The development of geothermal energy technologies within social contexts, and their integration into society

Dr. Judith Bremer

Implementing deep geothermal technologies!?

Bürgerentscheid gefordert

Bürgerinitiative hat über 1.500 Unterschriften gegen Geothermie in Waldsee überreicht

Eine Bürgerinitiative will verhindern, dass in Waldsee (Rhein-Pfalz-Kreis) eine Tiefengeothermie-Anlage entsteht. Sie hat am Donnerstag im Rathaus ein Bürgerbegehren mit mehr als 1.500 Unterschriften eingereicht.

Von Nancy Lau

Stand: 18.12.2025, 18:02 Uhr

Großer Schatz oder großes Risiko: Wie sicher ist Geothermie?

Energiesorgen durch den Ukraine-Krieg geben der Geothermie neuen Schub. Doch Beben und Bodenhebungen durch Bohrungen in der Vergangenheit sorgen für Ängste.

Meller, C.; Schill, E.; Bremer, J.; et al. (2018) Geothermics, 73, 133–145. doi:10.1016/j.geothermics.2017.07.008

Geckeis

Appell von Bürgerinitiativen

Kritik an Geothermie wird lauter

red/jk 10.02.2022 - 18:08 Uhr

1. Lesung | Anhörung | 2./3. Lesung

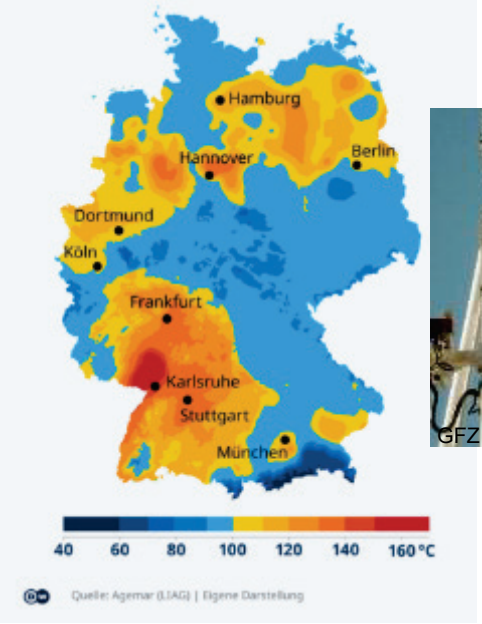
Energie

Kritik von Sachverständigen an Geothermie-Gesetz

The energy transition: a societal challenge

Energy transition

- One of the greatest challenges of our time
- Affects the whole of society
- Requires transformation
- Society's response is complex

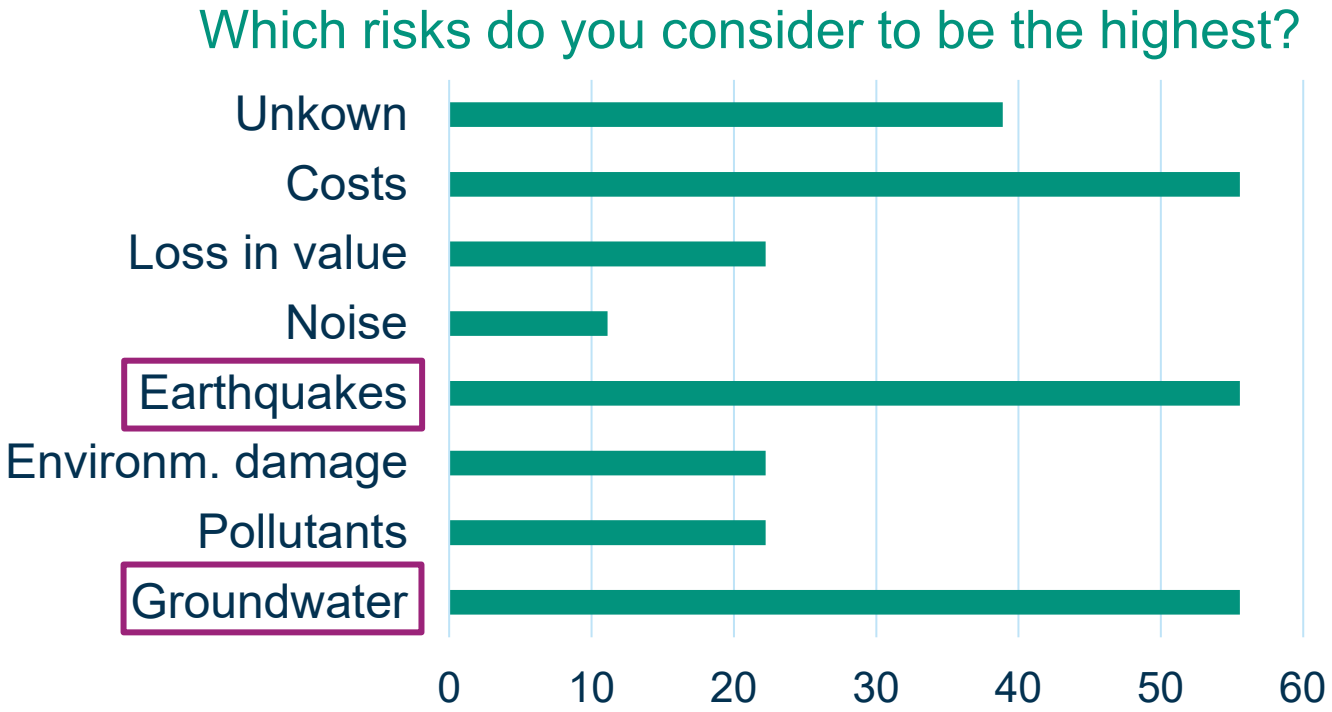


Societal discourse needed for new technologies

- Chances ↔ Risks
- Benefits ↔ Loads and burdens
- Costs ↔ Long-term value
- Speed ↔ System stability
- Top-down ↔ Collaborative, …

Deep geothermal energy in the societal discourse

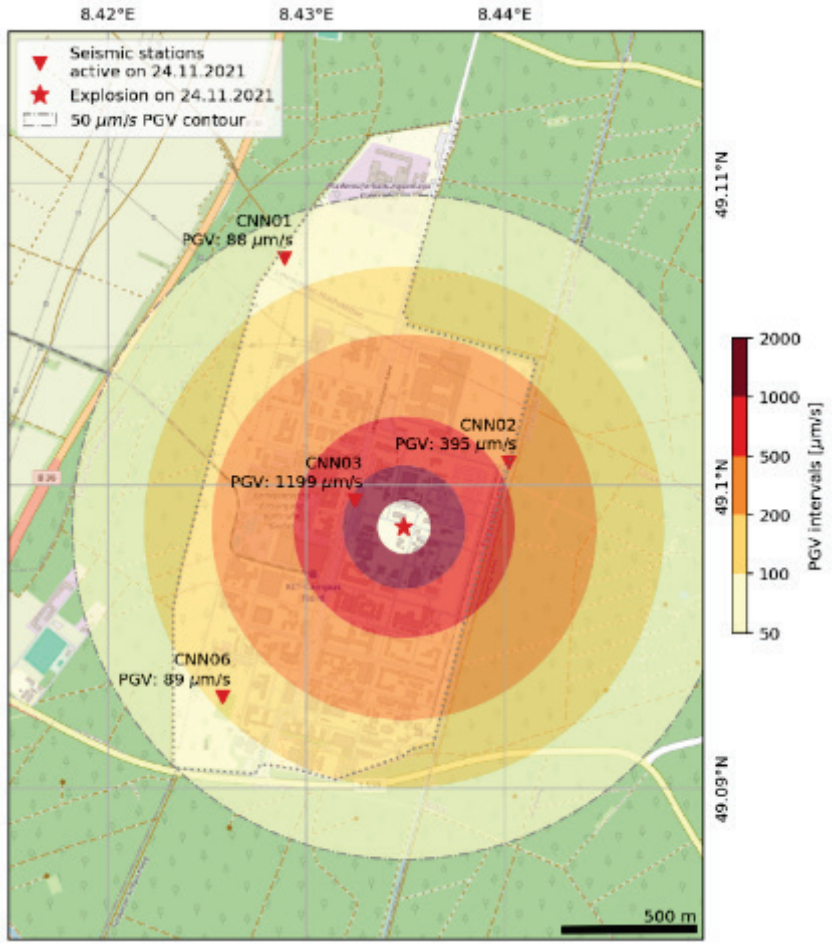
- Overall, recognition of geothermal energy as a renewable technology
  - Acceptance on a general level
  - Policy support ahead of public debate
- At the local level
  - Frequent reservation or even resistance
  - Highly emotional debate
    → concerns, fears
  - Cultural factors
  - Risk perception dominates debate



Not representative survey in a school project

The role of risk perception – an example

- Geothermal research infrastructure DeepStor on CN
- Risk management
  - Dense seismometer network
  - Traffic light system
  - Basis for operative decisions
  - Sensitive infrastructures → Very safety-conscious design
- Accidental explosion triggering ground motions
  → exceeded defined alert threshold by factor 4



- Almost non-existent reaction

↕

- Typical reactions of the press in geothermal context

Acceptance and acceptability

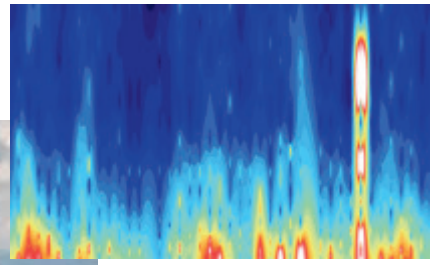
- Acceptability
  - Judgement factors according to common values of a society
  - Objectively feasible and reasonable
  - Usually: risks minimal to added value
  - Emphasis on process
  - More factual level

- Acceptance
  - Individual consent of a project by those affected
  - Positive response towards a technology through attitudes, intentions, and behaviors
  - Tolerance – positive attitude – commitment
  - Emphasis on outcome
  - More emotionally led

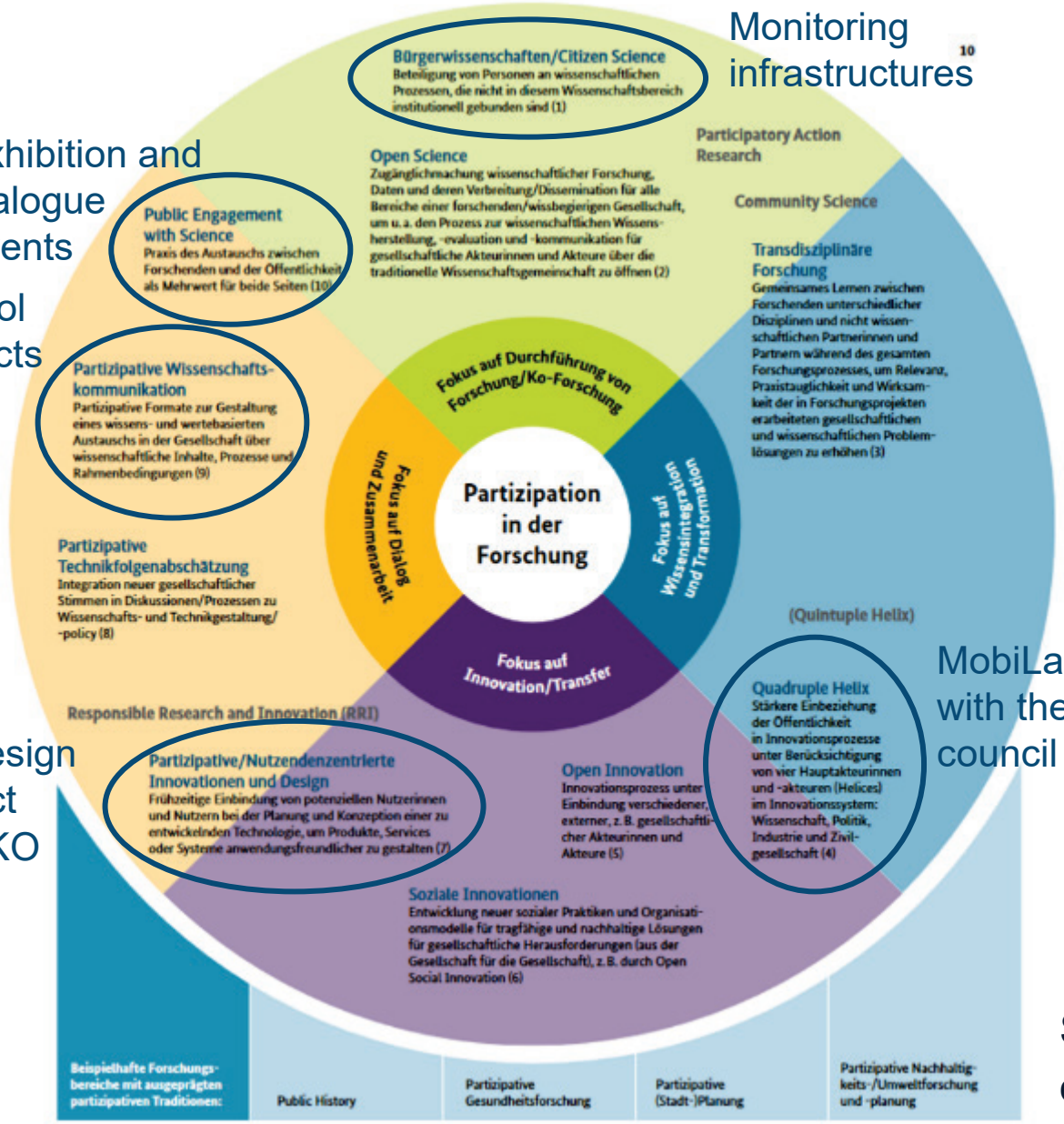
How can research contribute to the debate?

- Research to enhance acceptability
  - Increasing added values
  - Decreasing risks → sustainability

- Active role in debate
  - Providing neutral information
  - Fostering dialogue
  - Offering participation



Participation formats in research



Multiple formats,
four main focal points:

- Research
- Transformation
- Innovation
- Collaboration

Relatively low degree of participatory research in energy research!

Source: Participation strategy of the Ministry of Research

Joint conceptualization in GECKO
Co-design project

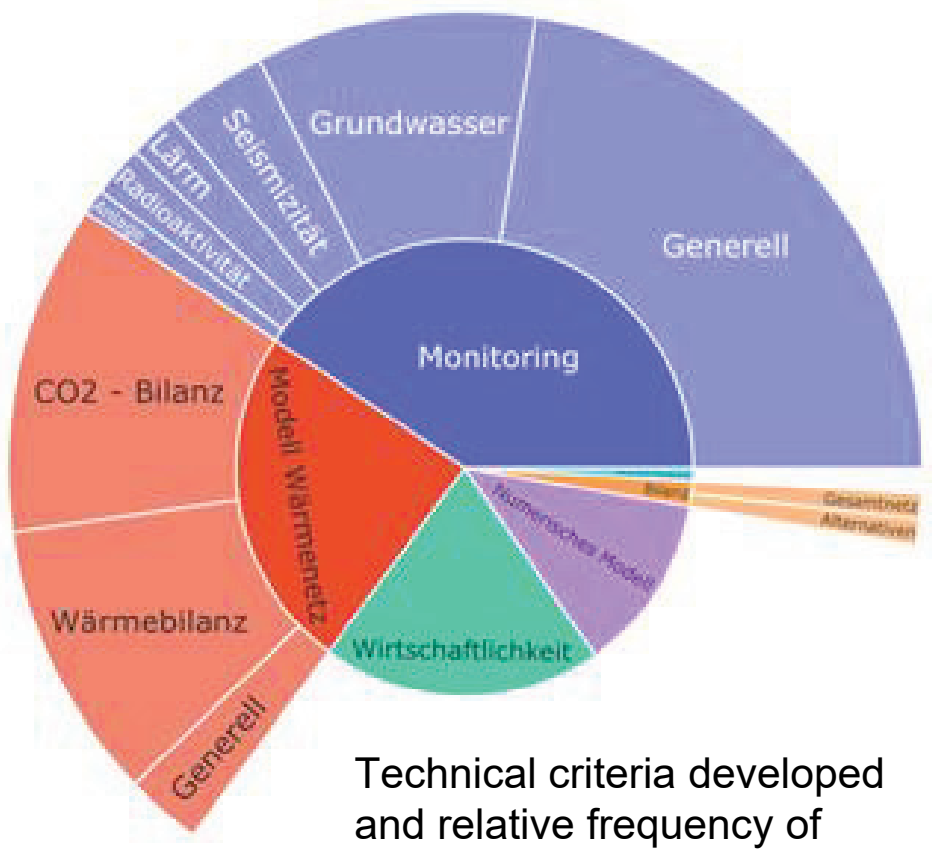
GECKO – Climate neutral heat provision at KIT Campus North

- Joint concept development
- Project partners
  - Geoscientists, social scientists
  - Ökoinstitut
  - KIT employees
  - Residents + initiatives

Quote: '... that I don't really notice anything, [...]. Except that there is CO2-neutral heat supply.'

Joint conceptualization in GECKO
Co-design project

- Establishment of project criteria
  - Local energy transition
  - Environmental protection
  - Transparency and participation
  - Quality of life
  - Economic efficiency
- Integration in technical studies
  → translation of criteria into model parameters
- Favoring project scenarios
- Recommendations for action



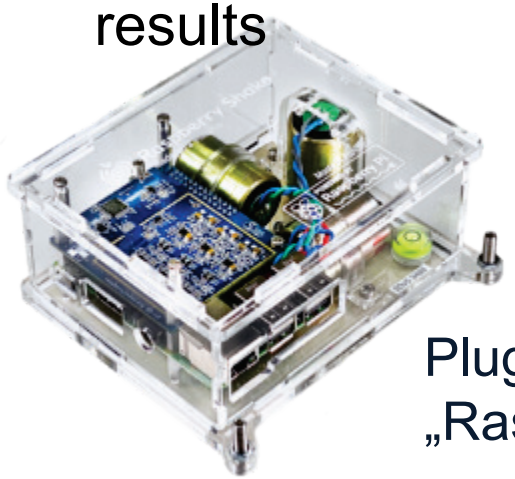
Technical criteria developed and relative frequency of their mentions

Schill, E., Rösch, C. et al.

Particpative monitoring of Citizen Science project

DeepStor

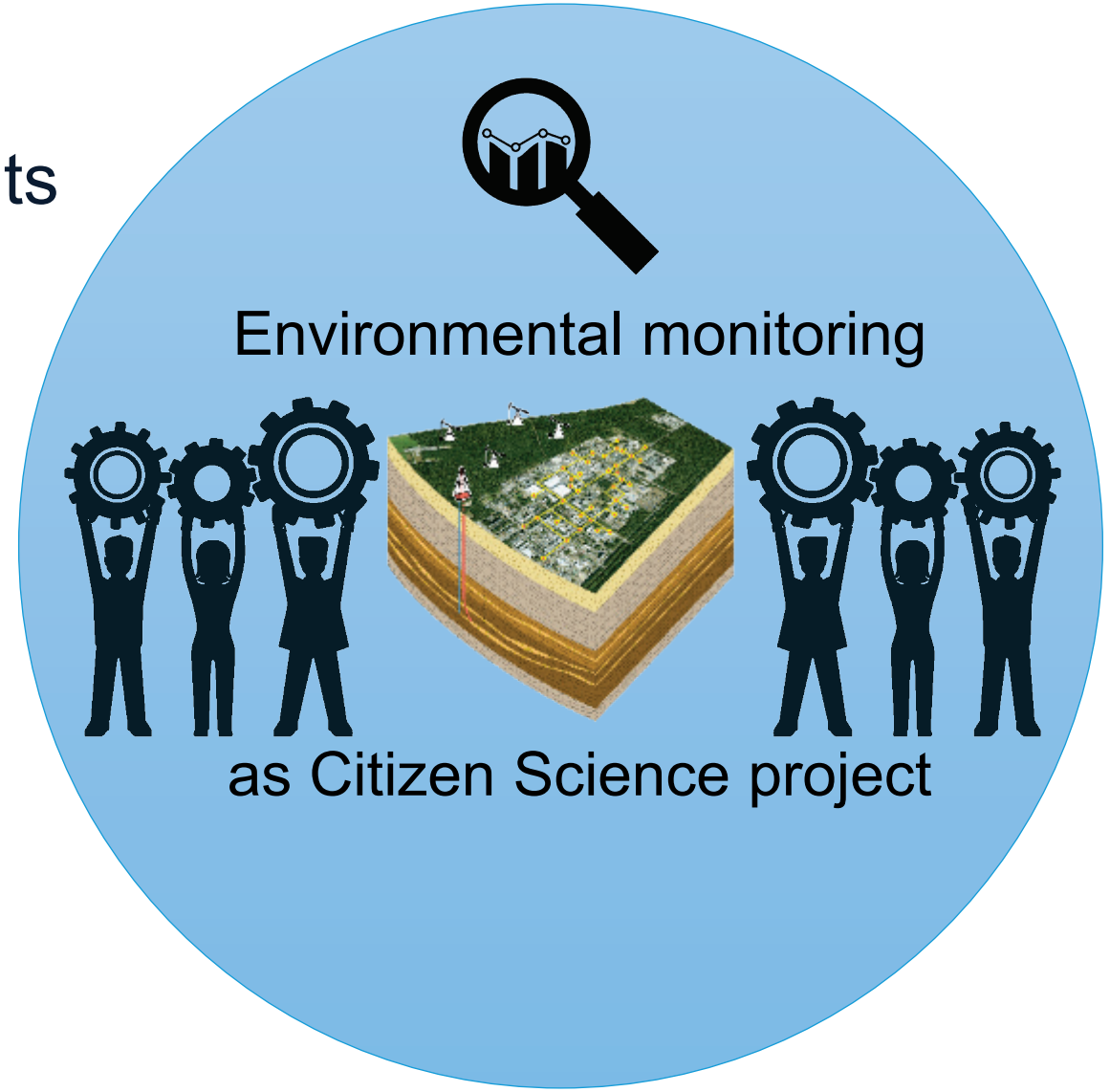
- Seismic monitoring with local residents
  - Residents host seismometers
  - Transparent measurements
  - Joint interpretation of the measurement results



Plug-and-Play Seismometer „Raspberry Shake“

Bremer, J., Azzola, J., Moczek, N., Kohl, T. (20226): Geothermal Energy 14 (1), 3. doi:10.1186/s40517-026-00373-w

- Possible other joint measurements
  - Radon, noise, groundwater



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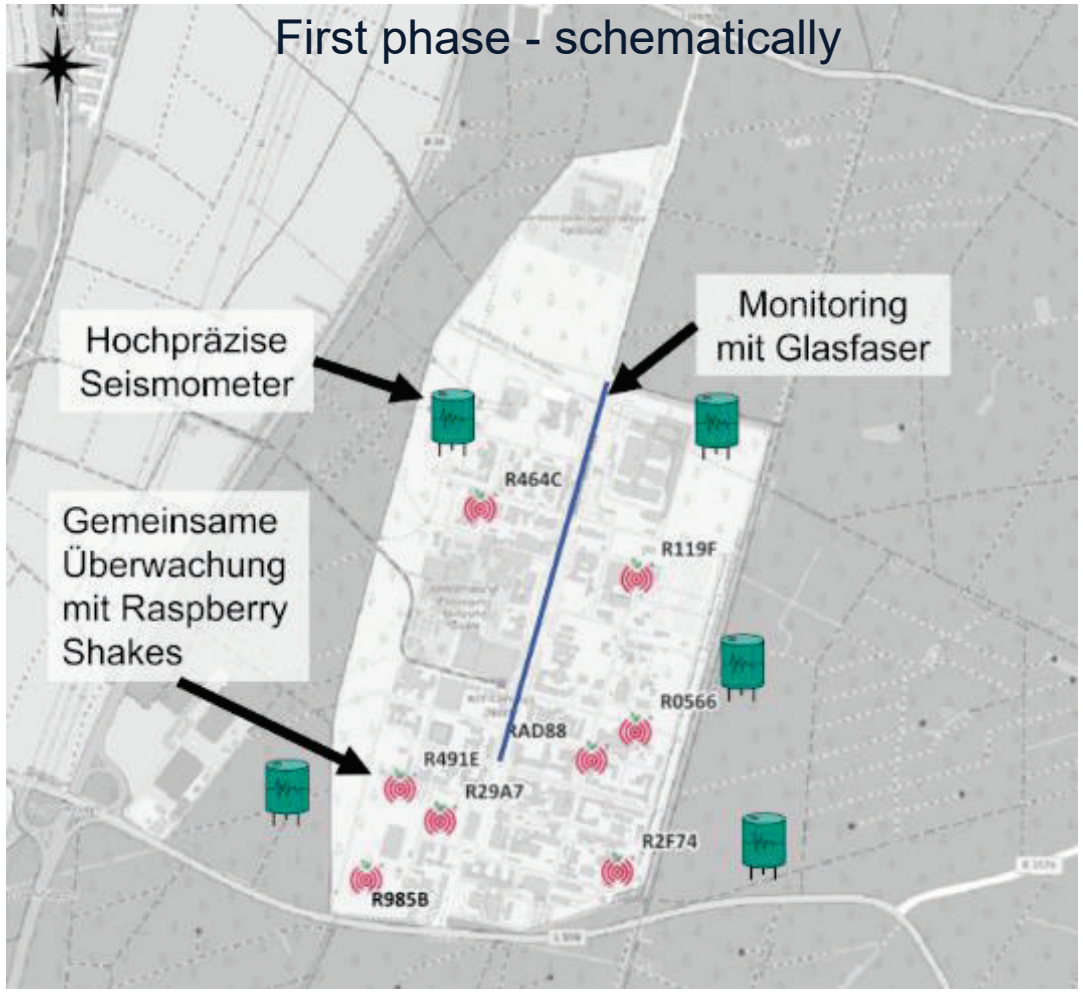
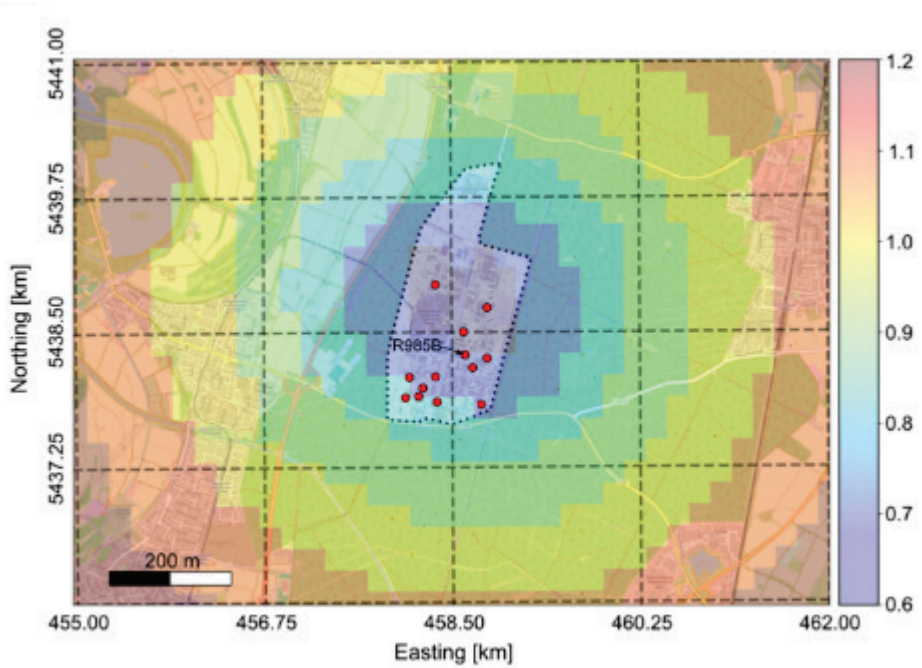
Particpative monitoring of Citizen Science project

DeepStor



Actually installed sensors:

https://geothermics.agw.kit.edu/sensor/qgisweb/qgis.html



Detection threshold with Raspberry Shake network:
Minimum magnitude detectable

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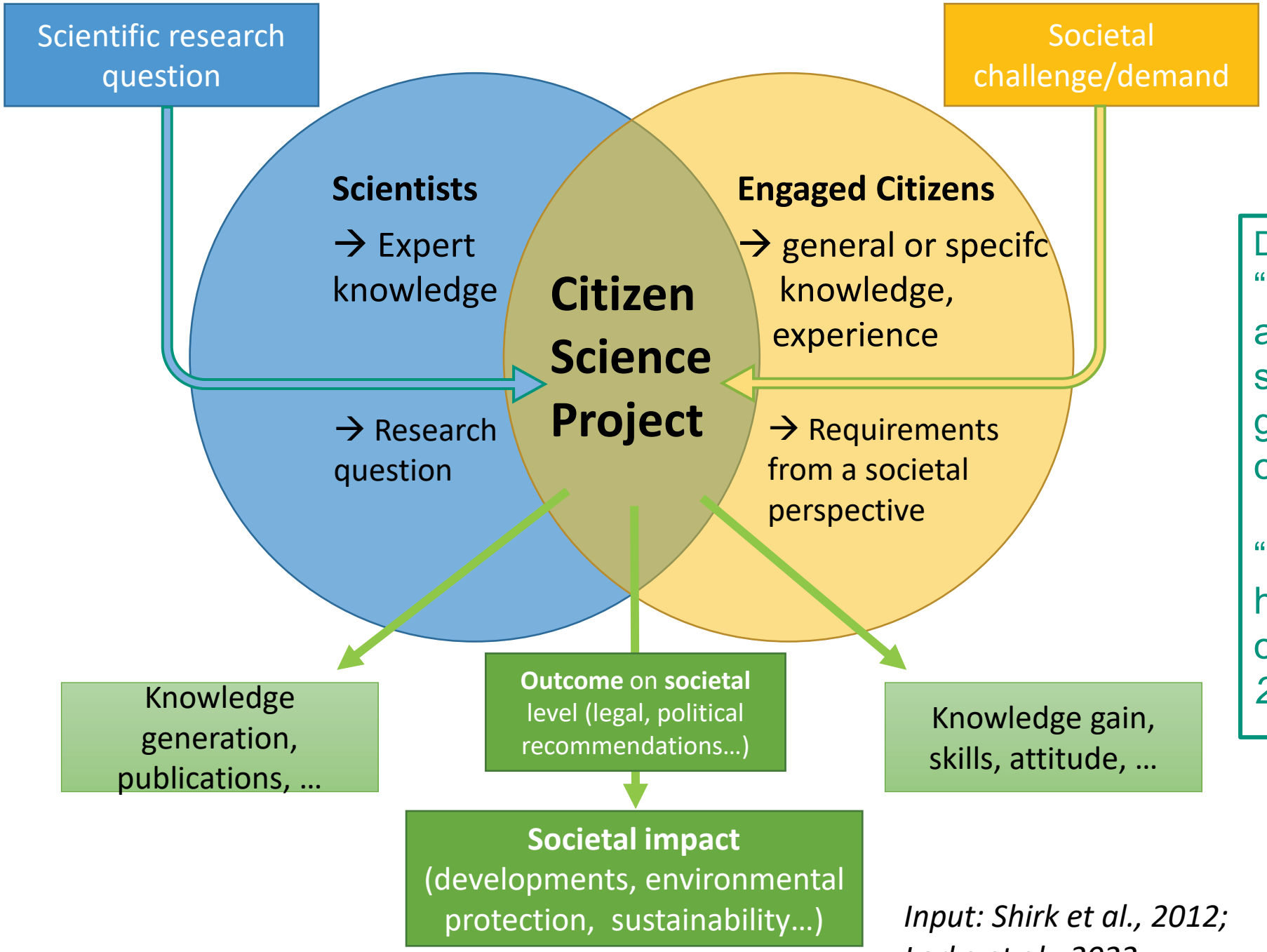


Definition:
"Citizen science projects actively involve citizens in scientific endeavour that generates new knowledge or understanding" (*ECSA*)

"Citizen science projects have a genuine science outcome" (*Robinson et al., 2018*)

Input: Shirk et al., 2012; Lorke et al., 2022

Suggested criteria for Citizen Science
(*Turrini et al., 2018; Robinson, 2010; Heigl et al., 2020*)

Active participation

- Participants do not provide resources passively
- Added value for all participants
- Objectives unachievable without the citizen scientists
- Citizen scientists must be involved in at least one project element

Knowledge generation

- Formulation of scientific question, hypothesis or goal
- New knowledge must be generated, or new methods developed

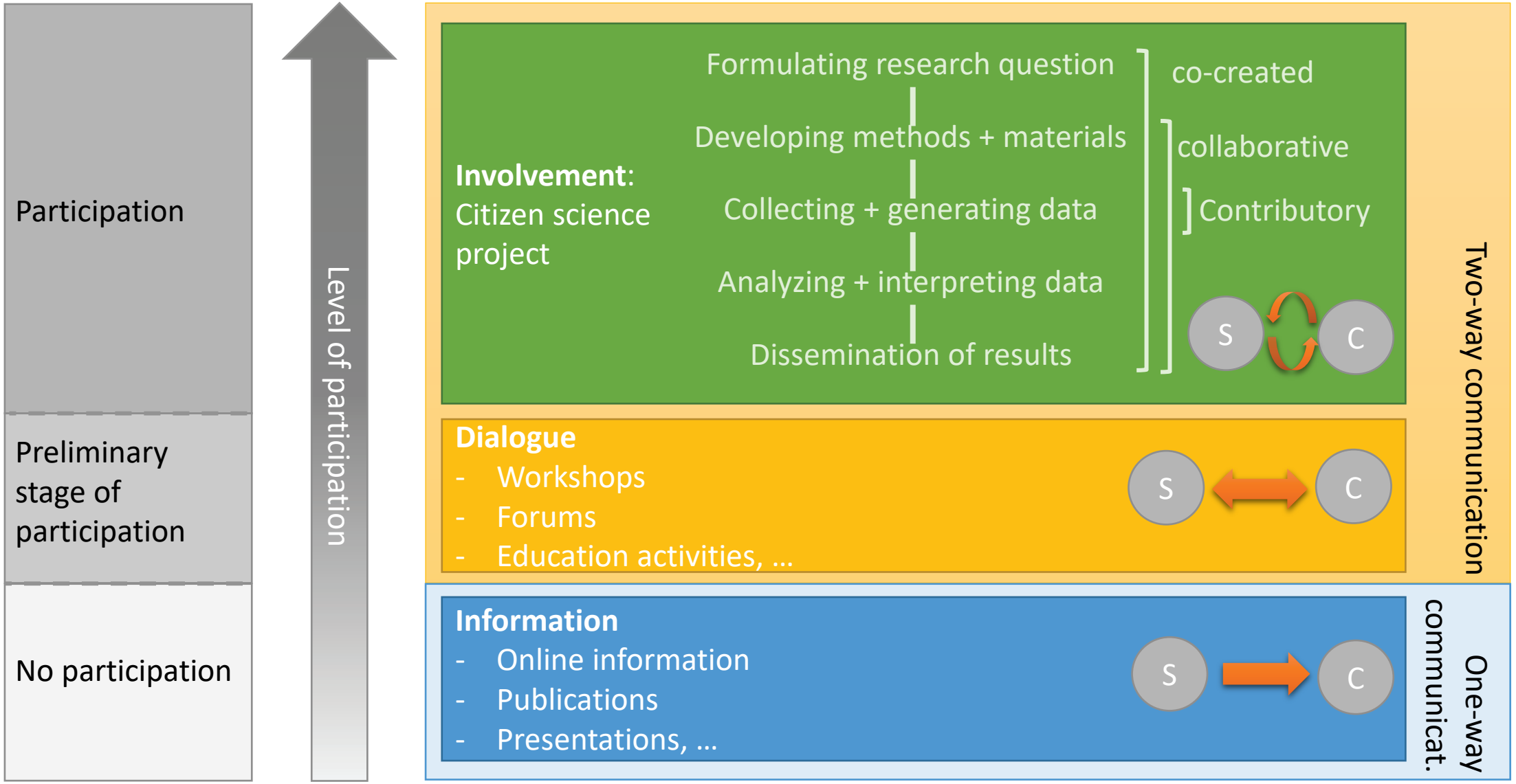
Open Access

- Open Science principles for data and results

Governance principles: ethics, data policy, …

- Communication: Different interest groups are addressed accordingly

Citizen Science in the ladder of participation



Input: *Shirk et al., 2012; Arnstein, 1969/Wright, 2010; Tomasson/VA*

Measurement tool – Interface to other formats

Experience: Tool appears open, arouses curiosity, stimulates a spirit of inquiry and seems manageable

Intensive, complex

Collaboration

Zugänglichkeit

Partizipationslevel

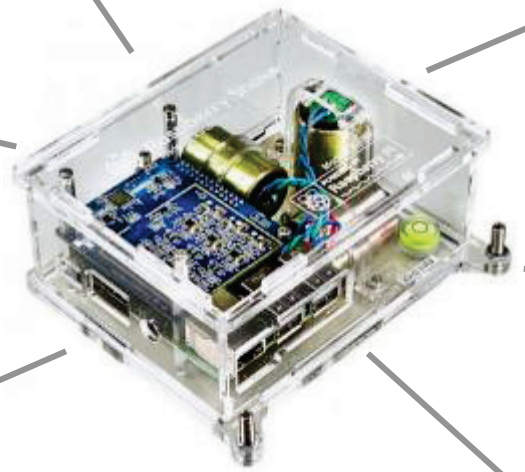
Low-threshold

Information

Joint monitoring measurements

School projects (incl. role playing games)

Integration into research



Dialogue events

Co-Design of tools (Visualization, …)

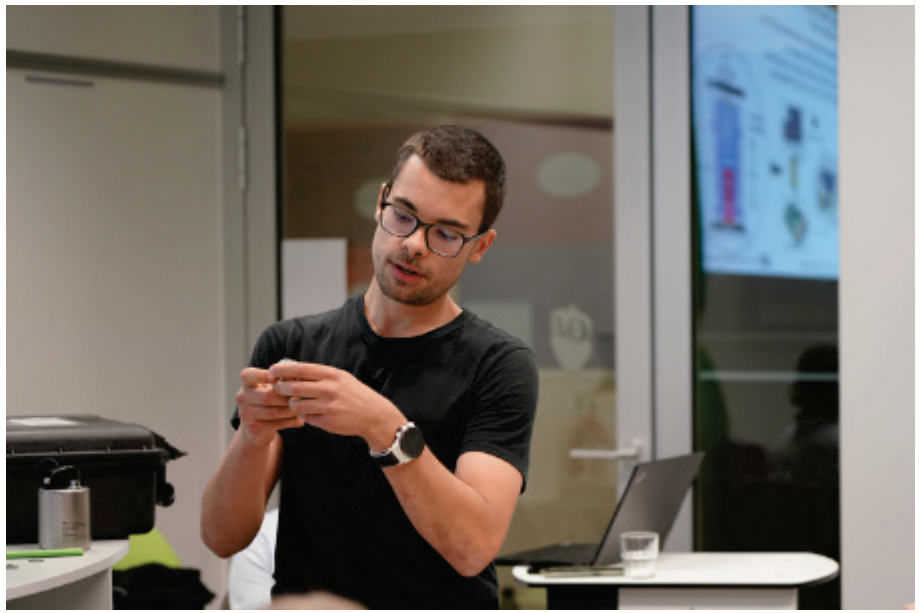
Workshops

Measurement of ambient noise around a plant
Public engagement – Participative science communication

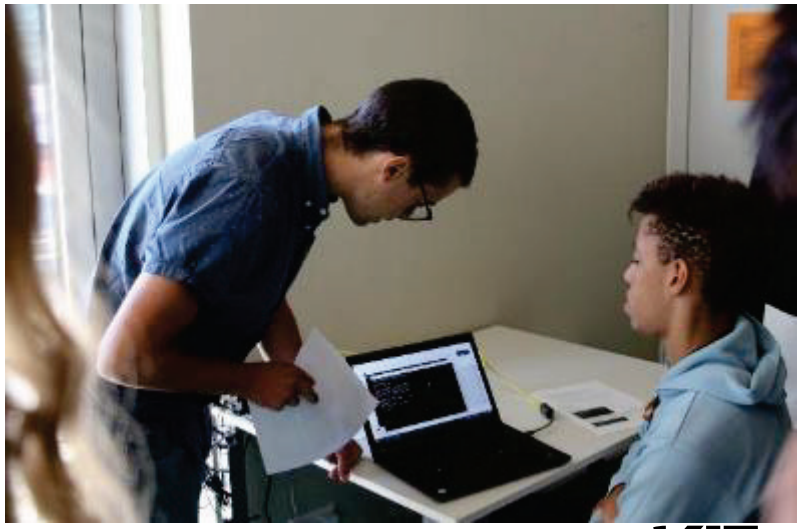
- Active knowledge transfer: role playing game
- Context: Geothermal plant in Bruchsal

EnBW

HEISENBERG-GYMNASIUM



Azzola, J., & Bremer, J. (2025) *Societal Impacts*, *5*, doi.org/10.1016/j.socimp.2025.100116



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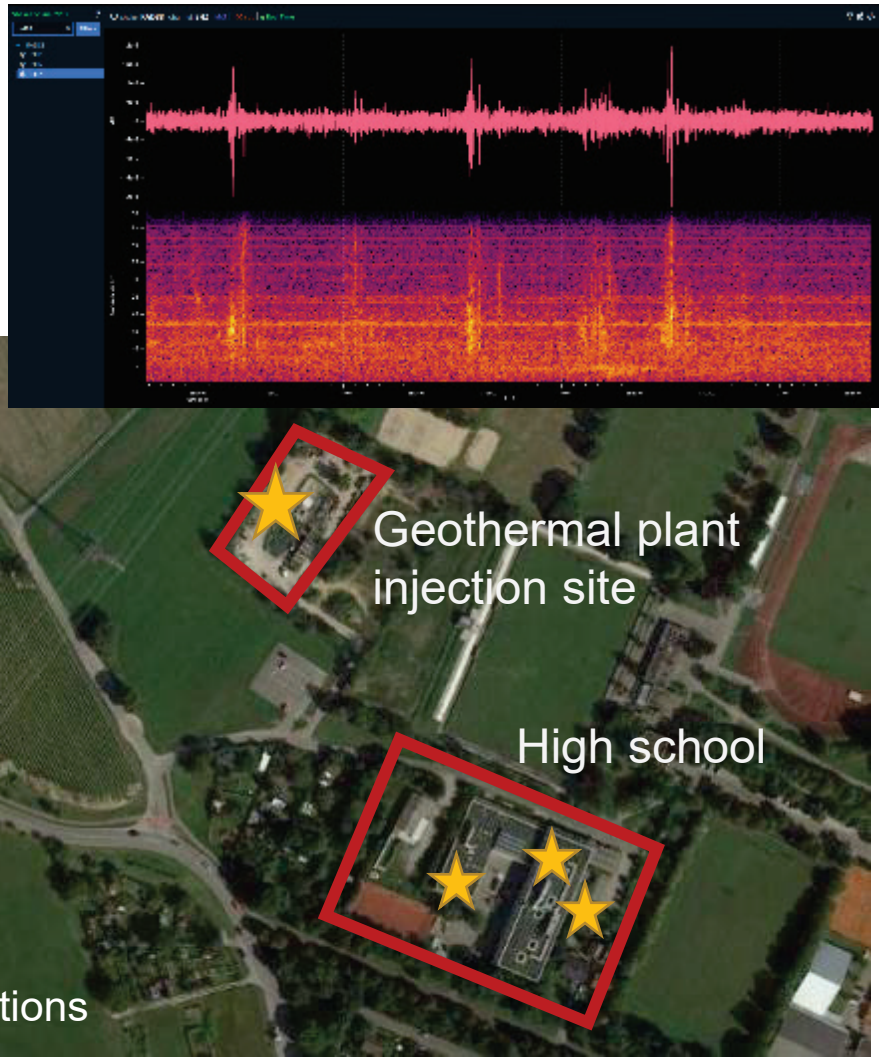
Measurement of ambient noise around a plant
Public engagement – Participative science communication

Task

- Take on the role of a seismologist
- Find location for a new seismometer
  → comparative seismic noise measurements
- Perform whole process chain

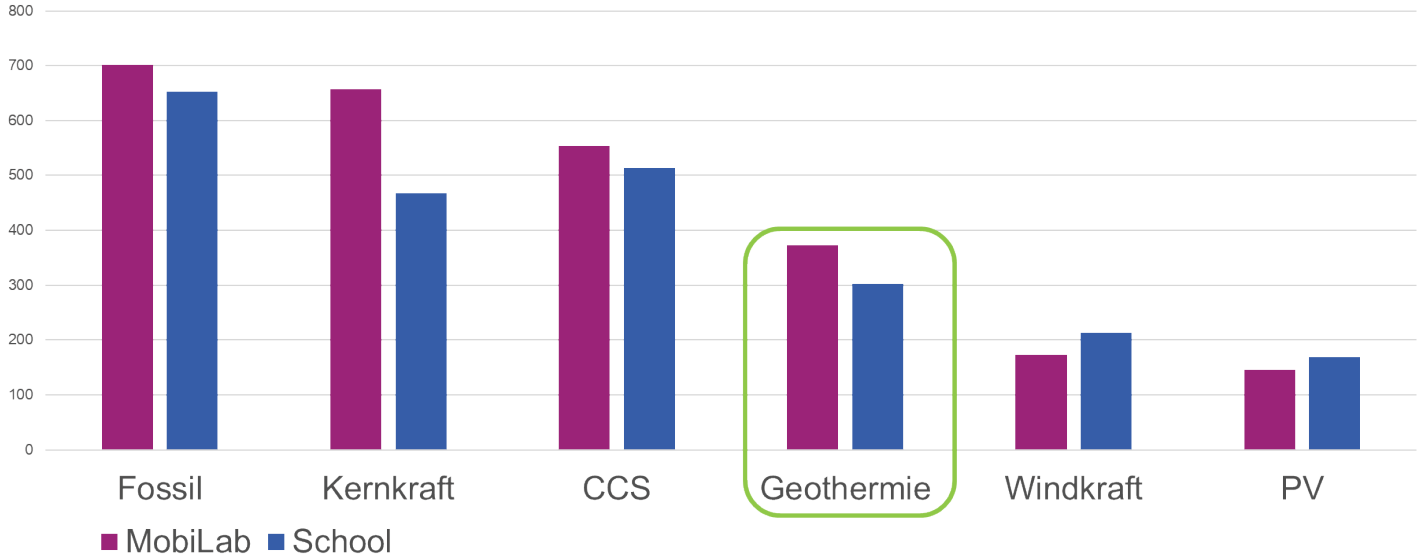
Effects

- Multiplication effects
- Knowledge gain and experiene
  → Also on risk management and workflows!
- Hardware test, feedback, ideas, …



Market place event with MobiLab
Public engagement – Participative science communication

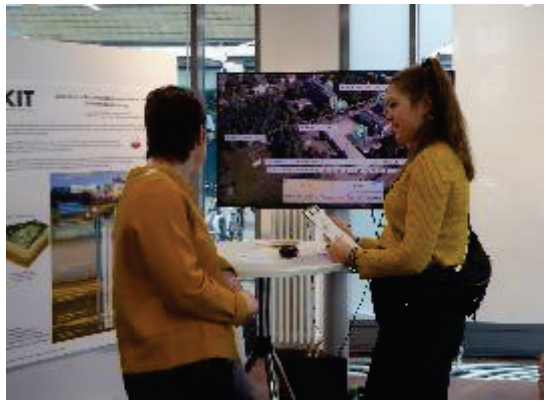
- Low-threshold experiments and games
  - introduce passers-by to seismology
  - give them a “feel” for seismicity
- Background information on geothermal energy
- Discussions
- Interviews

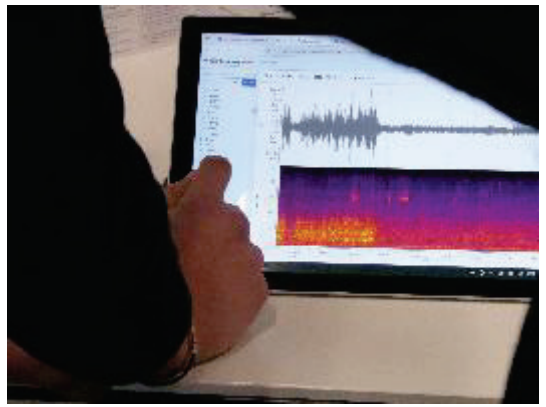


Exhibition event in the “Triangel”
Public engagement – Participative science communication

Moczek, N.; Bremer, J.; Azzola, J.; Häfner, P. (2026): Geothermische Energie, (113), 6–9.

- Establishment of a **learning environment for deep geothermal storage**
- Mixture of formats:
  - Hands-on experiments
  - Talk and dialogue
  - Virtual reality



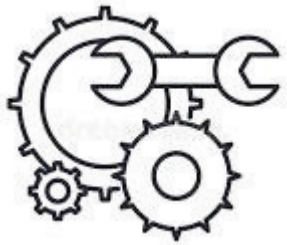


Bilder: Moczek

Take home messages

Scientific-technological development of “geothermal batteries”

- High demand
- High potential, e.g., in exploited oil formations
- Challenges to be solved, especially in geochemical management

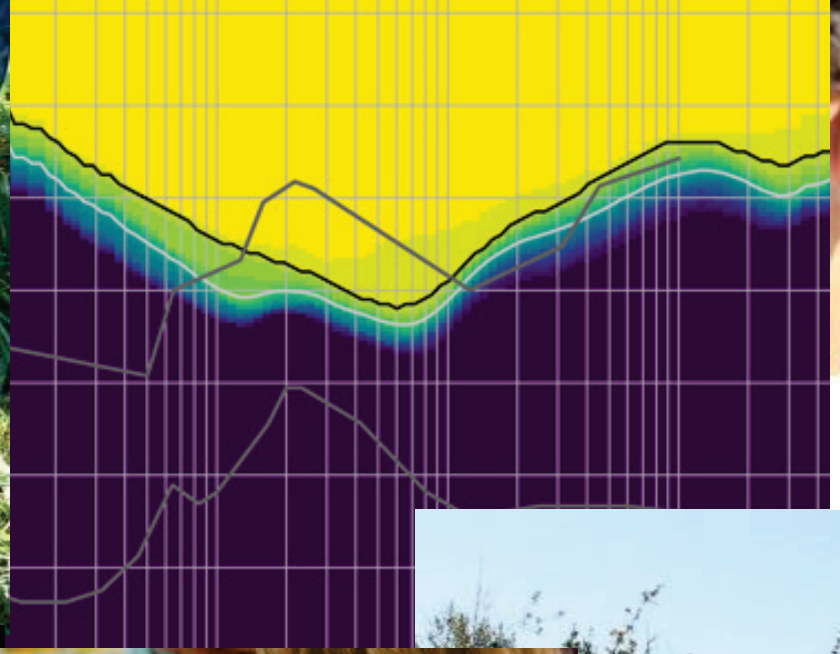


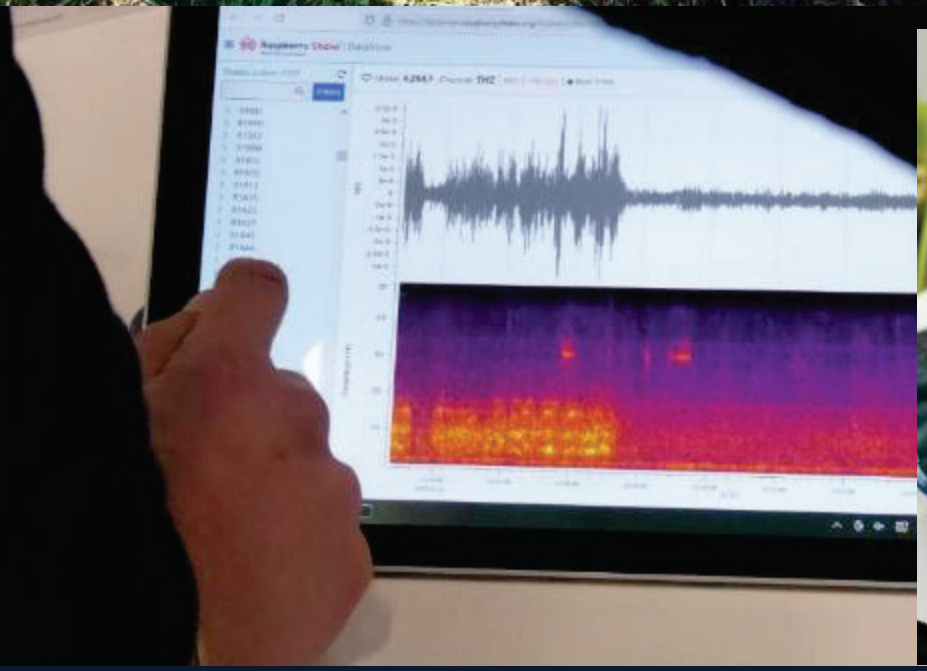
Science as important “actor” in the energy transition

- Enhance acceptability by responsible research → solution orientation
- Provide neutral information as communication basis
- Enable and foster dialogue and participation

Societal discourse

- Deep geothermal as contested renewable energy technology
- Constructive general and local debate necessary





Monitoring, learning, researching and developing – together

Discussion

- How do you see your role as a scientist in society?
  Do you, as a scientist, feel responsible to include a broader segment of society in your research?
- Which chances and risks /difficulties come to your mind when thinking about citizen science and other participation formats?