Communicating induced seismicity of deep geothermal energy and shale gas: low-probability high-consequence events and uncertainty[1]

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1 Motivation

- Deep geothermal energy (DGE) guidelines [2,3] recommend to communicate low-probability high-consequence (LPHC) events of induced seismicity (IS) to the public.
- However, risk communication literature lacks empirical evidence on how to communicate LPHC events of IS and whether to address related uncertainty.

2 Research questions

1) How do **different formats** of written risk communication of IS affect the public's perception of this risk communication in terms of **understandability, trust, and concern**? We distinguish between three formats:
   - qualitative,
   - qualitative and quantitative,
   - qualitative and quantitative with risk comparisons.
2) How does **a statement of uncertainty and limited expert confidence** affect the public's perception of this risk communication in terms of understandability, trust, and concern?
3) How does the risk communication format affect the **public's perception of the risk** of IS?
4) To what extent does the technology, such as DGE and shale gas, affect the public's perception of the identical risk communication material?

3 Method

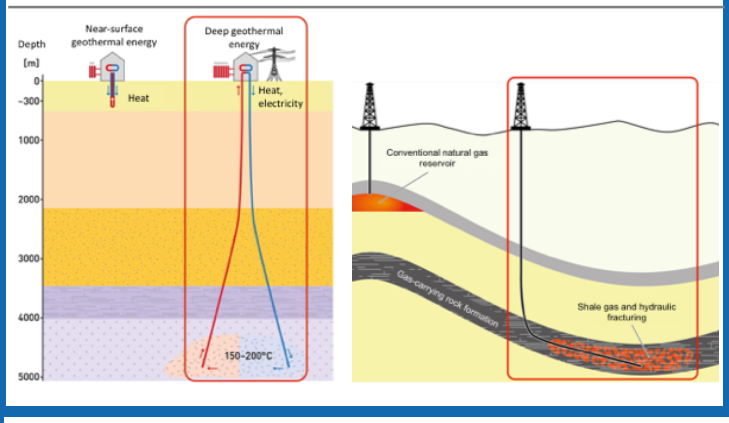
- Online survey August 2016
- Experimental design
- N = 590 participants recruited through access panel
- German-speaking part of Switzerland
- M = 43.74 years old (SD = 13.96 years)
- N = 299 female (50.7%)
- Slightly more educated than Swiss average
- 12 experimental conditions (C)

Table I Experimental conditions (C) of the survey

Format	Statement of uncertainty	Technology	
		DGE	Shale gas
Qualitative	Not included	C1	C7
	Included	C2	C8
Quantitative	Not included	C3	C9
	Included	C4	C10
Risk comparison	Not included	C5	C11
	Included	C6	C12

4 Technology framing

Figure I: Detail of technology framing
Left: Near surface and deep geothermal energy [4,5]
Right: Conventional gas and shale gas with hydraulic fracturing[6,7]



5 Risk communication for experimental conditions

Table II Examples of risk communication formats for different experimental conditions (C)

Qualitative format (C1, C7)

The risk study concluded for the week-long drilling and project operations in your community:
- Micro-earthquakes are virtually certain. These micro-earthquakes will be too small for humans to be felt.
- An earthquake that is lightly noticeable for humans is unlikely.
- An earthquake that is strongly felt and can cause slight damage (e.g. hair-line cracks or falling of small pieces of plaster) is exceptionally unlikely.
- An earthquake that is severely felt and can cause serious structural damage to average houses (e.g. large cracks in walls, falling of gable parts) is even more unlikely, thus also exceptionally unlikely.

Quantitative format with uncertainty and limited expert confidence (C4, C10)

The risk study concluded for the week-long drilling and project operations in your community:
- Micro-earthquakes are virtually certain. These micro-earthquakes will be too small for humans to be felt.
- An earthquake of magnitude 3 on the Richter scale that is lightly noticeable for humans has a probability of about 5%.
- An earthquake of magnitude 5 on the Richter scale that is strongly felt and can cause slight damage (e.g. hair-line cracks or falling of small pieces of plaster) is exceptionally unlikely. It has a probability of about 0.01%.
- An earthquake of magnitude 6 on the Richter scale that is severely felt and can cause serious structural damage to average houses (e.g. large cracks in walls, falling of gable parts) is even more unlikely, thus also exceptionally unlikely. It has a probability of about 0.001%.

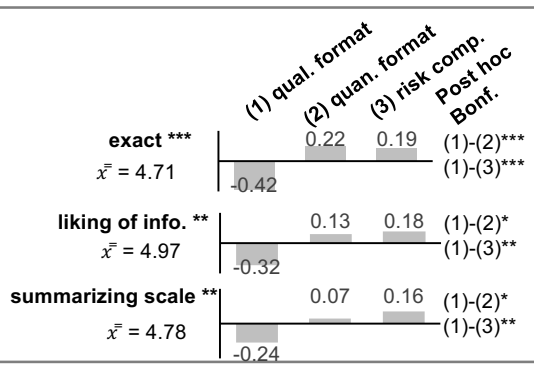
The risk assessment is based on best available methods. Due to unpredictable reactions in the subsoil, such risk assessments carry uncertainty. Therefore, experts can disagree on the exact probabilities and the largest possible earthquake.

6 Main results

Figures II-IV: $\bar{x}$: grand mean; significance level *p<0.05; ** p<0.01; ***p<0.001 for difference between conditions
Ratings range from 1= "do not agree at all" to 7= "completely agree". "Don't know" option coded as missing value.

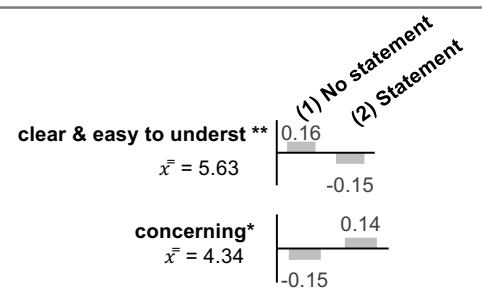
1) Risk communication format

Figure II: Perception of different risk communication formats between conditions



2) Including statement of uncertainty and expert confidence

Figure III: Effect of including a statement of uncertainty and expert confidence between conditions

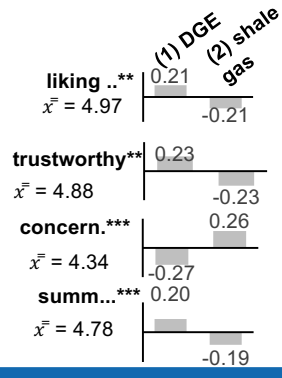


3) Perceived risk

- The format had no effect on respondents' risk perception of IS.
- The risk of IS seemed significantly less controllable when respondents read statement about uncertainty as compared to not reading about it (M 3.47, SD = 1.52 vs. M = 3.72, SD = 1.47), F(1,568)=3.91, p=0.048.
- Respondents perceived the risk of IS significantly higher for shale gas than for DGE (M = 4.81, SD = 1.13 vs. M = 4.19, SD = 1.14), F(1,589) = 43.83, p<0.001.

4) Technology framing

Figure IV: Effect of technology framing between conditions



Respondents accepted shale gas projects in their region significantly less than DGE projects (M = 3.47, SD = 1.70 vs. M = 5.02, SD = 1.36), t(481)=11.41, p<0.001.

7 Conclusions

- Respondents perceived the quantitative and risk comparison format more exact and liked it more. They also found it easier to understand (n.s.).
- Respondents perceived risk communication including uncertainty and expert confidence as less clear and more concerning.
- Respondents perceived identical risk communication for shale gas as less trustworthy, more concerning and liked it less than for DGE.

Recommendation for practitioners:
→ The public appreciates careful elaboration of risk communication with numbers and suitable risk comparisons.
→ The public might have difficulties in understanding information about uncertainty.
→ Besides the careful wording of risk communication, the context matters!

[1] Knoblauch T., Stauffacher M., Trutnevyte E. (2017). Communicating low-probability high-consequence risk, uncertainty and expert confidence: Induced seismicity of deep geothermal energy and shale gas. Risk Analysis. Under review.
[2] Trutnevyte, E., & Wiemer, S. (2017). Tailor-made risk governance for induced seismicity of geothermal energy projects. *Geothermics*, *65*, 295–312.
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70 NRP Energy Turnaround National Research Programme
FNSNF Swiss National Science Foundation