al., 2010). For instance, following Russia's invasion of Ukraine, public opinion in Germany shifted in favour of geothermal energy as a reliable, locally sourced alternative to reduce reliance on energy imports (Stadt Freiburg, 2022; Steffen et al., 2022), as indicated by the increased acceptance of geothermal energy, which rose from 30% in 2021 to 50% in 2024 (AEE, 2021).

Social acceptance is widely recognised as a central prerequisite for the successful implementation of energy infrastructure projects (Abdi et al., 2025a; Karytsas et al., 2021a; Korucan et al., 2024; Barich et al., 2021; Qorizki et al., 2021). The growing number of studies on the social acceptance of geothermal energy worldwide supports this view (Hymans and Fumiya, 2022; Shortall and Ali, 2017; Romanach et al., 2015; Meraz, 2025; Dowd et al., 2011; Vargas and Sofia, 2018; Renoth et al., 2023; Park, 2021). Acceptance is a multidimensional social process influenced by perceptions of risk and benefit, but also trust and the experiences of procedural and distributive justice (Renn et al., 2019). To improve acceptance, institutions must be trustworthy, perceptions of procedural and distributive justice must be positive, and the risks associated with induced seismicity must be effectively managed (Kassem et al., 2026a). Radtke and Renn (2024) demonstrate that participatory processes in energy transition projects can enhance democratic legitimacy and secure widespread social acceptance when various interest groups and governance approaches are considered (Radtke et al., 2024). Perceptions of risk can vary depending on the stakeholder groups involved and the governance arrangements in place, as well as across cultural, spatial, and temporal contexts (Abdi et al., 2025a; Shortall and Ali, 2017; Meraz, 2025; Carr-Cornish et al., 2014). Empirical studies show that people living in municipalities near a DGE project tend to be more sceptical than those living farther from potential exploration sites (Costa et al., 2017). Conversely, projects that have a strong local presence and the potential to foster social identification and local benefits are easier to establish than those without direct links to local municipalities (Chavot et al., 2018a; Cook et al., 2022). This is particularly true of projects financed by major investors, who are generally not interested in providing benefits to municipalities. Their main goals are to maximise profit and communicate

with the local population to reassure them (Qorizki et al., 2021; Hymans and Fumiya, 2022). Consequently, municipalities wish to be involved in planning and decision-making processes. From this perspective, participatory governance and early stakeholder involvement are essential for enhancing legitimacy and acceptance, particularly in the context of contested energy technologies (Radtko et al., 2024). Including the expectations and concerns of stakeholders in a shared vision of DGE projects can improve their acceptance (Chilvers et al., 2021; Gooding et al., 2023; Der Schoor et al., 2015; Zwickel et al., 2022). This is particularly important when the planning process provides municipalities with tangible benefits, such as reliable and affordable energy and added value through the extraction of domestic resources, including lithium and copper (Meraz, 2025; Vargas and Sofia, 2018; Abdi et al., 2024a; Kurek et al., 2024; Malau et al., 2020; Knoblauch et al., 2019). To prevent

social exclusion and avoid favouring one group over another, stakeholders must be meaningfully involved in the planning process (Renoth et al., 2023; Reed and Hannah, 2023). However, stakeholder integration is neither straightforward nor universal, and there is no standardised approach to determining who should be included as stakeholders (Ruef et al., 2020; Pellizzone et al., 2017). The perception and acceptance of a DGE project by stakeholders influence its feasibility (Karytsas et al., 2021b), and if these stakeholders are not carefully selected, certain social groups that perceive risks differently may be overlooked (Chavot et al., 2018b; Goedkoop et al., 2016; Rohse et al., 2024). Inclusive engagement of stakeholders was found to be crucial for the acceptance of DGE in European, American and African countries (Balzan-Alzate et al., 2021; Abdi et al., 2024b, 2024c).

Against the backdrop of the current state of knowledge and the need

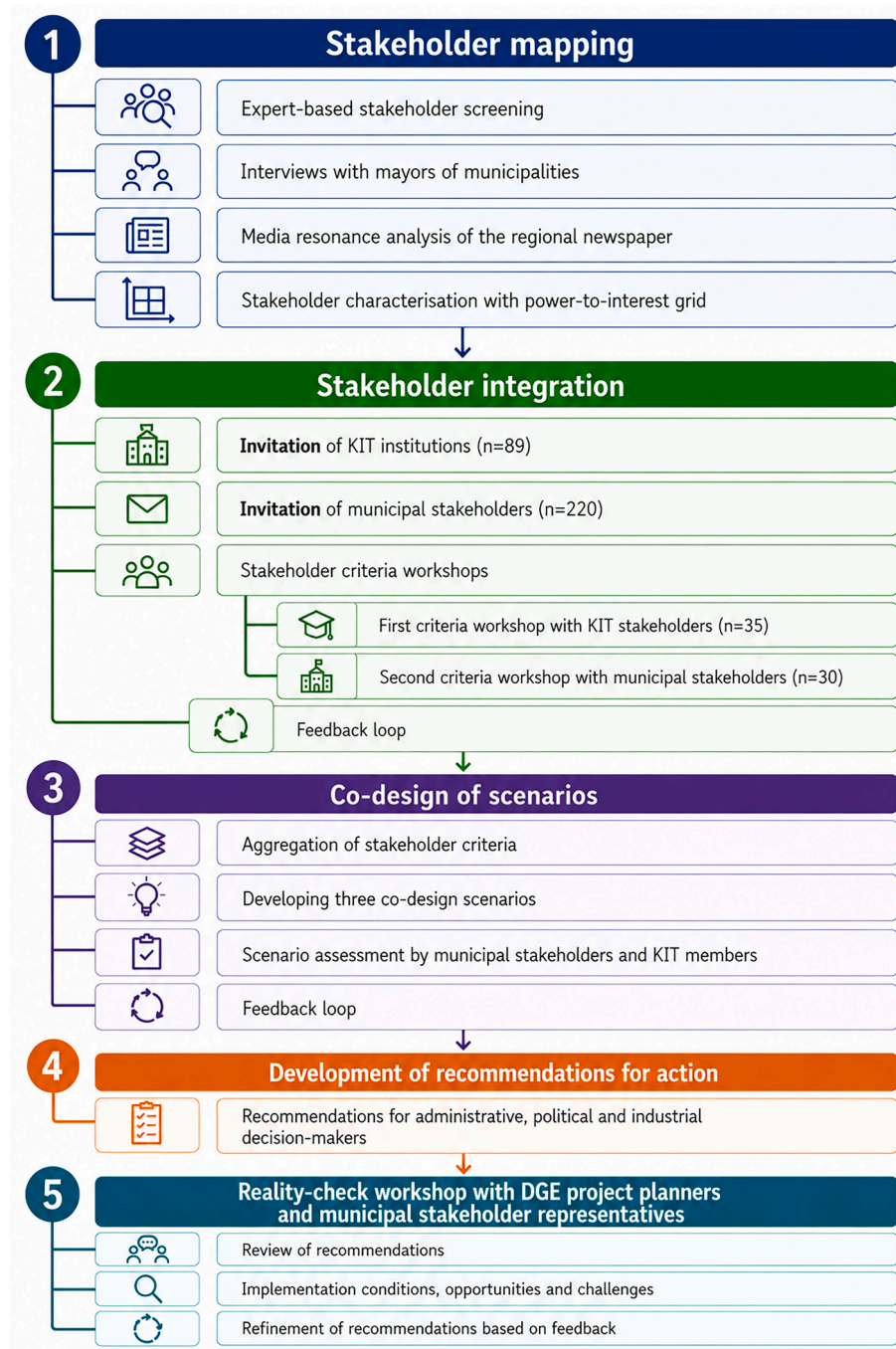


Fig. 1. Overview of the co-design method applied in the study.

to involve stakeholders in the planning of a DGE project to ensure procedural and distributive justice, the aim of this inter- and transdisciplinary study was to DGE project acceptance by systematically and comprehensively examining stakeholders' needs, concerns, and expectations, and translating these into scenarios illustrating possible DGE visions. As stakeholder involvement is central to the co-design method, this study addressed the question of which local stakeholders should be included in the co-design process. The aim was to involve as many stakeholders as possible in the process, as this can significantly influence the outcome in terms of acceptance (Renoth et al., 2023). The co-design method was applied to a DGE project for the decarbonisation of the district heating system at the Campus North of the Karlsruhe Institute of Technology (KIT). Site conditions are favourable in the Upper Rhine Valley region where KIT is located, as geothermal resources largely coincide with favourable surface conditions, making the region a preferred target for geothermal utilisation (Frey et al., 2023). Furthermore, using DGE in the Upper Rhine Graben region could produce enough lithium each year to make around 1.2 million batteries for electric vehicles (Weinand et al., 2023).

2. Methodology

The co-design framework is based on stakeholder mapping and integration, as well as developing explorative scenarios. The aim is to encourage co-integration, co-production and co-evaluation. This approach emphasises the importance of meaningfully involving stakeholders in knowledge generation and decision-making processes from the outset (Meraz, 2025; Malau et al., 2020; Knoblauch et al., 2019). Fig. 1 provides an overview of the methodology.

In the preliminary phase of the inter- and transdisciplinary study, a review of participation and communication processes relating to geothermal energy was conducted. This was done by examining two contrasting case studies. The DGE project in St Gallen, Switzerland, is a successful example of stakeholder engagement. In contrast, the near-surface geothermal energy project in Staufen, Germany, has received

widespread media coverage due to its failures, which include seismic damage to buildings in the city centre (Burbaum and Ingo, 2013). The project has also been criticised for its inadequate communication and participation processes (Mbah et al., 2021a). Although geothermal energy in Staufen was already in use, the study's authors decided to analyse this case because of its relevance to risk communication. The aim was to gain insights into communication and public engagement. Despite their technical differences, both cases provided valuable results regarding stakeholder engagement and communication strategies that can foster acceptance. These include building trust, transparent communication, and the early and ongoing involvement of stakeholders (Mbah et al., 2021b). The St. Gallen case study highlighted the importance of tailoring strategies and formats to the local context, which varies significantly in Switzerland due to referendums, a specific form of democracy that can either challenge or legitimise projects, thereby shaping the implementation process in terms of pace and design (Rose, 2019; Ejderyan et al., 2019; Moeck et al., 2015). The preliminary study's findings confirm that the authors' decision to prioritise comprehensive and conscientious stakeholder engagement in the co-design process was appropriate.

2.1. Stakeholder mapping

The co-design process began with a comprehensive mapping of stakeholders in the area in which the planned DGE project is to be constructed (see Fig. 1). This encompasses Campus North of KIT, located in the municipality of Eggenstein-Leopoldshafen in south-west Germany, as well as the city of Karlsruhe and its surrounding suburban municipalities, which are in close proximity to the planned site (Fig. 2).

Stakeholder identification followed a three-step approach (see Fig. 1). The study's authors used the social site characterisation framework proposed by Wade and Greenberg (Wade et al., 2011) to identify stakeholders to include in the co-design process. The aim was to integrate a broad range of stakeholders, including marginalised groups who might hold specific risk perceptions due to their social, cultural or

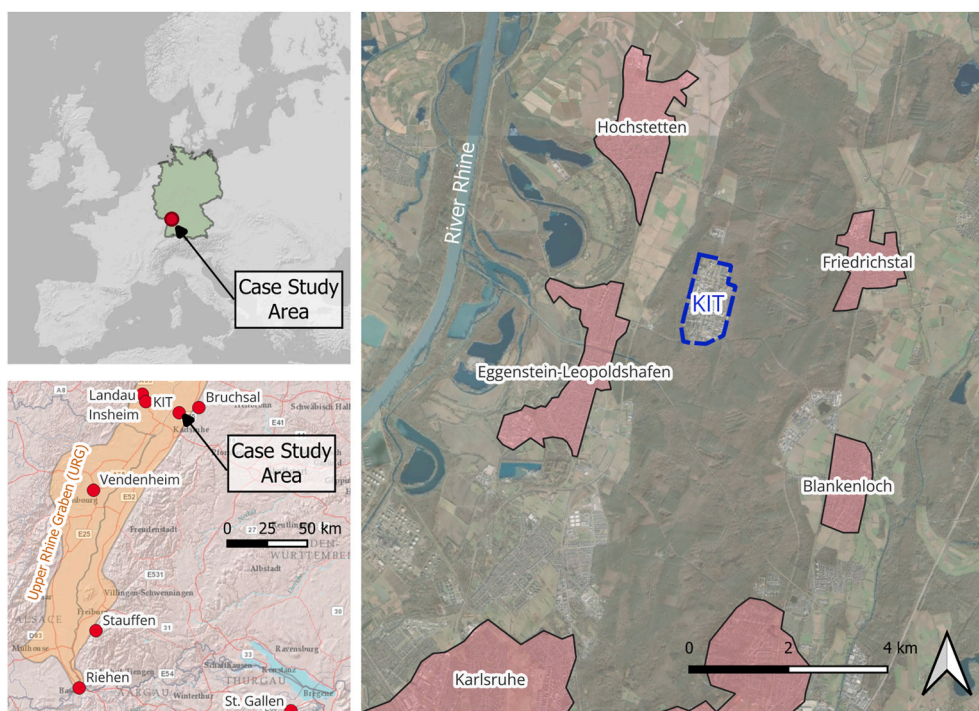


Fig. 2. Map illustrating the geographical location of the DGE project within Europe (top left) and the surrounding municipalities included in the study (right), as well as the existing DGE plants in the Upper Rhine Graben (red dots bottom left). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

religious backgrounds. First, a stakeholder screening analysis was conducted by the project team and structured around a series of guiding questions (adapted from Wade and Greenberg, 2011, p. 25) (Wade et al., 2011). Second, qualitative expert interviews (Meuser et al., 2009) were conducted with mayors of municipalities in the vicinity of the DGE project (see Supplementary Materials S1 and S2). Five out of ten mayors responded, with interviews lasting between 30 min and 1 h. Because of the Coronavirus pandemic, interviews were conducted by telephone or video conference. We audio-recorded interviews with consent; otherwise, the interviewer took notes. The third step involved conducting a media resonance analysis to search for articles on DGE in the online database of the regional daily newspaper *Badische Neueste Nachrichten* (BNN) between March 2017 and May 2020. Using the search terms 'geothermal energy', 'deep heat', 'deep geothermal energy' and 'geothermal energy', this yielded around 50 articles. The articles ranged from short notes to longer pieces of around three pages.

Methodological triangulation was employed in the social site characterisation by combining stakeholder and context mapping, qualitative expert interviews with mayors, and an analysis of regional media. These complementary methods and data sources were also used to develop and contextualise the stakeholder landscape and the relevant criteria, concerns and interests to provide insight into the context in which the workshops took place. The participatory process itself included an additional step of triangulation: the results from the KIT and municipal stakeholder criteria workshops were combined and discussed at the third workshop on scenarios, which included participants from both groups. This enabled the findings and perspectives from the separate workshops to be compared, reflected on, and further consolidated. The results of the comprehensive, multi-step stakeholder identification process were compiled into a single list. The study's authors assessed and categorised the broad range of identified stakeholders by linking them to their level of interest in and ability to influence the DGE project, using the power/interest grid scheme (Freeman et al., 2001). Based on this analysis, the relevant stakeholders to be involved in the co-design process were identified and categorised into two groups: (1) KIT employees and affiliates, given that KIT employs over 10,000 people, and (2) representatives and stakeholders of municipalities, civil society organisations, and regional institutions. This was done to prevent discussions from being dominated by KIT stakeholders, which could marginalise other social groups and civil society organisations (Lelieveldt and Wouter, 2023).

2.2. Stakeholder integration

Two workshops were organised, one for each stakeholder group (KIT and municipal stakeholders), to identify their respective needs, expectations, concerns, and priorities regarding the DGE project. All identified stakeholders were invited to either the KIT or the municipal stakeholder workshop. A follow-up scenario workshop was organised for the municipal stakeholders who had taken part in the criteria workshop, as well as for selected representatives from the KIT workshop. The aim was to ensure continuity with the results from the KIT criteria workshop while avoiding any potential dominance or leadership by academic participants. Furthermore, KIT's plan to work with a regional energy supplier to use the local DGE resource to decarbonise the district heating network on KIT Campus North is already part of the planning process. However, the needs and expectations of nearby municipalities and their stakeholders were not taken into account so far.

Both workshops were held online due to the Coronavirus pandemic, and each lasted half a morning, from 9.00 a.m. to 1.00 p.m. The KIT workshop took place on 16 October 2020 with 35 participants, and the workshop with municipal stakeholders took place on 14 November 2020 with 30 participants. Two moderators facilitated the workshops, and one note-taker documented them. During the group work, each group was supported by one moderator and one note-taker. The moderators' role was to ensure that all participants had equal opportunities to contribute

to the discussion and that different perspectives and arguments could be expressed. The small groups were formed to achieve a balanced distribution by gender and institutional affiliation. In the scenario workshop, municipal stakeholders from the criteria workshops were deliberately mixed across the small groups with representative participants from the KIT workshop to facilitate exchange between the two participant groups. The workshops were conducted in accordance with pre-defined facilitation guidelines and guiding questions, and followed a structured programme. They began with general information and introductory explanations to ensure all participants had a comparable level of knowledge about the DGE project and the workshop's aim. Participants then worked in small groups of roughly equal size, in which they identified and discussed criteria they considered relevant for evaluating the DGE project. Participants then presented and discussed the results of the small-group discussions in a plenary session. Participants then prioritised the identified criteria by vote. We used interactive online tools to visualise results, particularly Conceptboard and Mentimeter. At the end of the workshop, a feedback session was held to gauge participants' satisfaction with how it went. The workshop discussions, including the small-group sessions, were recorded with participants' prior consent. The recordings were transcribed in full and anonymised. The transcripts documented and analysed participants' arguments and the reasoning behind them. Written contributions on Post-it notes and notes taken during the workshops served as additional documentation. The audio recording from the municipal stakeholder workshop was subjected to qualitative content analysis and carried out in three stages: (1) discursive assignment of the recorded criteria to cluster terms (prioritised key terms: transparency, cost-effectiveness and safety; other terms: local authority cooperation, sustainability, carbon neutrality and energy transition); (2) feedback of the documentation to the participants for comment; and (3) in-depth transcript analysis using MAXQDA, with revision of the classifications where necessary. The results were then reviewed by the study's authors, who were also responsible for summarising and analysing the results (see Supplementary Materials S3).

2.3. Scenario development

The consolidated results of the workshops involving KIT and municipal stakeholders were used to define three explorative scenarios for DGE projects. The first scenario only considered KIT's needs and expectations. Scenarios two and three included heat distribution to the surrounding municipalities, supporting them in transitioning to renewable heating sources while mitigating the risk of induced seismicity (Moeck et al., 2020; Hartmann et al., 2023). The study region is located within a geothermal anomaly in the Upper Rhine Valley, which makes these scenarios feasible in principle. There are fluid pathways at temperatures of around 170 °C at depths of approximately 3000 m (Ejderyan et al., 2020), with an expected annual potential output of 186 TWh (Frey et al., 2023), which equates to 5% of Germany's energy demand (Kock et al., 2012). These favourable conditions also entail a moderate earthquake risk, with a 10% probability of exceeding a maximum ground acceleration of 0.2 g over 50 years (Giardini et al., 2014). The Upper Rhine Graben is a region of Europe renowned for its geothermal energy exploitation and development projects, particularly in France, Germany, and Switzerland. Over the last 20 years, numerous seismic events and uplifts have occurred around DGE project sites such as Landau, Insheim and Vendenheim (see Fig. 2). These events have raised concerns among local populations (Fiori et al., 2023; Groos et al., 2013; Heimlich et al., 2015; Dalmás et al., 2022). In some cases, such as in Basel, Switzerland, where an enhanced geothermal system project damaged infrastructure and buildings, these events have resulted in projects being cancelled (Mignan et al., 2015; Häring et al., 2008).

2.4. Feedback workshop

The scenario workshop results were analysed and summarised to

provide comprehensive recommendations for the administrative, political, and industrial decision-makers involved in DGE projects. These recommendations were then reviewed by KIT and the regional energy company experts responsible for the technical, economic and communication aspects of a DGE project. The rationale for the feedback workshop was to operationalise the core principles of transdisciplinarity by validating, contextualising, and concretising the results at the decision interface. The aim of the feedback workshop was to maximise the relevance, uptake and impact of the project outcomes, validate the study results through direct exchange, analyse the practicality and resilience of the recommendations in relation to real-world constraints, and strengthen the transition from knowledge to action. The feedback workshop also aimed to increase the transparency and traceability of the process for participating stakeholders.

3. Results

The 'Results' section presents the findings from the various sections: (1) stakeholder mapping, (2) KIT stakeholder criteria workshop, (2) municipal stakeholder criteria workshop, (3) co-design of scenario, (4) stakeholder scenario assessment and recommendations for action.

3.1. Stakeholder mapping

The media resonance analysis revealed that induced seismicity hinders acceptance, thereby diminishing the importance of the contributions that DGE makes to climate protection, the decarbonisation of district heating and the improvement of the sustainability and resilience of the energy system. Based on the media analysis, four main stakeholder groups were identified: (1) supporters of the technology, such as project developers and plant operators; (2) opponents of the use of DGE due to the risk of seismic events, groundwater contamination and hazardous waste production; (3) mayors and local politicians who complain that local interests are not considered because they are not involved in the project planning and approval process; and (4) scientists from KIT, some of whom research and communicate information about the DGE

technology and its impacts and others with sensitive research infrastructure.

The study's authors drew up the final list of stakeholder groups based on the results of the stakeholder screening analysis, the interviews, and the media analysis, and structured it accordingly. The result is a comprehensive stakeholder landscape encompassing administrative bodies, civic groups, environmental and heritage initiatives, educational and trade institutions, businesses with high heating demands, and various community organisations relevant to the DGE project. The KIT stakeholders included the presidency and department heads, institute directors, administrative departments, student representatives, the facility management team, and the public relations team. The breadth and diversity of the identified stakeholders at KIT and in the municipalities reveal that a DGE project could have implications that extend far beyond technical and administrative interests and could intersect with the identity of the research institution or municipalities, environmental values, economic needs, and institutional and municipal social structures. This underscores the importance of an inclusive, carefully tailored participation process. Fig. 3 shows the 32 stakeholder categories derived from the authors' assessment conducted prior to the participatory process and their levels of interest and ability to influence the project in a power/interest grid. The aim of this categorisation was to capture the broadest possible range of stakeholder groups, rather than to assess or rank their relative importance.

All stakeholder groups were invited to participate in the workshop. We followed up in writing and by telephone to confirm their interest and availability. Of the 217 municipal stakeholders who were invited, 30 took part in the workshop, which equates to a relatively high response rate of 13.8%. For the KIT workshop, invitations were distributed widely across KIT institutions and organisational units, including scientific, administrative, and cross-cutting functions, rather than to a defined number of individuals. Of the 89 institutions and organisational units contacted, 21 responded, which equates to a relatively high response rate of 23.68%. A total of 35 persons took part in the KIT workshop. Since the invitations were distributed at the institutional rather than individual level, an individual response rate cannot be calculated for the

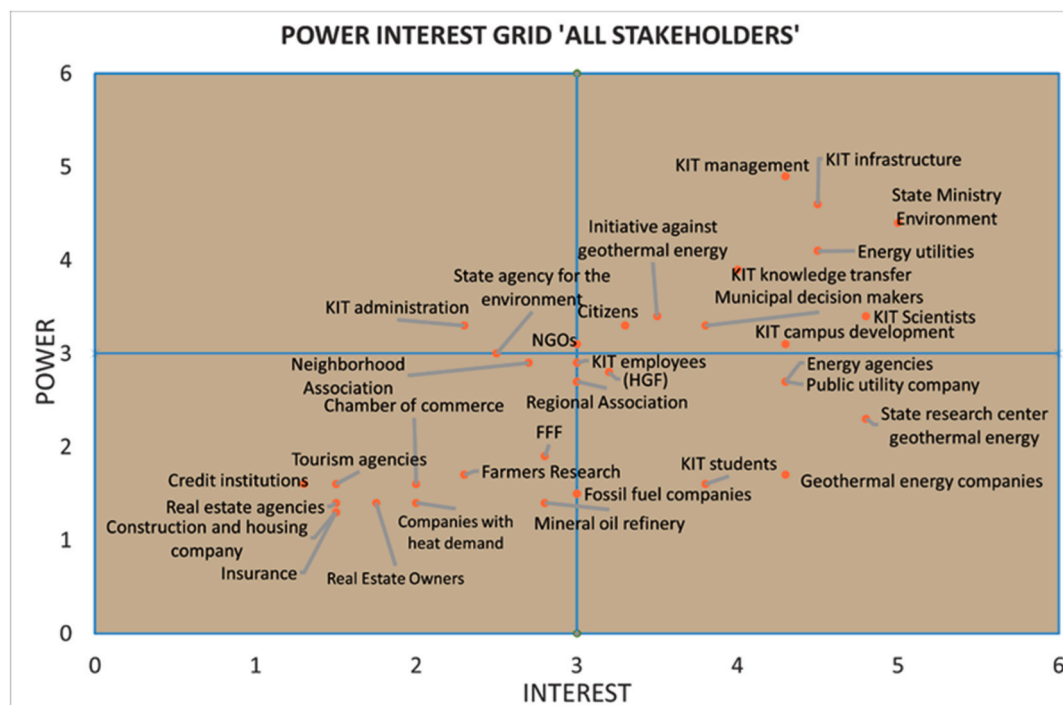


Fig. 3. Power-interest grid showing the stakeholder categories (n = 32), based on the results of the social site characterisation (value '0' means no power/interest, value '6' means high power/interest).

KIT workshop. Fig. 4 shows that the majority of participants in the criteria workshop were researchers (scientific staff), who had a high level of interest but less power than managers and facility managers. However, they were not the only participants; managers, students and administrative and facilities management staff were also involved.

The analysis of the municipal stakeholders participating in the workshop and their power and interest in the DGE plant, presented in Fig. 5, shows that political decision-makers constituted the majority of participants, with high interest and power compared to other participants, including members of the Friday for Future movement and citizens.

3.2. KIT stakeholder criteria workshop

The results of the KIT stakeholder criteria workshop indicate that participants primarily associated DGE with positive contributions to climate protection, a sustainable energy supply, and district heating, which they considered more important than the disadvantages, such as seismic risks and economic efficiency (Table 1). However, the high priority placed on researching the future impacts and on exploring alternatives for decarbonising the energy system shows that the participants also had a critical view of DGE and its possible negative impacts. With regard to the DGE project, stakeholders considered transparency, data sharing, and open and honest communication crucial for building trust and addressing concerns, while seismic risks and safety measures were considered less important. The involvement of municipalities and local authorities in planning and approving geothermal projects and energy use was considered particularly important. This divergence from the usual pros-and-cons assessment of DGE projects stems from the high proportion of stakeholders working in science and academic administration.

3.3. Municipal stakeholder criteria workshop

During the municipal stakeholder criteria workshop, participants entered three critical keywords into a word cloud (Fig. 6). The main expectation regarding distributive justice in the use of DGEs was their contribution to climate protection, decarbonised energy portfolios, and municipal district heating systems.

Participants raised concerns about seismic risks and how to mitigate

them, and about protecting the natural and built environments – particularly groundwater and buildings. They emphasised the importance of transparency and proactive communication, as well as of providing clear and honest information. The main concerns focused on technical design, economic efficiency, cost-risk-benefit ratios, legal liability and financial security. They regarded cooperating with municipalities to consider local contexts and expectations as essential. However, they considered public participation less important, as was the added value it would provide to citizens. This suggests a high level of trust in local authorities and politicians. Participants regarded independent scientific evaluations as crucial for building trust, enabling fair comparisons with other renewable energy sources, and ensuring inclusive planning that guarantees the fair distribution of burdens and benefits. The general recommendation was to consider all technical and social possibilities for achieving a sustainable and resilient energy supply, rather than focusing solely on DGE.

3.4. Co-design of scenarios

The study's authors developed the explorative scenarios based on the results of the two workshops, taking into account technical and economic criteria, as well as the participatory and social aspects identified during the workshops. Although the scenarios are simplified and only roughly outlined due to project-related constraints, they provide much more detailed contextualisation than usual. The scenarios are not intended to replace actual planning; rather, they reflect the needs and expectations of those involved in the process while ensuring fundamental feasibility and plausibility. The results were structured into three categories: (1) socio-political criteria; (2) technical and non-technical criteria; and (3) criteria that can be translated into model language and quantified using calculations and sensitivity analysis. The modelled criteria, in particular, addressed municipal stakeholders' concerns about the seismic activity associated with a DGE project – a common issue in other regions and countries (Buijze et al., 2019; Majer et al., 2007). Risk mitigation was achieved by simulating flow and heat transport, and by restricting the geothermal flow rate to 25 L per second. This ensured that pressure changes remained below 2 Megapascals (MPa). The Multiphysics subsurface model (version 6.0) was coupled with a simplified heat network model for KIT Campus North (Zwickel et al., 2022). The quantitative modelling was based on KIT's annual heat demand of around 29,000 MWh_{th} (KIT, 2018). To maximise benefits for the municipalities and ensure a heat supply during the winter months, a detailed 3D geological framework was used to model an underground high-temperature aquifer thermal energy storage (HT-ATES) system (>50 °C) (Frey et al., 2022; Fleuchaus et al., 2020a; Stricker et al., 2020). The framework was derived from geophysical and borehole data (Bauer et al., 2025) and from relevant heat-transfer units between the basement and the tertiary reservoirs in the former Leopoldshafen oil field (Schill et al., 2024). The simulation involved an HT-ATES system operating at a rate of 5–10 L/s. Fig. 7 shows that a DGE plant could meet the base-load heating demand of KIT Campus North and a neighbouring municipality. Adding an HT-ATES would cover most of the KIT Campus North's heating demand during the winter.

The economic figures provided in the scenarios are indicative assumptions rather than the results of a comprehensive financial appraisal. Therefore, the expected return on investment is a target rather than a calculated internal rate of return, as the plant is expected to be profitable. Based on rough estimates, the following investments were considered: €20 million for a municipal DGE plant, €3 million for HT-ATES and €60 million per 10,000 inhabitants over ten years for district heating network development. Additional operating costs were estimated at €160,000 per year for 8000 h at full load over a 30-year lifetime. Scenario 1 focuses on supplying KIT's base heat load. The DGE plant produces around 9.2 MW of heat, covering KIT's 2.2 MW base load. The HT-ATES stores any surplus heat. This reduces KIT's CO₂ emissions by around 65% (Schill et al., 2024). Risk mitigation measures

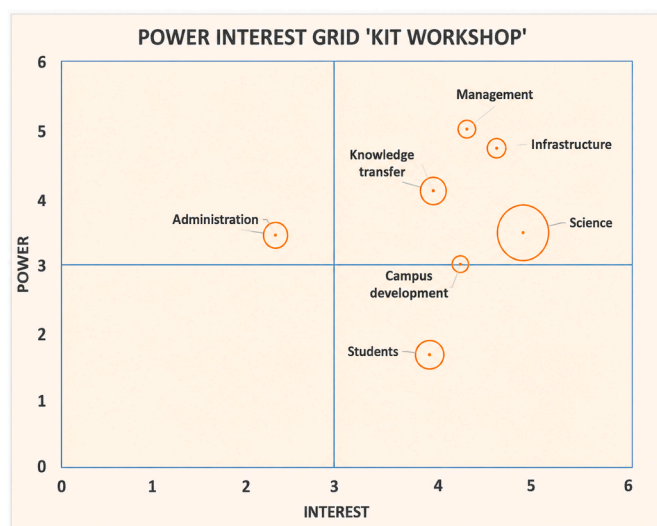


Fig. 4. Power-interest grid of KIT stakeholders (n = 35), showing the share of stakeholders per category in red circles, based on the results of Social Site Characterisation (value '0' means no power/interest, value '6' means high power/interest). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

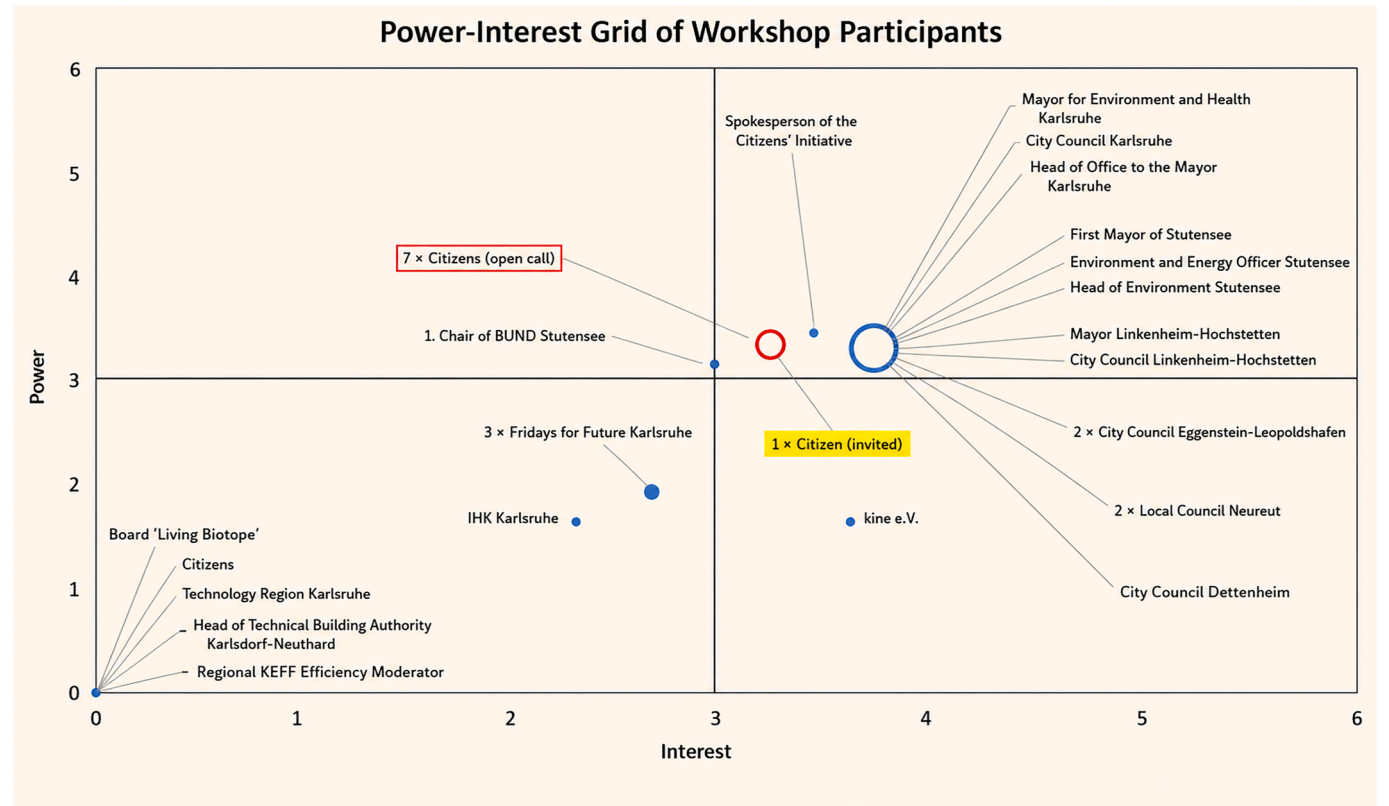


Fig. 5. Power-interest grid of municipal stakeholders (n = 30), showing the share of stakeholders per category in red circles, based on the results of Social Site Characterisation (value '0' means no power/interest, value '6' means high power/interest). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Ranking of the criteria developed in the KIT stakeholder workshop. Each participant (n = 35) was given 7 points to allocate.

Criteria to evaluate DGE projects	Ranking
Sustainability and climate protection (KIT and beyond)	57
Assessment of future impacts	28
Assessment of alternatives	27
Transparency and communication	24
Integration of communities and citizens	21
Networking of research and teaching	20
General safety, in particular seismicity	18
Technical specifications	16
Economic efficiency	7

include continuous monitoring of seismic activity, implementation of a traffic-light warning system and provision of liability coverage through the Mining Compensation Fund. Transparent communication is facilitated via digital platforms, an information centre and public dialogue events. Public participation is not considered.

Scenario 2 builds on Scenario 1 by incorporating a second HT-ATES connected to the DGE plant described in the previous scenario. This facility provides around 3 MW of heat for KIT and a neighbouring municipality. A private operator manages the DGE plant, enabling municipal stakeholder participation. Risk management and transparency measures are considered to be in place. Stakeholder roundtables, workshops and surveys are held regularly. The amount of CO₂ saved depends on the number of connected buildings, the type and quantity of

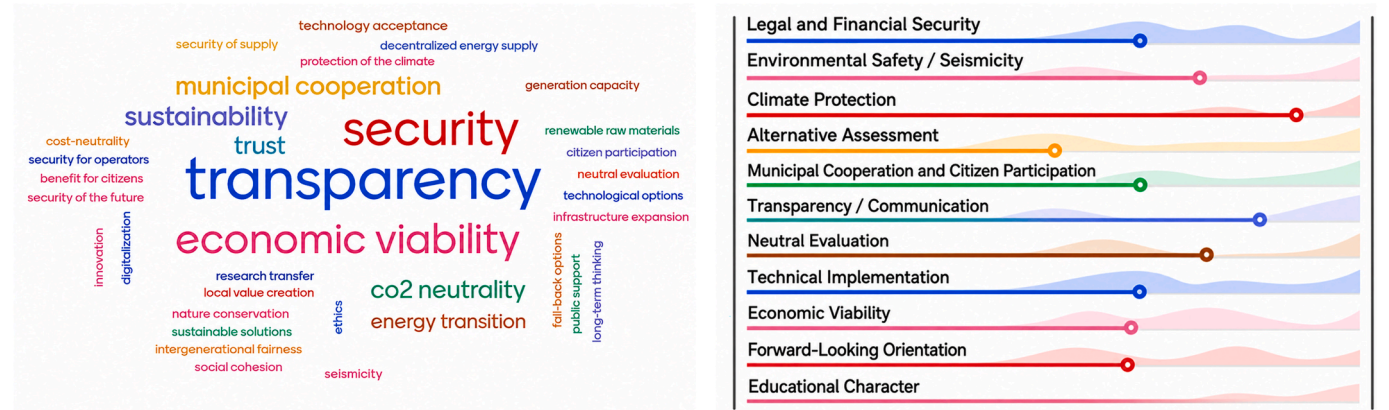


Fig. 6. Word cloud of the three most critical keywords identified by municipal stakeholders (n = 30), with more frequently selected criteria appearing larger, translated with DeepL.

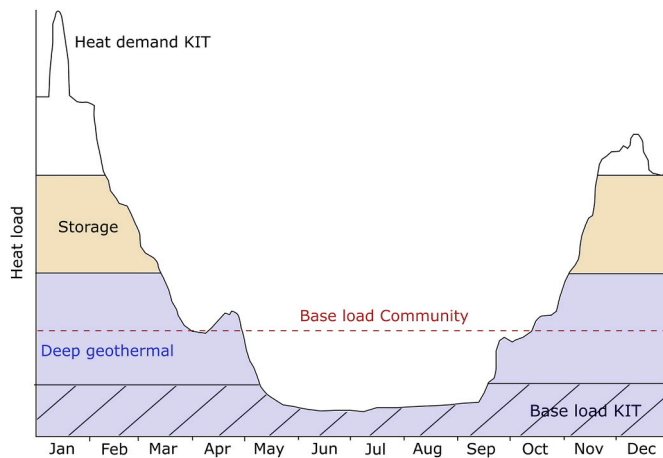


Fig. 7. DGE plant with heat storage system (HT-ATES) covering the heat demands of KIT Campus North and the base load heat demand of a municipality in the neighborhood.

displaced fossil fuels, and the economic viability of constructing new networks. Profitability is challenging because the plant is close to KIT, resulting in a longer and more costly connection to the municipality's district heating systems.

Scenario 3 involves two DGE plants working together, with one supplying KIT and the other supplying the municipalities. Close collaboration with stakeholders ensures effective risk management, transparent decision-making, and communication tailored to different groups' needs. To be profitable, the district heating infrastructure requires a return on investment of 3–4%. This could be achieved through national and state funding, as well as high connection rates among businesses and residents. The municipality would benefit from replacing fossil fuel sources to reduce CO₂ emissions, enhance resilience and become more appealing to residents and businesses while retaining local added value.

3.5. Stakeholder scenario assessment and recommendations for action

During the scenario workshop, participants highlighted the importance of trust in DGE project developers and operators, as well as their commitment to mitigating seismic risks and groundwater pollution. They also emphasised proactive communication from a designated person with adequate budgetary support, along with accessible, understandable environmental monitoring data and independent expertise, to ensure the credibility of the information provided. The feasibility of Scenario 3 was called into question because it requires local ownership. This is because a DGE project requires substantial investment, which exceeds the budgets of most households and the debt levels of most municipalities. There are also complex insurance and liability issues in financially struggling municipalities, and exploration permits have already been allocated to industry stakeholders. Investing in a DGE project carries a high level of risk and may be unprofitable, as the investment extends beyond exploration to include district heating infrastructure and connections to residential properties and businesses (Barbier, 2002; Li et al., 2015b). To ensure stable base-load demand, high connection rates and significant heat consumers are required, as well as HT-ATES, to prevent inefficient electricity conversion and summer surpluses.

Participants in the scenario workshop recognised the potential of HT-ATES to bridge the seasonal gap between periods of peak heat demand and supply. They also acknowledged its benefits alongside the DGE project, as well as the opportunity it provides for municipal stakeholders to meet base-load heat demand. Because the technology is not widely used or known, no critical voices emerged. However, experts point out that social risks are likely to be more significant than technical risks

(Fleuchaus et al., 2020a; Dobson et al., 2025). Future co-design research projects should focus on comprehensive subsurface use scenarios by considering different alternatives and their socio-technical and environmental relevance, and examine the long-term role of HT-ATES in storing and supplying heat alongside a DGE plant in this context. This is because an HT-ATES system has a lifespan of more than 30 years, during which time it can have significant socio-ecological impacts, particularly on drinking water aquifers and water quality (Bloemendal et al., 2014).

During the scenario workshop, some participants expressed critical views, stating that the potential benefits do not outweigh the uncertainty surrounding the probability, predictability, and reversibility of adverse effects (Kubota et al., 2013), particularly the risk of induced seismicity [61] and the difficulty of managing unintended environmental impacts (Barbier, 2002). There is also a risk of missing out on profitability due to a lack of significant base-load demand. This risk is exacerbated by declining demand as new and existing buildings opt for alternative heating sources, such as heat pumps. Germany supports these politically and financially, and they can be supplied by local solar and wind production. This poses no seismic risk and is widely accepted. Therefore, scenario 2 was favoured over scenario 3, along with the proposal that local authorities should be permitted to use geothermal energy through legislative measures. In this context, stakeholders criticised the current mining law for excluding municipalities from the decision-making process. They argued that regionally based plant developers and operators are essential in order to avoid resistance and ensure procedural and distributive justice (see Supplementary Materials S4).

The results of the feedback workshop were recorded in the author's notes and used to inform the recommendations for action, which were summarised based on the results of the criteria and scenario assessment workshops. The aim was to develop best practice guidelines for DGE projects to increase their practical application (see Supplementary Materials S5).

4. Discussion

Renewable energy sources, particularly solar PV and wind power, are expanding rapidly and could account for up to two-thirds of the global primary energy supply by 2050 (Hassan et al., 2024). This is mainly because they are approaching cost parity with fossil-fuel-generated energy after a decade of dramatic cost reductions (Ito, 2026). Besides, they offer opportunities to promote procedural and distributive justice in energy transitions. Citizens, energy cooperatives and local communities can contribute to the design, location, governance and ownership of projects and share the economic, social and energy benefits. Evidence from Germany, Europe, Asia, Africa and Australia suggests that energy communities can strengthen local influence and promote fair distribution of benefits (Corasaniti et al., 2025) given the appropriate design of institutional decision-making processes (Shejale et al., 2025). Recent case-based research likewise highlights the importance of meaningful consultation in solar development in Brazil and Portugal (Rielli et al., 2025), as well as in wind development in Kenya (Ndi, 2024; Akrofi et al., 2024). Similar debates are evident in Southeast Asia and Australia, where community renewable energy initiatives and Indigenous–corporate partnerships may enhance local agency but cannot secure equitable outcomes alone (Ridho et al., 2025).

The study's findings show that stakeholders recognise the potential of DGEs to achieve climate neutrality in heating systems, but are concerned about seismic and environmental impacts, as well as adverse public perception. Furthermore, DGE projects encounter procedural and distributive justice challenges due to socio-technical and economic requirements and uncertainties, such as accessing and utilising resources, navigating permitting and licensing processes, the substantial investment required for DGE plants and HT-ATES systems, the risk of drilling failure, operating costs, storage efficiency, network distance and connection rates. All of these factors can deter private entrepreneurs

from participating and investing (Huculak et al., 2015; Anatolitis et al., 2024; Toth et al., 2025). The study's findings indicate that, for municipalities in Germany, local ownership is not feasible due to complex insurance and liability issues, and because the investment costs exceed the budgets of most households and the debt levels of most municipalities.

The scenario method is widely used in research and decision-making at global, European and national levels to assess future renewable energy use and provide insights into its deployment (Luderer et al., 2014; Nam et al., 2020; Hansen et al., 2019). While renewable energy production has long-term sociotechnical, economic and environmental impacts on municipalities, the development of local-scale scenarios has not yet been widely investigated (Busch, 2017). The co-design method developed in this study addresses the needs, concerns, and expectations of stakeholders, translating them into visions of the future. This is achieved by developing criteria-based scenarios, which enable DGE to move beyond its controversial role. These scenarios offer stakeholders a better basis for discussion than one-way information from DGE plant developers or operators, which are often viewed critically because they typically only communicate positive information without openly addressing risks (Kunze et al., 2017; Stauffacher et al., 2015). In line with previous studies, the authors argue that co-designing scenarios can promote both procedural and distributive justice, thereby encouraging fair decision-making processes at a local level (Roddiss et al., 2018; Ghimire et al., 2026). A Turkish study mapping stakeholder discourses surrounding the expansion of geothermal energy confirms this and emphasises the importance of systematically involving local stakeholders in a transparent co-design process to implement the principles of procedural and distributive justice in DGE planning (Spijkerboer et al., 2025). This finding is supported by a study emphasising that weak communication and limited participation can intensify opposition [179] and a recent Dutch case study which found that the lack of transparency and communication in the development of a DGE project generated anxiety and suspicion among communities and stakeholders who were neither involved nor obvious beneficiaries (Duijn et al., 2024a). The co-design scenarios developed in this study are suitable for considering not only current and short-term issues, but also long-term ones. Recent research in New Zealand suggests that the importance of justice issues is often underestimated, and concludes that justice cannot be evaluated within the timeframe of a short-term project (Parson et al., 2025). In this context, the authors emphasise the importance of historical relationships, cultural authority and resource control for a legitimate geothermal transition.

The study's finding that involving stakeholders in the co-design process strengthens trust and credibility in the design of a DGE project is supported by previous studies (Enerchange, 2014; Leucht, 2012; Dialog, 2023). Similarly, the finding that comprehensive stakeholder engagement and participation are crucial for integrating diverse risk perspectives, including financial risk, is also supported by previous studies (Bidwell, 2016; Hendriks, 2005; Süsser et al., 2017). Other studies support the idea that including stakeholders in the initial planning stage and introducing legal and political frameworks that facilitate this boosts public confidence in DGE, provided the processes are not overly academic or politicised (Ejderyan et al., 2019, 2020; Turnhout et al., 2020; Galende-Sánchez et al., 2021). Moreover, other studies support the idea that meaningfully engaging stakeholders from the very beginning can foster trust between local municipalities and developers of a DGE project, potentially mitigating conflicts and costs (Renoth et al., 2023; Karytsas and Olympia, 2021; Hildebrand et al., 2022).

In line with previous findings, this study indicates that the perception of risk among stakeholders was positively affected by the trustworthiness of the project team and the participatory process (Der Schoor et al., 2015; Freeman et al., 2001). As this study was based on the recognition and credibility of KIT and the Institute for Applied Ecology as renowned research institutions, this probably encouraged consistent participation in the co-design process and reduced distrust, as observed in previous studies (Stauffacher et al., 2015; Dalla et al., 2020;

Trutnevyte and Olivier, 2018; Zaunbrecher et al., 2018). This is supported by research on risk perception and acceptance, which shows that trust in responsible institutions and independent expertise plays a central role in shaping how stakeholders interpret and evaluate risks (Renn et al., 2013, 2019). The study's finding that institutional credibility and transparent, participatory processes can build trust in DGE projects is consistent with previous research (Metze et al., 2023; Kassem et al., 2026b; Abdi et al., 2025b). In contrast, another DGE project near KIT received much less trust and acceptance, mainly because a for-profit, foreign-owned DGE company planned it to maximise profits for investors (including a Danish pension fund), regardless of local needs, concerns, and expectations.

A key finding of the study is that acceptance of a DGE project depends on how well it is integrated into the local context, particularly with regard to the local energy transition, energy sharing and decarbonisation of the local heat supply. A French study based on surveys and focus groups conducted in a region similar to the case study region in terms of geography, society, and culture supports the idea that the perceived risks and benefits of a DGE project depend on how communities experience and interpret territory and on the commitment of local governments to the energy transition (Chavot et al., 2018b). This can be achieved by exploring the key values and preferences surrounding DGE, sustainability and participatory aspects (Ulpiani et al., 2023; Campos et al., 2022), involving organisational, structural, technological and spatial configurations (Becker et al., 2017). While conducting such a comprehensive co-design study would be interesting from an academic viewpoint, it would require significantly more resources and complex modelling (Hiremath et al., 2007).

Despite conducting a systematic stakeholder mapping exercise and integrating various stakeholders, the study failed to engage with marginalised and silent stakeholders from different cultural and religious backgrounds, including ordinary people and those disadvantaged in terms of education and/or economics, according to Plaza-Úbeda et al. (2010) (Reed, 2008). In line with previous findings, the authors believe that engaging with all stakeholders would have contributed to broader sustainable development and social responsibility goals in the energy transition. Reasons for non-attendance can be manifold, ranging from a lack of interest to insufficient resources [180]. Conversely, a significant number of local decision-makers participated in the study's workshops although the co-design process was not embedded in legally mandated procedures (Boussagué, 2016). However, rather than feeling disillusioned and disempowered, the stakeholders recognised the value of their involvement in the research project. This aligns with the findings of other studies (Lelieveldt and Wouter, 2023; Deckert et al., 2020; Lennon et al., 2019).

The study findings are consistent with previous research indicating that clearly and transparently communicating risk-mitigation strategies (e.g. real-time monitoring and traffic-light systems) and establishing clear stop rules can prevent misunderstandings and promote acceptance (Knoblauch et al., 2018, 2019; Trutnevyte and Olivier, 2018; Zhou et al., 2024; Trutnevyte et al., 2017). This aligns with literature indicating that transparent, easily understandable risk management systems, user-friendly citizen monitoring systems, and clear liability regulations and compensation mechanisms are essential for gaining approval and improving acceptance (Yaghoubi et al., 2024; Anis, 2025; Abesser et al., 2023; Wiemer et al., 2017; Kraft et al., 2025; Duijn et al., 2024b). The study also found that perceptions of and attitudes towards projects are influenced by the sharing of benefits and profits, as well as by the establishment of mechanisms to retain added value locally and manage risk. These expectations reflect concerns about distributive justice and the legitimacy of the flow of value. This is consistent with studies emphasising that distributive justice and energy-sharing options are prerequisites for municipal tolerance and local acceptance (Schneider et al., 2011; Bonciani et al., 2023).

Unlike previous studies, which concluded that DGE projects in remote rural areas were the most promising (Carr-Cornish et al., 2014;

Knoblauch et al., 2019), this study found that stakeholders preferred nearby plants with robust risk management, heat supply potential and HT-ATES benefits, provided these were economically and technically feasible. The literature also reflects the generally positive response to HT-ATES, a technology that is still relatively unknown to the general public. These shared benefits are a key aspect of this positive perception, but they must be confirmed by further research. Further research should explicitly address potential subsurface risks and strengthen opportunities for transparent monitoring, good governance involving multiple users, and a robust legal framework (Fleuchaus et al., 2020b). As there are currently no clear regulations governing the use of the subsurface for HT-ATES, concerns could arise regarding groundwater protection and NIMBY effects (Dobson et al., 2025). Further research is needed to address the largely neglected social and justice risks of HT-ATES, despite experts considering these to be more critical than technical risks (Fleuchaus et al., 2020b).

5. Conclusions

The co-design approach is well-suited to embedding a DGE project within the context of the energy transition. It can translate the needs, concerns and expectations of stakeholders into scenarios and identify opportunities for risk mitigation through adjusted flow rates, as well as for shared use of geothermal resources to decarbonise municipal and private heating systems. Alongside the desire for more equitable use of geothermal resources between the project developer and neighbouring communities, transparent, early and continuous engagement, and clear and honest communication of risks and risk management strategies are considered important. While the co-design method can promote procedural justice, achieving the expectations identified in the scenarios, such as greater distributive justice with regard to non-monetary or monetary values, is often difficult in practice due to the necessary political, legal, economic or infrastructural prerequisites. This is particularly true of the shared use of geothermal energy for decarbonising local heat supply, since municipalities generally lack the legal means and financial resources to cover the high investment costs of municipal networks and the economic risk associated with geothermal systems. The study highlights the importance of the co-design process, involving a broad spectrum of stakeholders, including critical voices, as well as the trustworthiness, regional roots and recognition of the DGE project developers. When international, for-profit investment companies seek to develop a geothermal project, a neutral organisation led by scientific, independent experts is needed to facilitate the co-design process and develop scenarios. This is because these project developers are often perceived as lacking credibility and are suspected of merely treating the co-design process as a participative formality without being genuinely interested in addressing the community's needs, concerns and expectations.

CRedit authorship contribution statement

Christine Rösch: Writing – original draft, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Florian Bauer:** Writing – review & editing, Visualization, Software, Investigation, Data curation. **Christina Benighaus:** Writing – review & editing, Validation, Methodology, Investigation. **Judith Krohn:** Writing – review & editing, Investigation. **Sophie Kuppler:** Writing – review & editing, Validation, Methodology, Investigation, Conceptualization. **Melanie Mbah:** Writing – review & editing, Validation, Methodology, Investigation, Conceptualization. **Katharina Schätzler:** Writing – review & editing, Validation, Methodology, Investigation. **Ulrich Steiner:** Writing – review & editing, Validation, Methodology, Investigation, Data curation.

Data statement

The original data are available here: <https://www.gecko-geot.bernie.de/aktuelles>. The raw data supporting this article's conclusions are available on request.

Declaration of generative AI in scientific writing

This manuscript was prepared using AI-assisted translation and writing from DeepL for proofreading and linguistic refinement.

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Declaration of competing interest

The authors Christine Rösch, Florian Bauer, Christina Benighaus, Judith Krohn, Sophie Kuppler, Melanie Mbah, Katharina Schätzler, and Ulrich Steiner declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jclepro.2026.149624>.

Data availability

Data will be made available on request.

References

- Abdi, Mahamoud, Abdek, Takehiko Murayama, Nishikizawa, Shigeo, Suwanteep, Kultip, 2024c. Social acceptance and associated risks of geothermal energy development in East Africa: perspectives from geothermal energy developers. *Clean Energy* 8, 20–33. <https://doi.org/10.1093/ce/zkae051>.
- Abdi, Mahamoud, Abdek, Takehiko Murayama, Nishikizawa, Shigeo, Suwanteep, Kultip, 2025a. Factors influencing trust in geothermal energy projects: case of seven projects in East-Africa. *International Journal of Sustainable Energy Planning and Management* 46, 78–91. <https://doi.org/10.54337/ijsep.10001>.
- Abdi, Mahamoud, Abdek, Takehiko Murayama, Nishikizawa, Shigeo, Suwanteep, Kultip, 2025b. Factors influencing trust in geothermal energy projects: case of seven projects in East-Africa. *International Journal of Sustainable Energy Planning and Management* 46, 78–91. <https://doi.org/10.54337/ijsep.10001>.
- Abdi, Mahamoud, Abdek, Takehiko Murayama, Nishikizawa, Shigeo, Suwanteep, Kultip, Mariita, Nicholas Obuya, 2024a. Determinants of community acceptance of geothermal energy projects: a case study on a geothermal energy project in Kenya. *Renew. Energy Focus* 50, 100594. <https://doi.org/10.1016/j.ref.2024.100594>.
- Abdi, Mahamoud, Abdek, Takehiko Murayama, Nishikizawa, Shigeo, Suwanteep, Kultip, Mariita, Nicholas Obuya, 2024b. Determinants of community acceptance of geothermal energy projects: a case study on a geothermal energy project in Kenya. *Renew. Energy Focus* 50, 100594. <https://doi.org/10.1016/j.ref.2024.100594>.
- Abesser, Corinna, Ryder, Stacia, Rohse, Melanie, 2023. Considering Geothermal Energy Regulations in the UK.
- Agemar, Thorsten, Weber, Josef, Schulz, Rüdiger, 2014. Deep geothermal energy production in Germany. *Energies* 7, 4397–4416. <https://doi.org/10.3390/en7074397>.
- Agentur für Erneuerbare Energien e.V. (AEE), 2021. Akzeptanzumfrage 2021: Klimapolitik - Bürger*innen Wollen Mehr Erneuerbare Energien.
- Akrofi, Mark M., McLellan, Benjamin C., Okitasari, Mahesti, 2024. Characterizing 'injustices' in clean energy transitions in Africa. *Energy Sustain. Dev.* 83, 101546. <https://doi.org/10.1016/j.esd.2024.101546>.
- Akzeptanz von Geothermie, 2025. Ergebnisse einer Bevölkerungs- und Stakeholderbefragung. Universität Leipzig. https://www.sozphil.uni-leipzig.de/fi/leadmin/Fakult%C3%A4t_SozPhil/Institut_KMW/Communication_Management/2024/EASyQuart-Plus_Projekt/Wolf_et_al._2025-Akzeptanz_von_Geothermie.pdf.
- Anatolitis, Vasilios, Bojek, Piotr, Briens, François, Buisson, Eric, Criswell, Trevor, Dallard, Julie, Fabozzi, Eric, Kueppers, Martin, Lyons, Martina, Martinez, Laura Mari, 2024. The future of geothermal energy. In: *The Future of Geothermal Energy: Anatolitis, Vasilios| Ubojek, Piotr| Ubriens, François| Ubuissou, Eric| Ucriiswell,*

- Trevor| Udallard, Julie| Ufabozzi, Eric| Ukueppers, Martin| Ulyons, Martina| Umartinez, Laura Mari. International Energy Agency [Paris].
- Anis, Talha, 2025. Assessing stakeholder risk perceptions and their impact on the acceptance of deep geothermal energy. *Vaasa* 2.
- Balzan-Alzate, D., López-Sánchez, J., Blessent, D., Raymond, J., Dezayes, C., Portela, J.P., Ramírez Restrepo, E., et al., 2021. An online survey to explore the awareness and acceptance of geothermal energy among an educated segment of the population in five European and American countries. *Geotherm. Energy* 9, 9. <https://doi.org/10.1186/s40517-021-00188-x>.
- Barbier, Enrico, 2002. Geothermal energy technology and current status: an overview. *Renew. Sustain. Energy Rev.* 6, 3–65. [https://doi.org/10.1016/S1364-0321\(02\)00002-3](https://doi.org/10.1016/S1364-0321(02)00002-3).
- Barich, Amel, Stoklosa, Alicja W., Hildebrand, Jan, Elfasson, Ottó, Medgyes, Tamás, Quinonez, Gauthier, Casillas, Ana C., Fernandez, Isabel, 2021. Social license to operate in geothermal energy. *Energies* 15, 139. <https://doi.org/10.3390/en15010139>.
- Batel, Susana, Devine-Wright, Patrick, 2015. A critical and empirical analysis of the national-local 'gap' in public responses to large-scale energy infrastructures. *J. Environ. Plann. Manag.* 58, 1076–1095. <https://doi.org/10.1080/09640568.2014.914020>.
- Bauer, Florian, Grimmer, Jens, Haupt, Jens, Hertweck, Thomas, Schill, Eva, 2025. Development of intra-rift basins during stress field change in the central Upper Rhine Graben (SW Germany), 4 *Tectonics* 44, e2024TC008721. <https://doi.org/10.1029/2024TC008721>.
- Becker, Sören, Naumann, Matthias, 2017. Energy democracy: mapping the debate on energy alternatives. *Geogr. Compass* 11, e12321. <https://doi.org/10.1111/gec3.12321>.
- Benighaus, C., Bleicher, A., 2019. Neither risky technology nor renewable electricity: contested frames in the development of geothermal energy in Germany. *Energy Res. Social Sci.* 47, 46–55. <https://doi.org/10.1016/j.erss.2018.08.022>.
- Bidwell, David, 2016. Thinking through participation in renewable energy decisions. *Nat. Energy* 1, 16051. <https://doi.org/10.1038/nenergy.2016.51>.
- Bloemendal, Martin, Olsthoorn, Theo, Frank, Boons, 2014. How to achieve optimal and sustainable use of the subsurface for Aquifer Thermal Energy Storage. *Energy Policy* 66, 104–114. <https://doi.org/10.1016/j.enpol.2013.11.034>.
- Bonciani, D., Barich, A., Vichi, M., 2024. Increasing the social acceptance of geothermal energy projects grounding on lessons learned and NIMBY interventions. In: Fifth EAGE Global Energy Transition Conference & Exhibition (GET 2024). European Association of Geoscientists & Engineers, Rotterdam, Netherlands, pp. 1–5. <https://doi.org/10.3997/2214-4609.202421226>.
- Bonciani, Dario, Barich, Amel, Vichi, Marco, Pippuchi, Alice, Torsello, Loredana, 2023. Communicating geothermal geoscience results to improve public policies and social acceptance of geothermal energy. *European Federation of Geologists*. <https://doi.org/10.5281/ZENODO.10463545>.
- Boussaguet, Laurie, 2016. Participatory mechanisms as symbolic policy instruments? *Comp. Eur. Polit.* 14, 107–124. <https://doi.org/10.1057/cep.2015.12>.
- Brémaud, Maëlle, Burnside, Neil M., Shipton, Zoe K., Willems, Cees J.L., Pujol, Martin, Bossennec, Claire, 2025. International database of hot sedimentary aquifer geothermal projects: de-risking future projects by identifying key success and failure criteria. *Geoenergy* 3. <https://doi.org/10.1144/geoenergy2024-031> geoenergy2024-031.
- Buijze, L., Bijsterveldt, van L., Cremer, H., Paap, B., Veldkamp, H., Wassing, B., van Wees, J.-D., Heege, ter J., 2019. Review of Worldwide Geothermal Project Mechanisms and Occurrence of Induced Seismicity. TNO. R100043 2019.
- Bundesministerium der Justiz und für Verbraucherschutz, 2025. Gesetz Zur Beschleunigung Des Ausbaus Von Geothermieanlagen, Wärmepumpen, Wärmeleitungen Und Wärmespeichern* (Geothermie-Beschleunigungsgesetz - Geobg).
- Burbaum, Ulrich, Ingo, Sass, 2013. Gebirgsmechanische Ursachen Der Risse an Gebäuden Und Straßen Der Stadt Staufen Im Breisgau.
- Busch, Gerald, 2017. A spatial explicit scenario method to support participative regional land-use decisions regarding economic and ecological options of short rotation coppice (SRC) for renewable energy production on arable land: case study application for the Göttingen district, Germany. *Energy Sustain. Soc.* 7, 2. <https://doi.org/10.1186/s13705-017-0105-4>.
- Campos, Inés, Brito, Miguel, De Souza, Debora, Santino, Afas, Luz, Guilherme, Pera, David, 2022. Structuring the problem of an inclusive and sustainable energy transition – a pilot study. *J. Clean. Prod.* 365, 132763. <https://doi.org/10.1016/j.jclepro.2022.132763>.
- Carr-Cornish, Simone, Romanach, Lygia, 2014. Differences in public perceptions of geothermal energy technology in Australia. *Energies* 7, 1555–1575. <https://doi.org/10.3390/en7031555>.
- Carrera, Gallego, Diana, Mack, Alexander, 2010. Sustainability assessment of energy technologies via social indicators: results of a survey among European energy experts. *Energy Policy* 38, 1030–1039. <https://doi.org/10.1016/j.enpol.2009.10.055>.
- Chavot, Philippe, Heimlich, Christine, Masseran, Anne, Serrano, Yeny, Zoungrana, Jean, Bodin, Cyrille, 2018a. Social shaping of deep geothermal projects in Alsace: politics, stakeholder attitudes and local democracy. *Geotherm. Energy* 6, 26. <https://doi.org/10.1186/s40517-018-0111-6>.
- Chavot, Philippe, Heimlich, Christine, Masseran, Anne, Serrano, Yeny, Zoungrana, Jean, Bodin, Cyrille, 2018b. Social shaping of deep geothermal projects in Alsace: politics, stakeholder attitudes and local democracy. *Geotherm. Energy* 6, 26. <https://doi.org/10.1186/s40517-018-0111-6>.
- Chilvers, Jason, Bellamy, Rob, Pallett, Helen, Hargreaves, Tom, 2021. A systemic approach to mapping participation with low-carbon energy transitions. *Nat. Energy* 6, 250–259. <https://doi.org/10.1038/s41560-020-00762-w>.
- Cook, David, Karlsdóttir, Ingibjörg, Minelgaite, Inga, 2022. Enjoying the heat? Co-Creation of stakeholder benefits and sustainable energy development within projects in the geothermal sector. *Energies* 15, 1029. <https://doi.org/10.3390/en15031029>.
- Corasaniti, Sandra, Coppa, Paolo, Atzori, Dario, Rehman, Ateeq Ur, 2025. Renewable energy communities (RECs): european and worldwide distribution, different technologies, management, and modeling. *Energies* 18, 3961. <https://doi.org/10.3390/en18153961>.
- Costa, D., Pereira, V., Góis, J., Danko, A., Fiúza, A., 2017. Understanding public perception of hydraulic fracturing: a case study in Spain. *J. Environ. Manag.* 204, 551–562. <https://doi.org/10.1016/j.jenvman.2017.09.001>.
- Cousse, Julia, Trutnevyte, Evelina, Hahnel, Ulf J.J., 2021. Tell me how you feel about geothermal energy: affect as a revealing factor of the role of seismic risk on public acceptance. *Energy Policy* 158, 112547. <https://doi.org/10.1016/j.enpol.2021.112547>.
- Dalla, Longa, Francesco, Larissa P. Nogueira, Limberger, Jon, Van Wees, Jan-Diederik, Van Der Zwaan, Bob, 2020. Scenarios for geothermal energy deployment in Europe. *Energy* 206, 118060. <https://doi.org/10.1016/j.energy.2020.118060>.
- Dalmais, Eléonore, Ravier, Guillaume, Vincent, Maurer, Fries, David, Genter, Albert, Pandélis, Béatrice, 2022. Environmental and socio-economic impact of deep geothermal energy, an upper rhine Graben perspective. In: *Geothermal Energy-Challenges and Improvements*. IntechOpen.
- Daniilidis, Alexandros, Alpsay, Betül, Herber, Rien, 2017. Impact of technical and economic uncertainties on the economic performance of a deep geothermal heat system. *Renew. Energy* 114, 805–816. <https://doi.org/10.1016/j.renene.2017.07.090>.
- Deckert, Anna, Dembski, Fabian, Ulmer, Frank, Ruddat, Michael, Wössner, Uwe, 2020. Digital tools in stakeholder participation for the German Energy Transition. Can digital tools improve participation and its outcome? In: *The Role of Public Participation in Energy Transitions*. Elsevier, pp. 161–177. <https://doi.org/10.1016/B978-0-12-819515-4.00009-X>.
- Der Schoor, Van, Tineke, Scholtens, Bert, 2015. Power to the people: local community initiatives and the transition to sustainable energy. *Renew. Sustain. Energy Rev.* 43, 666–675. <https://doi.org/10.1016/j.rser.2014.10.089>.
- Dialog, Basis, 2023. Geothermie in der Rhein-Neckar-Region. In: *Abschlussbericht Und Handlungsempfehlungen Des Dialogforums Mit Zufallsbürger*innen*. Schwetzingen: Geohardt - Ein Unternehmen Von Enbw Und MVV.
- Die Bundesregierung, 2023. Entwurf eines Gesetz für die Wärmeplanung und zur Dekarbonisierung der Wärmenetze. <https://dserver.bundestag.de/brd/2023/03-88-23.pdf>. Bundesrat Drucksache 388/23.
- Dobson, Patrick, McLing, Travis, Spycher, Nicolas, Fleuchaus, Paul, Neupane, Ghanashyam, Doughty, Christine, Zhang, Yingqi, et al., 2025. High-temperature aquifer thermal energy storage (HT-ATES) projects in Germany and the Netherlands—review and lessons learned. *Energies* 18, 6292. <https://doi.org/10.3390/en18236292>.
- Dowd, Anne-Maree, Boughen, Naomi, Ashworth, Peta, Carr-Cornish, Simone, 2011. Geothermal technology in Australia: investigating social acceptance. *Energy Policy* 39, 6301–6307. <https://doi.org/10.1016/j.enpol.2011.07.029>.
- Duijn, Michael, Van Popering-Verkerk, Jitske, Sambell, Karlien, Puts, Hanneke, 2024a. Value-sensitive design under ground? Exploring the community-based monitoring of a geothermal project in the Netherlands. *Energy Res. Social Sci.* 118, 103768. <https://doi.org/10.1016/j.erss.2024.103768>.
- Duijn, Michael, van Popering-Verkerk, Jitske, Sambell, Karlien, Puts, Hanneke, 2024b. Value-sensitive design under ground? Exploring the community-based monitoring of a geothermal project in the Netherlands. In: *Energy Research & Social Science*, 118. Elsevier, 103768.
- Edwards, B., Kraft, T., Cauzzi, C., Kastli, P., Wiemer, S., 2015. Seismic monitoring and analysis of deep geothermal projects in St Gallen and Basel, Switzerland. *Geophys. J. Int.* 201, 1022–1039. <https://doi.org/10.1093/gji/ggv059>.
- EEG, 2023. Gesetz Für Den Ausbau Erneuerbarer Energien (Erneuerbare-Energien-Gesetz - EEG 2023).
- Ejderyan, Olivier, Ruef, Franziska, Stauffacher, Michael, 2019. In: *Geothermal Energy and Society*, Manzella, Adele, Allansdottir, Agnes, Pellizzone, Anna (Eds.), *Geothermal Energy in Switzerland: Highlighting the Role of Context*, vol. 67. Springer International Publishing, Cham, pp. 239–257. https://doi.org/10.1007/978-3-319-78286-7_15. Lecture Notes in Energy.
- Ejderyan, Olivier, Ruef, Franziska, Stauffacher, Michael, 2020. Entanglement of top-down and Bottom-Up: sociotechnical innovation pathways of geothermal energy in Switzerland. *J. Environ. Dev.* 29, 99–122. <https://doi.org/10.1177/1070496519886008>.
- Enerchange, 2014. Öffentlichkeitsarbeit Für Geothermieprojekte.
- Energieverbrauch für fossile und erneuerbare Wärme. <https://www.umweltbundesamt.de/daten/umweltzustand-trends/energie/energieverbrauch-fuer-fossile-erneuerbare-waerme>, 2026.
- Erneuerbare Energien in Zahlen, 2026. <https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/erneuerbare-energien-in-zahlen#berblick>. March 5.
- Fiori, Rémi, Vergne, Jérôme, Jean, Schmittbuhl, Zigone, Dimitri, 2023. Monitoring induced microseismicity in an urban context using very small seismic arrays: the case study of the Vendenheim EGS project. *GEOPHYSICS* 88, WB71–WB87. <https://doi.org/10.1190/geo2022-0620.1>.
- Fleuchaus, Paul, Schüppler, Simon, Bloemendal, Martin, Guglielmetti, Luca, Oliver, Opel, Blum, Philipp, 2020a. Risk analysis of high-temperature aquifer

- thermal energy storage (HT-ATES). *Renew. Sustain. Energy Rev.* 133, 110153. <https://doi.org/10.1016/j.rser.2020.110153>.
- Fleuchaus, Paul, Schuppeler, Simon, Bloemendal, Martin, Guglielmetti, Luca, Oliver, Opel, Blum, Philipp, 2020b. Risk analysis of high-temperature aquifer thermal energy storage (HT-ATES). *Renew. Sustain. Energy Rev.* 133, 110153. <https://doi.org/10.1016/j.rser.2020.110153>.
- Foqha, Tareq, Refaat, Shady S., Mohammed, Amira, Farrag, Mostafa, Gamal, Haytham, 2026. Renewable energy sources: progress, challenges, and environmental benefits. *Renew. Sustain. Energy Rev.* 240, 117167. <https://doi.org/10.1016/j.rser.2026.117167>.
- Freeman, R. Edward Edward, McVea, John, 2001. A stakeholder approach to strategic management. *SSRN Electron. J.* <https://doi.org/10.2139/ssrn.263511>.
- Frey, Matthias, Bär, Kristian, Stober, Ingrid, Reinecker, John, Vaart, Jeroen Van Der, Sass, Ingo, 2022. Assessment of deep geothermal research and development in the Upper Rhine Graben. *Geotherm. Energy* 10, 18. <https://doi.org/10.1186/s40517-022-00226-2>.
- Frey, Matthias, Van Der Vaart, Jeroen, Bär, Kristian, Bossennec, Claire, Calcagno, Philippe, Dezayes, Chrystel, Sass, Ingo, 2023. Techno-economic assessment of geothermal resources in the Variscan basement of the Northern upper rhine Graben. *Nat. Resour. Res.* 32, 213–234. <https://doi.org/10.1007/s11053-022-10138-4>.
- Galende-Sánchez, Ester, Sorman, Alevgul H., 2021. From consultation toward co-production in science and policy: a critical systematic review of participatory climate and energy initiatives. *Energy Res. Social Sci.* 73, 101907. <https://doi.org/10.1016/j.erss.2020.101907>.
- Giardini, Domenico, Wössner, Jochen, Danciu, Laurentiu, 2014. Mapping Europe's seismic hazard. *EOS Trans. Am. Geophys. Union* 95, 261–262. <https://doi.org/10.1002/2014EO290001>.
- Goedkoop, Fleur, Devine-Wright, Patrick, 2016. Partnership or placation? The role of trust and justice in the shared ownership of renewable energy projects. *Energy Res. Social Sci.* 17, 135–146. <https://doi.org/10.1016/j.erss.2016.04.021>.
- Gooding, Luke, Devine-Wright, Patrick, Rohse, Melanie, Ford, Rebecca, Walker, Chad, Soutar, Iain, Devine-Wright, Hannah, 2023. The best-laid plans: tracing public engagement change in emergent Smart Local Energy Systems. *Energy Res. Social Sci.* 101, 103125. <https://doi.org/10.1016/j.erss.2023.103125>.
- Groos, Jörn, Zeiß, Jens, Grund, Michael, Ritter, Joachim, 2013. In: *Microseismicity at Two Geothermal Power Plants at Landau and Inheim in the Upper Rhine Graben, Germany*, vol. 15, p. 1.
- Grotelüschen, Frank, 2022. *Entwicklungspotenzial Der Geothermie in Deutschland*.
- Hansen, Kenneth, Vad Mathiesen, Brian, Ridjan Skov, Iva, 2019. Full energy system transition towards 100% renewable energy in Germany in 2050. *Renew. Sustain. Energy Rev.* 102, 1–13. <https://doi.org/10.1016/j.rser.2018.11.038>.
- Häring, Markus O., Ulrich, Schanz, Ladner, Florentin, Dyer, Ben C., 2008. Characterisation of the Basel 1 enhanced geothermal system. *Geothermics* 37, 469–495. <https://doi.org/10.1016/j.geothermics.2008.06.002>.
- Hassan, Qusay, Viktor, Patrik, Al-Musawi, Tariq J., Ali, Bashar Mahmood, Algburi, Sameer, Alzoubi, Haitham M., Ali, Khudhair Al-Jiboory, Sameen, Aws Zuhair, Salman, Hayder M., Jaszczur, Marek, 2024. The renewable energy role in the global energy Transformations. *Renew. Energy Focus* 48, 100545. <https://doi.org/10.1016/j.ref.2024.100545>.
- Heimlich, Christine, Goumelen, Noël, Masson, Frédéric, Jean, Schmittbuhl, Kim, Sang-Wan, Jérôme, Azzola, 2015. Uplift around the geothermal power plant of Landau (Germany) as observed by InSAR monitoring. In: *Geothermal Energy*, vol. 3. Springer, p. 2.
- Hendriks, Carolyn M., 2005. Participatory storylines and their influence on deliberative forums. *Policy Sci.* 38, 1–20. <https://doi.org/10.1007/s11077-005-0870-3>.
- Hildebrand, Jan, Jahns, Alena, Schwarz, Lea, Barich, Amel, 2022. Public perceptions of Geothermal Projects – new ways of measuring and monitoring local acceptance and social impacts. Zenodo. <https://doi.org/10.5281/ZENODO.7602374>.
- Hiremath, R.B., Shikha, S., Ravindranath, N.H., 2007. Decentralized energy planning: modeling and application—a review. *Renew. Sustain. Energy Rev.* 11, 729–752. <https://doi.org/10.1016/j.rser.2005.07.005>.
- Hirschberg, Stefan, Wiemer, Stefan, Burgherr, Peter (Eds.), 2014. *Energy from the Earth - Deep Geothermal as a Resource for the Future?* Vdf Hochschulverlag AG. <https://doi.org/10.3218/3655-8>.
- Huculak, Maciej, Jarczewski, Wojciech, Dej, Magdalena, 2015. Economic aspects of the use of deep geothermal heat in district heating in Poland. *Renew. Sustain. Energy Rev.* 49, 29–40. <https://doi.org/10.1016/j.rser.2015.04.057>.
- Ito, Koichiro, 2026. Renewable Energy Expansion: Key Challenges and Emerging Opportunities. National Bureau of Economic Research, Cambridge, MA. <https://doi.org/10.3386/w34644>.
- Jan, Fjornes, Hansjürgens, Johanna, Leoncio, David, Ulmer, Alina, 2024. *Status Quo: Politischer Rahmen Für Nachhaltiges Wirtschaften in Deutschland*.
- Karytsas, Spyridon, Olympia, Polyzoou, 2021. Social acceptance of geothermal power plants. In: *Thermodynamic Analysis and Optimization of Geothermal Power Plants*. Elsevier, pp. 65–79. <https://doi.org/10.1016/B978-0-12-821037-6.00004-4>.
- Karytsas, Spyridon, Polyzoou, Olympia, 2021a. Social acceptance of geothermal power plants. In: *Thermodynamic Analysis and Optimization of Geothermal Power Plants*. Elsevier, pp. 65–79. <https://doi.org/10.1016/B978-0-12-821037-6.00004-4>.
- European Commission. Joint Research Centre, Taylor, Nigel, Tumara, Drazen, Georgakaki, Alik, Ince, Ela, Letout, Simon, Mountraki, Aikaterini, Bermudez, Juan Gea, Schmitz, Andreas, 2025. *Energy Technology Observatory, Geothermal Energy in the European Union – Status Report on Technology Development, Trends, Value Chains and Markets – 2025*. Publications Office of the European Union, EUR. LU. <https://data.europa.eu/doi/10.2760/9841484>.
- Geothermal energy. https://energy.ec.europa.eu/topics/renewable-energy/geothermal-energy_en, 2026. August 6.
- Ghimire, Jiwath, Taamallah, Eyad, 2026. Scenario planning for renewable energy transition for rural towns in the United States: lessons from Algona City of Iowa, United States. *Frontiers of Urban and Rural Planning* 4, 17. <https://doi.org/10.1007/s44243-026-00087-4>.
- Hartmann, Katharina, Palm, Jenny, 2023. The role of thermal energy communities in Germany's heating transition. In: *Frontiers in Sustainable Cities*, vol. 4. Frontiers Media SA, 1027148.
- Hymans, Jacques E.C., Fumiya, Uchikoshi, 2022. To drill or not to drill: determinants of geothermal energy project siting in Japan. *Environ. Polit.* 31, 407–428. <https://doi.org/10.1080/09644016.2021.1918493>.
- Karytsas, Spyridon, Polyzoou, Olympia, 2021b. Social acceptance of geothermal power plants. In: *Thermodynamic Analysis and Optimization of Geothermal Power Plants*. Elsevier, pp. 65–79. <https://doi.org/10.1016/B978-0-12-821037-6.00004-4>.
- Kassem, Mukhtar A., Moscarillo, Andrea, 2026a. Public acceptance of geothermal energy in Europe: factors and strategies. *Next Energy* 12, 100711. <https://doi.org/10.1016/j.nxener.2026.100711>.
- Kassem, Mukhtar A., Moscarillo, Andrea, 2026b. Public acceptance of geothermal energy in Europe: factors and strategies. *Next Energy* 12, 100711. <https://doi.org/10.1016/j.nxener.2026.100711>.
- Kassem, Mukhtar A., Moscarillo, Andrea, Hollmüller, Pierre, 2025. Reducing LCOE in geothermal energy production in Switzerland: a comprehensive review of technological, economic, and policy strategies. *Energy Rep.* 13, 4403–4416. <https://doi.org/10.1016/j.egyr.2025.04.024>.
- KIT, 2018. *Integrated Master Plan 2030*. Karlsruhe Institute of Technology. Internal Reprt, not unshied.
- Knoblauch, Theresa A.K., Stauffacher, Michael, Trutnevyte, Evelina, 2018. Communicating low-probability high-consequence risk, uncertainty and expert confidence: induced seismicity of deep geothermal energy and shale gas. *application/pdf*. ETH Zurich 45. <https://doi.org/10.3929/ETHZ-B-000181351>.
- Knoblauch, Theresa A.K., Trutnevyte, Evelina, Stauffacher, Michael, 2019. Siting deep geothermal energy: acceptance of various risk and benefit scenarios in a Swiss-German cross-national study. *Energy Policy* 128, 807–816. <https://doi.org/10.1016/j.enpol.2019.01.019>.
- Kock, Nils, Kaltschmitt, Martin, 2012. Geothermisch erschließbare Niedertemperaturwärmesenken in Deutschland – Identifikation und Quantifizierung. *Z. Energiewirtschaft* 36, 191–203. <https://doi.org/10.1007/s12398-012-0079-z>.
- Korucan, Aysun, Derin-Güre, Pinar, Celebi, Bertug, Baker, Derek, Velde, Madeline Vander, 2024. Opportunities and challenges of geothermal energy in Türkiye. *Energy Sustain. Dev.* 79, 101417. <https://doi.org/10.1016/j.esd.2024.101417>.
- Kraft, Toni, Roth, Philippe, Ritz, Vanille, Antunes, Verónica, Zambrano, Tania Andrea Toledo, Wiemer, Stefan, 2025. *Good-Practice Guide for Managing Induced Seismicity in Deep Geothermal Energy Projects in Switzerland*. ETH Zurich.
- Kubota, Hiromi, Hondo, Hiroki, Hienuki, Shunichi, Kaieda, Hideshi, 2013. Determining barriers to developing geothermal power generation in Japan: societal acceptance by stakeholders involved in hot springs. *Energy Policy* 61, 1079–1087. <https://doi.org/10.1016/j.enpol.2013.05.084>.
- Kunze, Conrad, Hertel, Mareen, 2017. Contested deep geothermal energy in Germany—The emergence of an environmental protest movement. *Energy Res. Social Sci.* 27, 174–180. <https://doi.org/10.1016/j.erss.2016.11.007>.
- Kurek, Katarzyna A., Ophem, Johan Van, Strojny, Jacek, 2024. Arguments for a community-based approach to geothermal energy development. *Energies* 17, 2299. <https://doi.org/10.3390/en17102299>.
- Leiss, Bernd, Wagner, Bianca, Heinrichs, Till, Romanov, Dmitry, Tanner, David, Vollbrecht, Axel, Wemmer, Klaus, 2021. *Integrating Deep, Medium and Shallow Geothermal Energy into District Heating and Cooling System as an Energy Transition Approach for the Göttingen University Campus*, pp. 1–9.
- Lelieveldt, Herman, Wouter, Schram, 2023. Where are the citizens? Unravelling the lopsided nature of stakeholder participation in the Dutch regional energy transition. *Energy Res. Social Sci.* 96, 102925. <https://doi.org/10.1016/j.erss.2022.102925>.
- Lennon, Breffni, Dunphy, Niall P., Sanvicente, Estibaliz, 2019. Community acceptability and the energy transition: a citizens' perspective. *Energy Sustain. Soc.* 9, 35. <https://doi.org/10.1186/s13705-019-0218-z>.
- Leucht, Martina, 2012. *Medienresonanzanalyse zu Projekten der tiefen Geothermie in Landau, Bruchsal, Brühl und Unterhaching*. In: *Printmedienberichterstattung Der Leitmedien Und Ausgewählter Regional- U. Lokalzeitungen*.
- Li, Gensheng, Xie, Zixiao, Huang, Zhongwei, Song, Xianzhi, Wu, Xiaoguang, 2025. The role of deep geothermal resources in China's energy transition. *Engineering*, S2095809925007969. <https://doi.org/10.1016/j.eng.2025.12.012>.
- Li, Kewen, Bian, Huiyuan, Liu, Changwei, Zhang, Danfeng, Yang, Yanan, 2015a. Comparison of geothermal with solar and wind power generation systems. *Renew. Sustain. Energy Rev.* 42, 1464–1474. <https://doi.org/10.1016/j.rser.2014.10.049>.
- Li, Kewen, Bian, Huiyuan, Liu, Changwei, Zhang, Danfeng, Yang, Yanan, 2015b. Comparison of geothermal with solar and wind power generation systems. *Renew. Sustain. Energy Rev.* 42, 1464–1474. <https://doi.org/10.1016/j.rser.2014.10.049>.
- Liu, Po-Hsiang, Lin, Jui-Chu, 2025. Integrated risk assessment and mitigation strategies for geothermal energy development: technical, socio-political, and financial dimensions. *Sustainable Energy Research* 12, 64. <https://doi.org/10.1186/s40807-025-00218-3>.
- Luderer, Gunnar, Krey, Volker, Calvin, Katherine, Merrick, James, Mima, Silvana, Pietzcker, Robert, Vliet, Jasper Van, Wada, Kenichi, 2014. The role of renewable energy in climate stabilization: results from the EMF27 scenarios. *Clim. Change* 123, 427–441. <https://doi.org/10.1007/s10584-013-0924-z>.
- Majer, Ernest L., Baria, Roy, Stark, Mitch, Oates, Stephen, Bommer, Julian, Smith, Bill, Asanuma, Hiroshi, 2007. Induced seismicity associated with Enhanced Geothermal

- Systems. *Geothermics* 36, 185–222. <https://doi.org/10.1016/j.geothermics.2007.03.003>.
- Malau, H., Fajri, H., Yuanjaya, P., Saputra, B., Maani, K.D., 2020. Knowledge of local communities affected by the development of geothermal energy. *IOP Conf. Ser. Earth Environ. Sci.* 448, 012112. <https://doi.org/10.1088/1755-1315/448/1/012112>.
- Mbah, Melanie, Krohn, Judith, 2021a. In: *Die Bedeutung Von Kommunikation Und Beteiligung in Der Planung Und Umsetzung Von Geothermievorhaben—eine Fallstudie Zu Staufen (D) Und St. Gallen (CH)*. Öko-Institut Working Paper. Freiburg/Br. Öko-Institut eV, Darmstadt, Berlin. www.oeko.de/fileadmin/oekodo/c/WP-Geothermievorhaben.pdf.
- Mbah, Melanie, Krohn, Judith, 2021b. *Die Bedeutung Von Kommunikation Und Beteiligung in Der Planung Und Umsetzung Von Geothermievorhaben—eine Fallstudie Zu Staufen (D) Und St. Gallen (CH)*. Freiburg: Öko-Institut E.V.
- Meirbekova, Rauan, Bonciani, Dario, Ingi Olafsson, Dagur, Korucan, Aysun, Derin-Güre, Pinar, Harcouët-Menou, Virginie, Bero, Wilfried, 2024. Opportunities and challenges of geothermal energy: a comparative analysis of three European Cases—Belgium, Iceland, and Italy. *Energies* 17, 4134. <https://doi.org/10.3390/en17164134>.
- Meraz, Carlos Gorraez, 2025. *Social Acceptance of Geothermal Systems in the United States*.
- Metze, Tamara A.P., Van Den Broek, Jos, Van Est, Rinie, Cuppen, Eefje H.W.J., 2023. Participatory repertoires for aligning policy and society: an analysis of Dutch stakeholder views on deep geothermal energy. *Energy Res. Social Sci.* 98, 103019. <https://doi.org/10.1016/j.erss.2023.103019>.
- Meuser, Michael, Nagel, Ulrike, 2009. In: *Experts, Interviewing, Bogner, Alexander, Littig, Beate, Menz, Wolfgang (Eds.), The Expert Interview and Changes in Knowledge Production*. Palgrave Macmillan UK, London, pp. 17–42. https://doi.org/10.1057/9780230244276_2.
- Mignan, Arnaud, Landtwing, Delano, Kästli, Philipp, Mena, Banu, Wiemer, Stefan, 2015. Induced seismicity risk analysis of the 2006 Basel, Switzerland, Enhanced Geothermal System project: influence of uncertainties on risk mitigation. In: *Geothermics*, vol. 53. Elsevier, pp. 133–146.
- Moeck, Inga, Bloch, Thomas, Graf, René, Heuberger, Stefan, Kuhn, Pete, Naef, Henry, Sonderegger, Michael, Uhlig, Stephan, Wolgramm, Markus, 2015. *The St. Gallen Project: Development of Fault controlled geothermal systems in urban areas*. In: *Proceedings World Geothermal Congress 2015*. Melbourne, Australia, 19–25 April 2015.
- Moeck, Inga, Bracke, Rolf, Weber, Josef, 2020. *The energy transition from fossil fuels to geothermal energy—A German case study*, 1.
- Mueller, Florian, Steffen, Bjarne, Schmidt, Tobias S., 2026. Experience rates of current and future geothermal power technologies. *iScience* 29, 117113. <https://doi.org/10.1016/j.isci.2026.117113>.
- Nam, KiJoon, Hwangbo, Soonho, Yoo, ChangKyoo, 2020. A deep learning-based forecasting model for renewable energy scenarios to guide sustainable energy policy: a case study of Korea. *Renew. Sustain. Energy Rev.* 122, 109725. <https://doi.org/10.1016/j.rser.2020.109725>.
- Ndi, Franklin A., 2024. Justice concerns in large-scale renewable energy projects: a case study echoing the importance of procedural justice in wind energy development in Kenya. *Energy Sustain. Soc.* 14, 47. <https://doi.org/10.1186/s13705-024-00482-z>.
- Nkinyam, Charity M., Chika, Oliver Ujah, Asadu, Christian O., Kallon, Daramy V.V., 2025. Exploring geothermal energy as a sustainable source of energy: a systemic review. *Unconventional Resources* 6, 100149. <https://doi.org/10.1016/j.unres.2025.100149>.
- Park, Eunil, 2021. Social acceptance of renewable energy technologies in the post-fukushima era. *Front. Psychol.* 11, 612090. <https://doi.org/10.3389/fpsyg.2020.612090>.
- Parson, Phoebe, Luketina, Katherine, Barton, Barry, 2025. Geothermal energy, decarbonisation and the just transition: developments in governance and regulation. *J. Roy. Soc. N. Z.* 55, 873–892. <https://doi.org/10.1080/03036758.2025.2455496>.
- Pellizzone, Anna, Allansdottir, Agnes, De Franco, Roberto, Muttoni, Giovanni, Manzella, Adele, 2017. Geothermal energy and the public: a case study on deliberative citizens' engagement in central Italy. *Energy Policy* 101, 561–570. <https://doi.org/10.1016/j.enpol.2016.11.013>.
- Qorizki, Dhifa, Permadi, Dwiko B., Yuwono, Teguh, Rohman, Rohman, 2021. Should drill or shouldn't drill? Urban and rural dwellers' acceptance of geothermal power plant in Mount Slamet protection forest, Indonesia. *For. Soc.* 575–590. <https://doi.org/10.24259/fs.v5i2.13400>.
- Radtko, Jörg, Renn, Ortwin, 2024. Participation in energy transitions: a comparison of Policy styles. *Energy Res. Social Sci.* 118, 103743. <https://doi.org/10.1016/j.erss.2024.103743>.
- Reed, Mark S., 2008. Stakeholder participation for environmental management: a literature review. *Biol. Conserv.* 141, 2417–2431. <https://doi.org/10.1016/j.biocon.2008.07.014>.
- Reed, Mark S., Hannah, Rudman, 2023. Re-thinking research impact: voice, context and power at the interface of science, policy and practice. *Sustain. Sci.* 18, 967–981. <https://doi.org/10.1007/s11625-022-01216-w>.
- Renn, O., Hildebrand, J., 2019. Akzeptanz in der Energiewende. In: *Energiewende. Eine Sozialwissenschaftliche Einführung*. Springer, pp. 261–282.
- Renn, Ortwin, Benighaus, Christina, 2013. Perception of technological risk: insights from research and lessons for risk communication and management. *J. Risk Res.* 16, 293–313. Taylor & Francis.
- Renoth, Robin, Buchner, Elmar, Schmieder, Martin, Keim, Maximilian, Plechaty, Manfred, Drews, Michael, 2023. Social acceptance of geothermal technology on a global view: a systematic review. *Energy Sustain. Soc.* 13, 49. <https://doi.org/10.1186/s13705-023-00432-1>.
- Ridho, Zainur, Paksi, Arie Kusuma, Rohmatika, Fiya Ainur, 2025. Energy justice and inclusive transitions: lessons from community renewable energy in Southeast Asia. *Journal of Asian Energy Studies* 9, 268–291. <https://doi.org/10.24112/jaes.090015>.
- Rielli, L.E., Campos, I., 2025. The process matters: exploring public participation in solar energy projects in Brazil and Portugal. *Energy Res. Social Sci.* 125, 104078. <https://doi.org/10.1016/j.erss.2025.104078>.
- Roddie, Philippa, Carver, Stephen, Dallimer, Martin, Norman, Paul, Ziv, Guy, 2018. The role of community acceptance in planning outcomes for onshore wind and solar farms: an energy justice analysis. *Appl. Energy* 226, 353–364. <https://doi.org/10.1016/j.apenergy.2018.05.087>.
- Rohse, Melanie, Barich, Amel, Bossennec, Claire, Loschetter, Annick, Manzella, Adele, Pellizzone, Anna, Ryder, Stacia, Soutar, Iain, 2024. Prioritise inclusive, early, and continuous societal engagement to maximise the benefits of geothermal technologies. In: *Crowther, Ami, Foulds, Chris, Robison, Rosie, Gladkykh, Ganna (Eds.), Strengthening European Energy Policy*. Springer Nature Switzerland, Cham, pp. 31–43. https://doi.org/10.1007/978-3-031-66481-6_3.
- Romanach, Lygia, Carr-Cornish, Simone, Grace, Muriuki, 2015. Societal acceptance of an emerging energy technology: how is geothermal energy portrayed in Australian media? *Renew. Sustain. Energy Rev.* 42, 1143–1150. <https://doi.org/10.1016/j.rser.2014.10.088>.
- Rose, Richard, 2019. Referendum challenges to the EU's policy legitimacy – and how the EU responds. *J. Eur. Publ. Pol.* 26, 207–225. <https://doi.org/10.1080/13501763.2018.1426034>.
- Ruef, Franziska, Stauffacher, Michael, Ejderyan, Olivier, 2020. Blind spots of participation: how differently do geothermal energy managers and residents understand participation? *Energy Rep.* 6, 1950–1962. <https://doi.org/10.1016/j.egyr.2020.07.003>.
- Sanjuan, Bernard, Gourcerol, Blandine, Millot, Romain, Rettenmaier, Detlev, Jeandel, Elodie, Rombaut, Aurélien, 2022. Lithium-rich geothermal brines in Europe: an up-date about geochemical characteristics and implications for potential Li resources. *Geothermics* 101, 102385. <https://doi.org/10.1016/j.geothermics.2022.102385>.
- Schill, Eva, Knaute, Roland, Garipi, Xheni, Bauer, Florian, 2024. *DeepStor - Heat cycling in the deep and medium-deep subsurface*. In: *Proceedings , 49th Workshop on Geothermal Reservoir Engineering Stanford University*. Stanford, California, February 12–14, 2024.
- Schneider, En, Snieder, Roel, 2011. Putting partnership first: a dialogue model for science and risk communication. *GSA Today* 21, 36–37. <https://doi.org/10.1130/GSATG106GW.1>.
- Shejale, Sharayu, Zhan, Mallory Xinyu, Sahakian, Marlyne, Aleksieva, Remina, Biresselioglu, Mehmet Efe, Bogdanova, Victoria, Cardone, Barbara, et al., 2025. Participation as a pathway to procedural justice: a review of energy initiatives across eight European countries. *Energy Res. Social Sci.* 122, 103982. <https://doi.org/10.1016/j.erss.2025.103982>.
- Shortall, Ruth, Ali, Kharrazi, 2017. Cultural factors of sustainable energy development: a case study of geothermal energy in Iceland and Japan. *Renew. Sustain. Energy Rev.* 79, 101–109. <https://doi.org/10.1016/j.rser.2017.05.029>.
- Soltani, M., Moradi Kashkooli, Farshad, Souri, Mohammad, Rafiei, Behnam, Jabarifar, Mohammad, Gharali, Kobra, Nathwani, Jatin S., 2021. Environmental, economic, and social impacts of geothermal energy systems. *Renew. Sustain. Energy Rev.* 140, 110750. <https://doi.org/10.1016/j.rser.2021.110750>.
- Spijkerboer, Rozanne C., Turhan, Ethemcan, 2025. Deep, hot and contested: assembling the geothermal rush in Turkey. *Appl. Energy* 388, 125665. <https://doi.org/10.1016/j.apenergy.2025.125665>.
- Stadt, Freiburg, 2022. *Bürgerschaftsrat „Erdwärme – Breisgau. Abschlussbericht und Handlungsempfehlungen*. <https://www.dialogbasis.de/dialoge/buerger-dialoge/b%3BC3%BCrgerschaftsrat-erdwaerme-breisgau.html>.
- Stauffacher, Michael, Muggli, Nora, Scolobig, Anna, Moser, Corinne, 2015. Framing deep geothermal energy in mass media: the case of Switzerland. *Technol. Forecast. Soc. Change* 98, 60–70. <https://doi.org/10.1016/j.techfore.2015.05.018>.
- Steffen, Bjarne, Patt, Anthony, 2022. A historical turning point? Early evidence on how the Russia-Ukraine war changes public support for clean energy policies. *Energy Res. Social Sci.* 91, 102758. <https://doi.org/10.1016/j.erss.2022.102758>.
- Stobbe, Marc, Henrike, Groeger, Veit, Bürger, Christoph, Kost, Jessica, Thomsen, 2026. *Kommunale Wärmeplanung in Deutschland. Auswertung abgeschlossener Wärmepläne im Projekt KOMpare (Stand 07/2026)*. Freiburg: Öko-Institut e.V. (Hrsg.). <https://www.oeko.de/publikation/kommunale-waermeplanung-in-deutschland-1/>.
- Stricker, Kai, Grimmer, Jens C., Egert, Robert, Bremer, Judith, Korzani, Maziar Gholami, Schill, Eva, Kohl, Thomas, 2020. The potential of depleted oil reservoirs for high-temperature storage systems. *Energies* 13, 6510. <https://doi.org/10.3390/en13246510>.
- Süsser, Diana, Döring, Martin, Ratter, Beate M.W., 2017. Harvesting energy: place and local entrepreneurship in community-based renewable energy transition. *Energy Policy* 101, 332–341. <https://doi.org/10.1016/j.enpol.2016.10.018>.
- Tester, Jefferson W., Beckers, Koenraad F., Hawkins, Adam J., Lukawski, Maciej Z., 2021. The evolving role of geothermal energy for decarbonizing the United States. In: *Energy & Environmental Science*, vol. 14. Royal Society of Chemistry, pp. 6211–6241.
- Toth, Aniko N., Antics, Miklos, Csrefko, Tamas, Fenerty, David K., 2025. *The Geothermal District Heating Market: Challenges and Opportunities in Europe*.
- Trutnevte, Evelina, Olivier, Ejderyan, 2018. Managing geoenergy-induced seismicity with society. *J. Risk Res.* 21, 1287–1294. <https://doi.org/10.1080/13669877.2017.1304979>.

- Trutnevyte, Evelina, Wiemer, Stefan, 2017. Tailor-made risk governance for induced seismicity of geothermal energy projects: an application to Switzerland. *Geothermics* 65, 295–312. <https://doi.org/10.1016/j.geothermics.2016.10.006>.
- Turnhout, Esther, Metze, Tamara, Wyborn, Carina, Klenk, Nicole, Louder, Elena, 2020. The politics of co-production: participation, power, and transformation. *Curr. Opin. Environ. Sustain.* 42, 15–21. <https://doi.org/10.1016/j.cosust.2019.11.009>.
- Ulpiani, G., Vetter, N., Shtjefni, D., Kakoulaki, G., Taylor, N., 2023. Let's hear it from the cities: on the role of renewable energy in reaching climate neutrality in urban Europe. *Renew. Sustain. Energy Rev.* 183, 113444. <https://doi.org/10.1016/j.rser.2023.113444>.
- Vargas, Payera, Sofia, 2018. Understanding social acceptance of geothermal energy: case study for Araucanía region, Chile. *Geothermics* 72, 138–144. <https://doi.org/10.1016/j.geothermics.2017.10.014>.
- Wade, Sarah, Greenberg, Salli, 2011. *Social Site Characterisation: from Concept to Application: a Review of Relevant Social Science Literature and a Toolkit for Social Site Characterisation*. Report. Global CCS Institute.
- Weber, J., Born, H., Pester, S., Moeck, I., 2020. Geothermal energy use in Germany, country update 2015–2019. *Proceedings World Geothermal Congress* 1.
- Weinand, Jann Michael, Vandenberg, Ganga, Risch, Stanley, Behrens, Johannes, Pflugradt, Noah, Linßen, Jochen, Stolten, Detlef, 2023. Low-carbon lithium extraction makes deep geothermal plants cost-competitive in future energy systems. *Adv. Appl. Energy* 11, 100148. <https://doi.org/10.1016/j.adapen.2023.100148>.
- Wiemer, Stefan, Kraft, Toni, Trutnevyte, Evelina, Roth, Philippe, 2017. “Good Practice” Guide for Managing Induced Seismicity in Deep Geothermal Energy Projects in Switzerland. ETH Zurich.
- Wüstenhagen, Rolf, Wolsink, Maarten, Bürer, Mary Jean, 2007. Social acceptance of renewable energy innovation: an introduction to the concept. *Energy Policy* 35, 2683–2691. <https://doi.org/10.1016/j.enpol.2006.12.001>.
- Yaghoubi, Ali, Schultz, Ryan, Hickson, Catherine, Wigston, Andrew, Dusseault, Maurice B., 2024. Induced seismicity traffic light protocol at the Alberta No. 1 geothermal project site. *Geothermics* 117, 102860. <https://doi.org/10.1016/j.geothermics.2023.102860>.
- Yao, Yue, Xu, Jin-Hua, Sun, De-Qiang, 2021. Untangling global levelised cost of electricity based on multi-factor learning curve for renewable energy: wind, solar, geothermal, hydropower and bioenergy. *J. Clean. Prod.* 285, 124827. <https://doi.org/10.1016/j.jclepro.2020.124827>.
- Younger, Paul, 2015. Geothermal energy: delivering on the global potential. *Energies* 8, 11737–11754. <https://doi.org/10.3390/en81011737>.
- Zaunbrecher, Barbara S., Kluge, Johanna, Ziefle, Martina, 2018. Exploring mental models of geothermal energy among laypeople in Germany as hidden drivers for acceptance. *Journal of Sustainable Development of Energy, Water and Environment Systems* 6, 446–463. <https://doi.org/10.13044/j.sdewes.d5.0192>.
- Zhou, Wen, Lanza, Federica, Grigoratos, Iason, Schultz, Ryan, Cousse, Julia, Trutnevyte, Evelina, Muntendam-Bos, Annemarie, Wiemer, Stefan, 2024. Managing induced seismicity risks from enhanced geothermal Systems: a Good Practice Guideline. *Rev. Geophys.* 62, e2024RG000849. <https://doi.org/10.1029/2024RG000849>.
- Zwickel, Philipp, Bauer, Florian, Schätzler, Katharina, Waczowicz, Simon, Hagenmeyer, Veit, Schill, Eva, 2022. Integrated concept of local heat transition using geothermal heat production, aquifer storage and optimal scheduling of distribution network. In: *Proceedings of the European Geothermal Congress 2022*. Berlin, Germany | 17-21 October 2022.