Well Integrity Atlas – Well integrity R&D needs in CO_2 storage/CO_2-EOR projects

FEW0191 – Task 7

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Define well integrity research needs based on input from CO_2 storage and CO_2-EOR operators

https://www.fortmorgantimes.com/2017/08/01/county-leaders-seeking-input-on-oil-and-gas-injection-wells/

Well Integrity Survey for Site Operators

- Vetted by industry and DOE
- Divided in four sections
  - Background information
  - Well integrity
  - Monitoring
  - Risk assessment
- Survey sent to 55 site operators
  - 29 in North America
- Received 22 responses
  - Responses are anonymous

Section 1: Background Information

1.1 – Current or future operations are best described as:

☐ Carbon dioxide storage in saline reservoirs

☐ Carbon dioxide storage in depleted oil and gas reservoirs

☐ Carbon dioxide enhanced oil recovery

☐ Other (please specify below)

Click or tap here to enter text.

1.2 – Current or future operations are best described as:

☐ Onshore

☐ Offshore

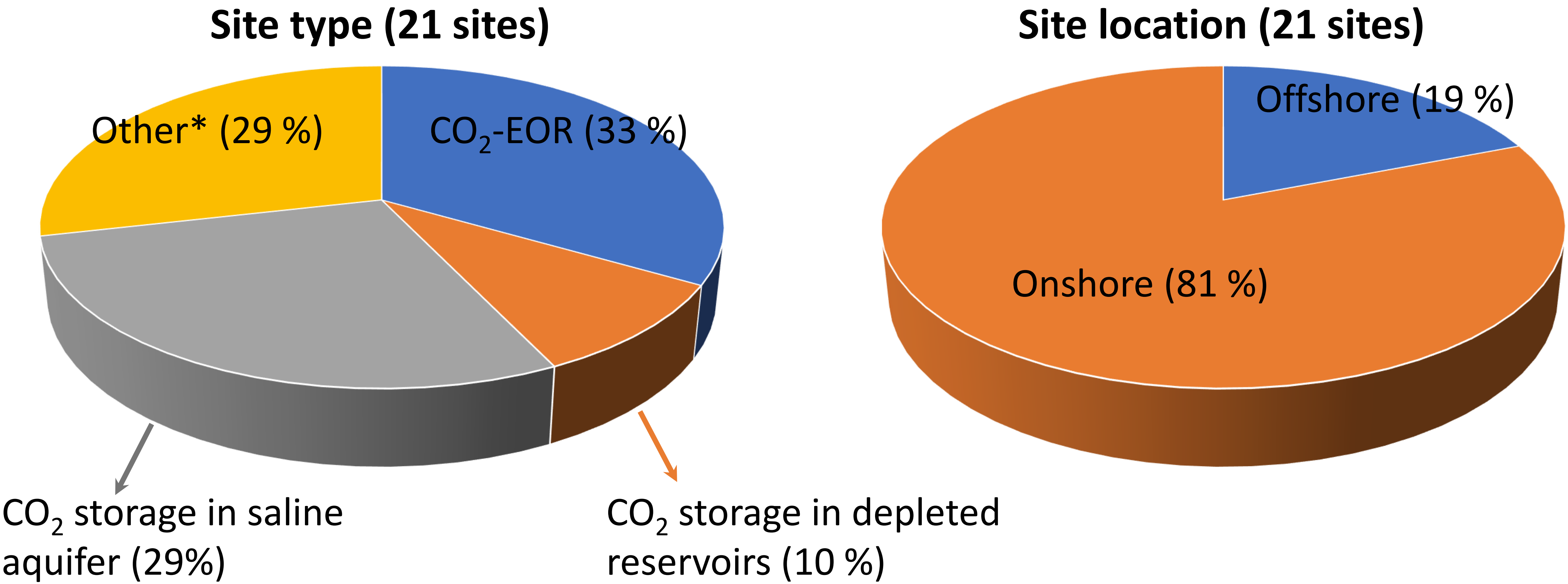
1.3 – What was the total duration of injection at your GCS site?

☐ Less than 1 year

☐ 1-9 years

☐ More than 9 years

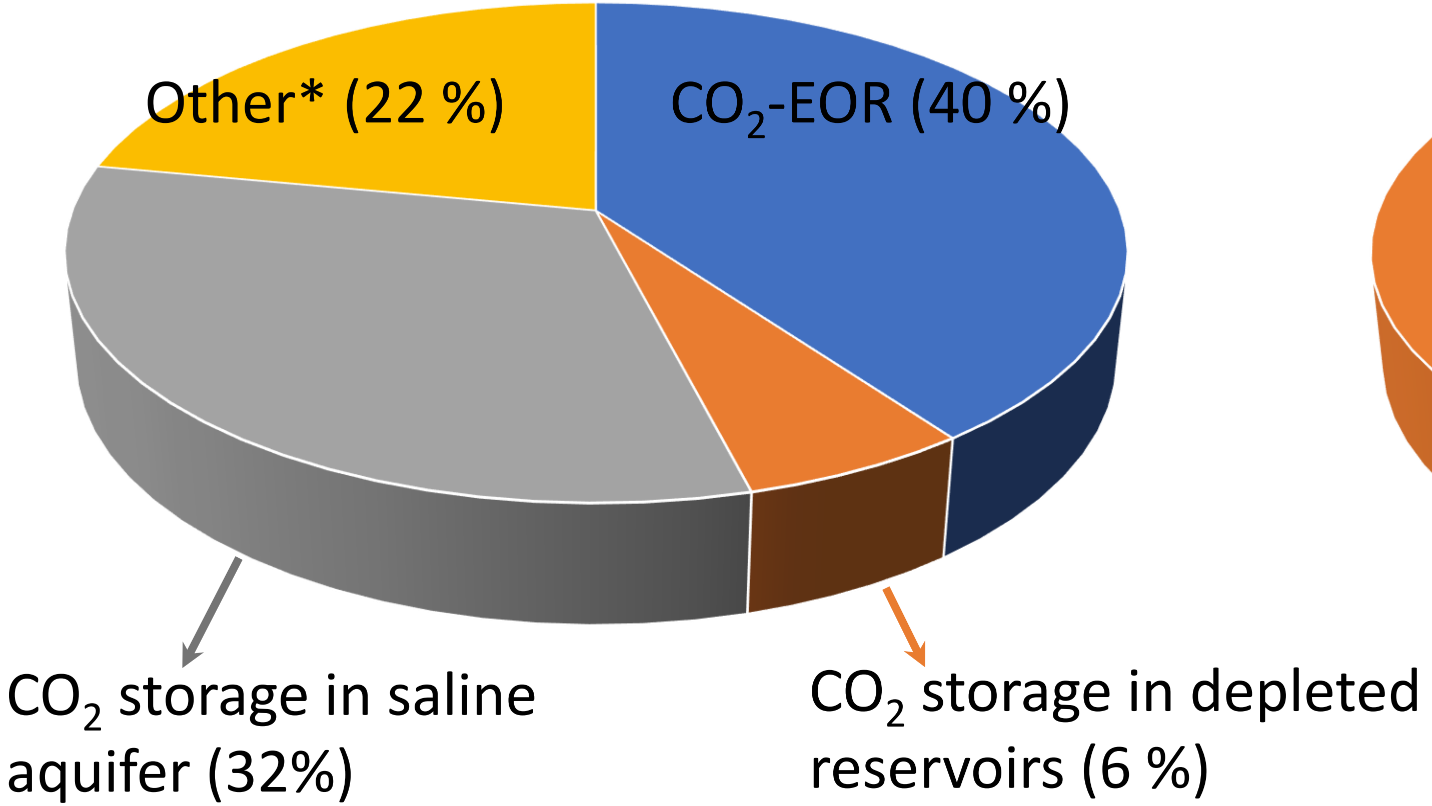
Site description: Mostly onshore with responses from both CO_2 storage and CO_2-EOR operators



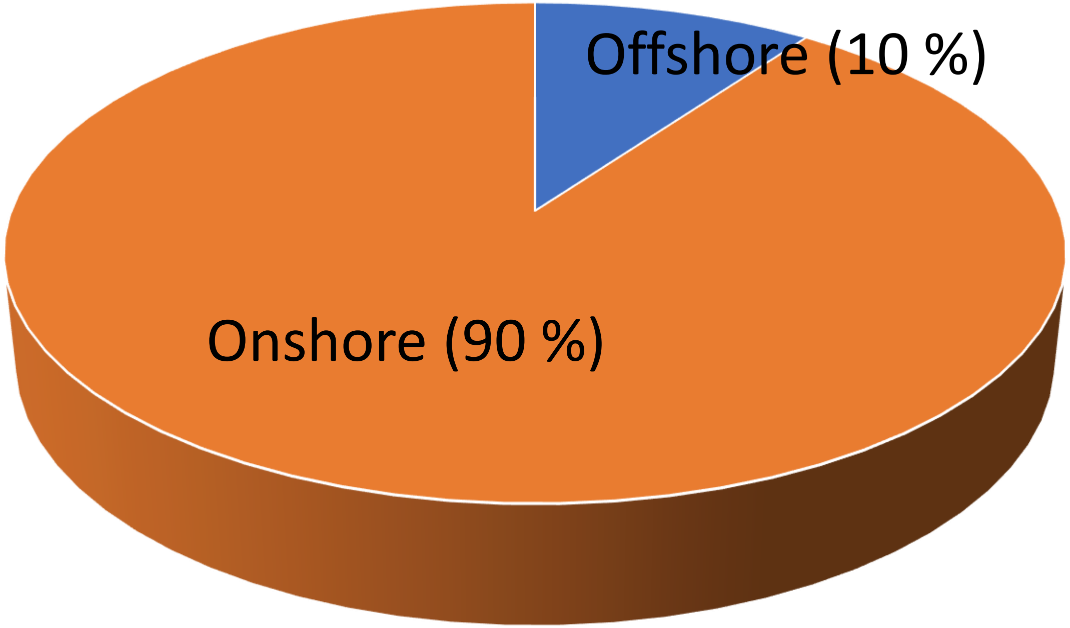
*Included variants of the other three types of sites like storage in both saline and depleted oil and gas reservoir, acid gas injection in natural gas reservoir

Comparison with literature survey showed a lack of responses from sites with CO_2 storage in coal seams

Site type (50 sites)

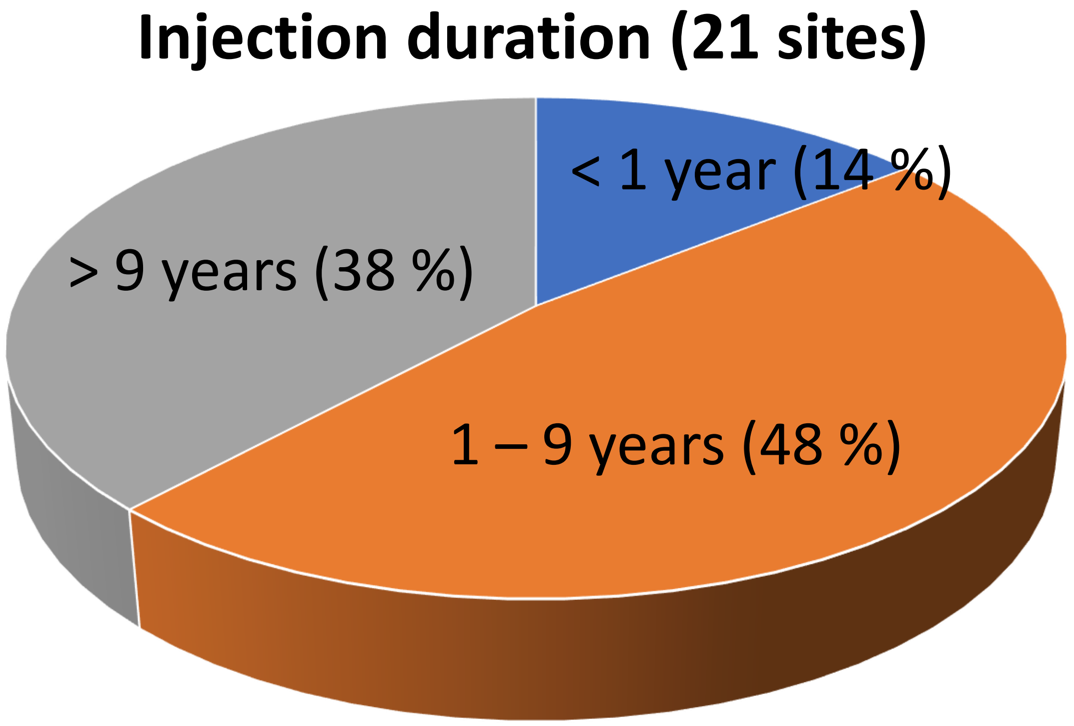


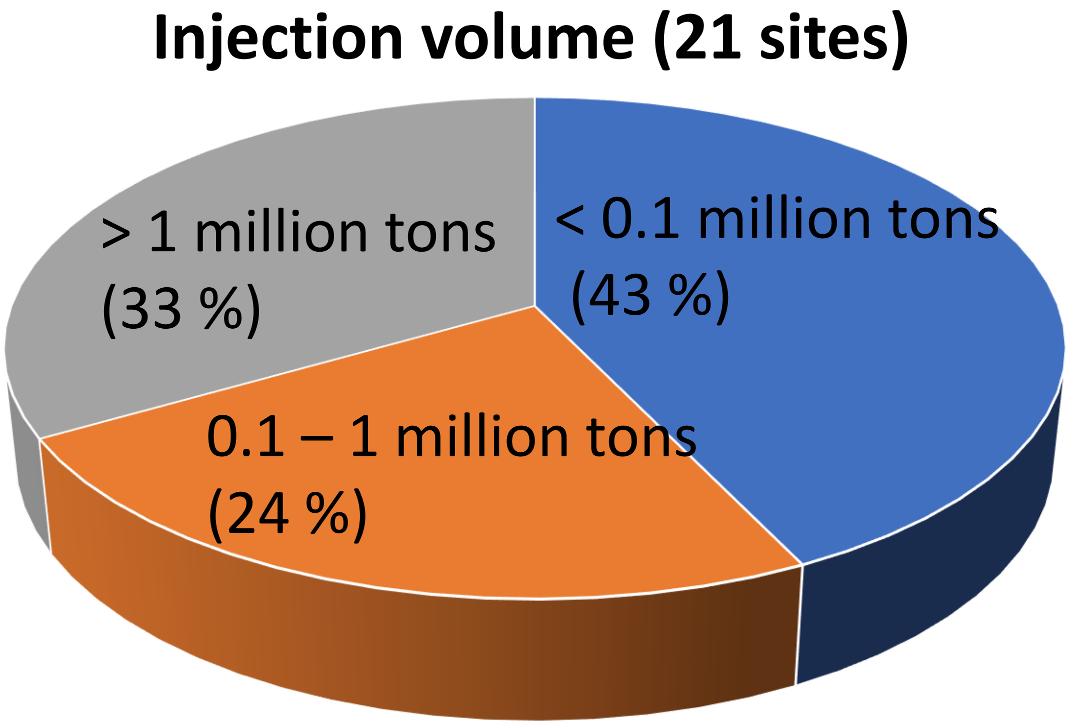
Site location (50 sites)



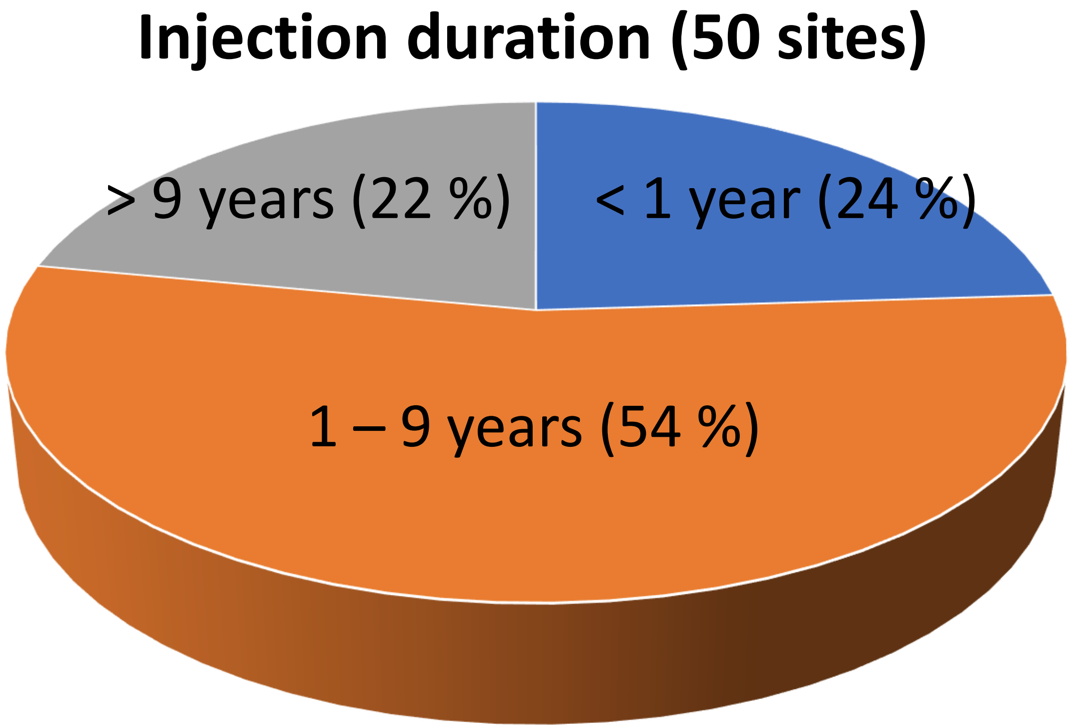
*Included 14 % of sites storing CO_2 in coal seams with or without coal bed methane production

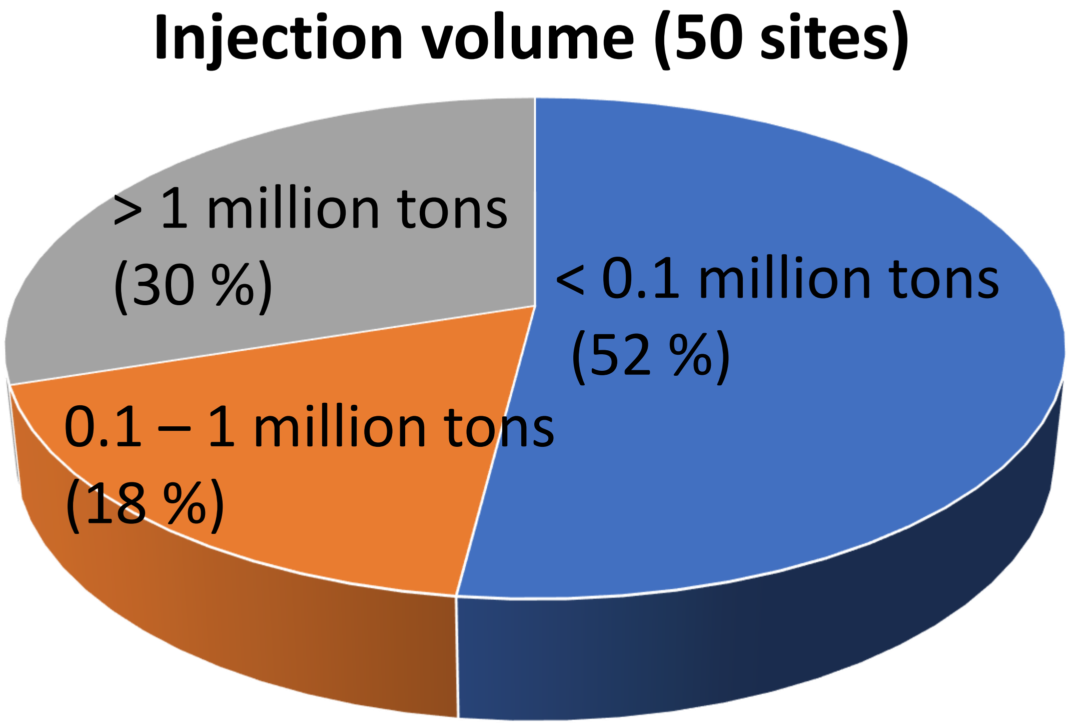
Injection details: Responses spanning all scales for injection volumes, rates and times





Literature survey skewed towards shorter and smaller projects

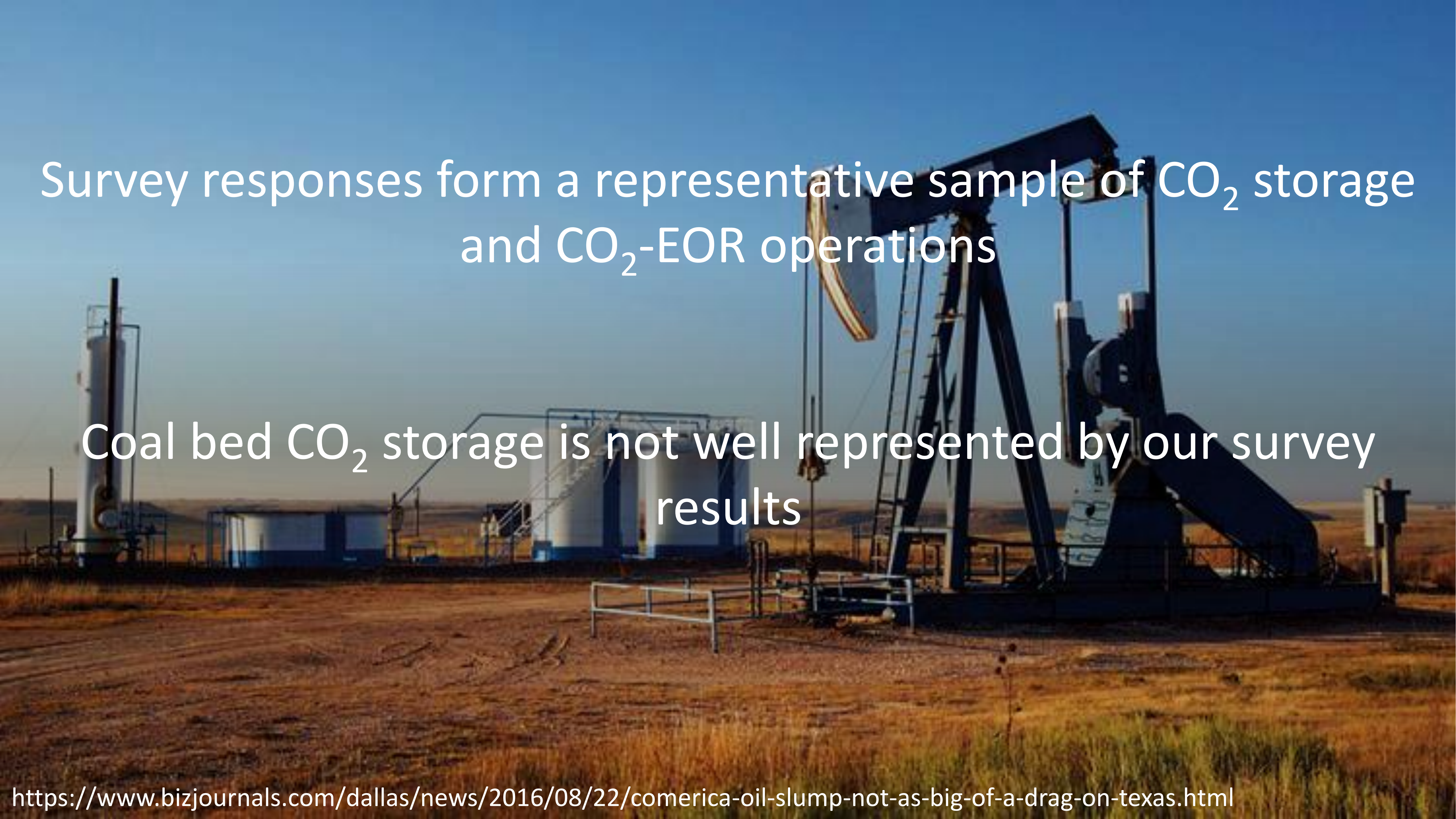




Reservoir properties

Description	Survey	Literature
Reservoir depth*	Mostly >1000 m deep (94%)	Larger fraction of sites with lower depths (30 %)
Pre-injection reservoir pressure	At or below hydrostatic (86 %)	Larger fraction of overpressured sites (26 %)
Reservoir temperature	Mostly below 100 °C (90 %)	Larger fraction of high temperature sites (28 %)
Reservoir rock*	Mostly sandstone (75 %)	Mostly sandstone (60 %)
Caprock	60 % shale, 23 % evaporite	Mostly shale and salt

*Sites with CO_2 storage in coal seams were typically shallower and had a non-sandstone reservoir



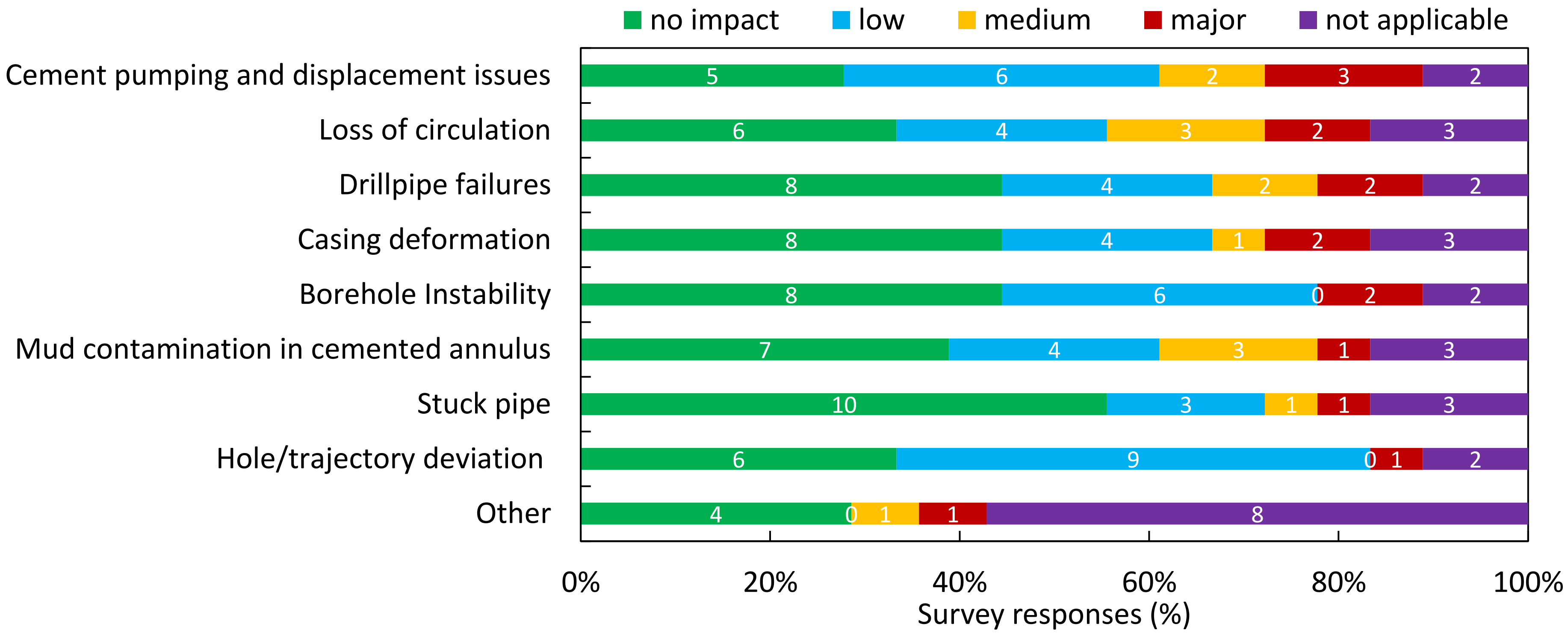
Survey responses form a representative sample of CO_2 storage and CO_2-EOR operations

Coal bed CO_2 storage is not well represented by our survey results

https://www.bizjournals.com/dallas/news/2016/08/22/comerica-oil-slump-not-as-big-of-a-drag-on-texas.html

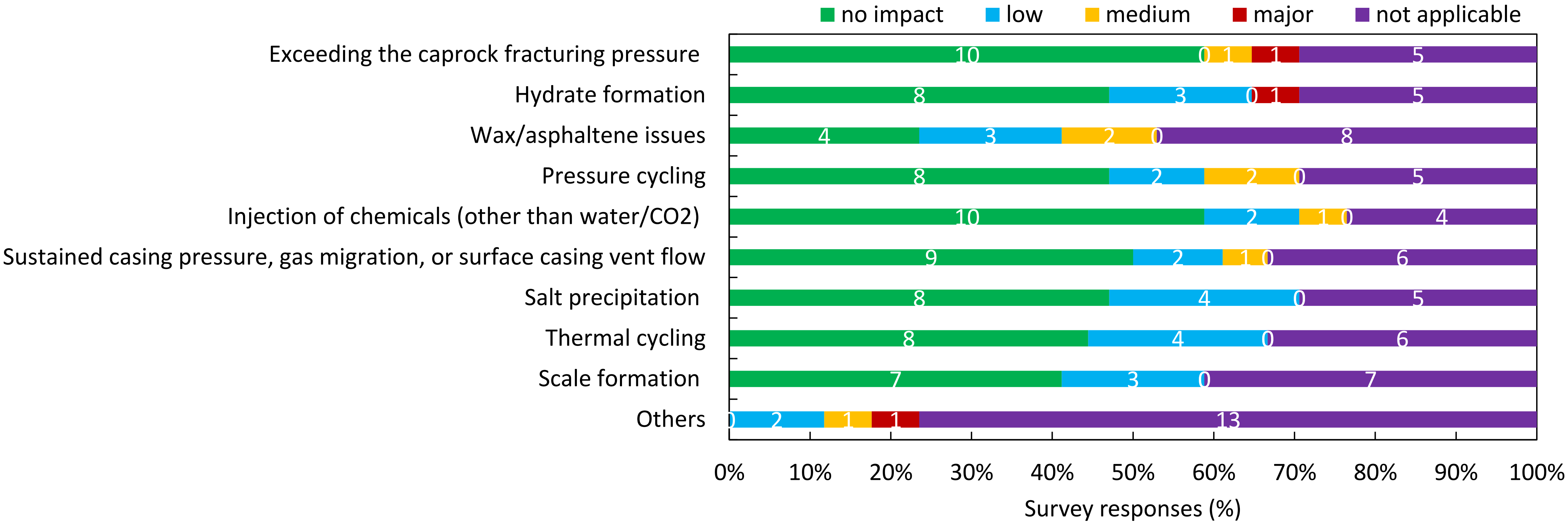
Impact of well construction issues on well integrity

- No and low impact is the most common response
- For every well construction issue at least one respondent categorized its negative impact as major



- Literature review
  - Poor cementing is generally considered the primary well construction issue at CO_2 storage sites
  - No systematic study on the impact of well construction issues on well integrity

Adverse impact of operational issues



- No impact is the most common response
- Only “Exceeding caprock fracturing pressure” and “Hydrate formation” had a major negative impact

Severity of operation issues based on literature survey

- Exceeding caprock fracturing pressure: Loss of site integrity
  - US EPA mandates that Class VI CO_2 injection wells should not exceed fracturing pressure
  - Sites potentially affected by this include:
    - Tubåen formation in the Snøhvit natural gas field
    - InSalah


10.1146/annurev-chembioeng-061010-114152

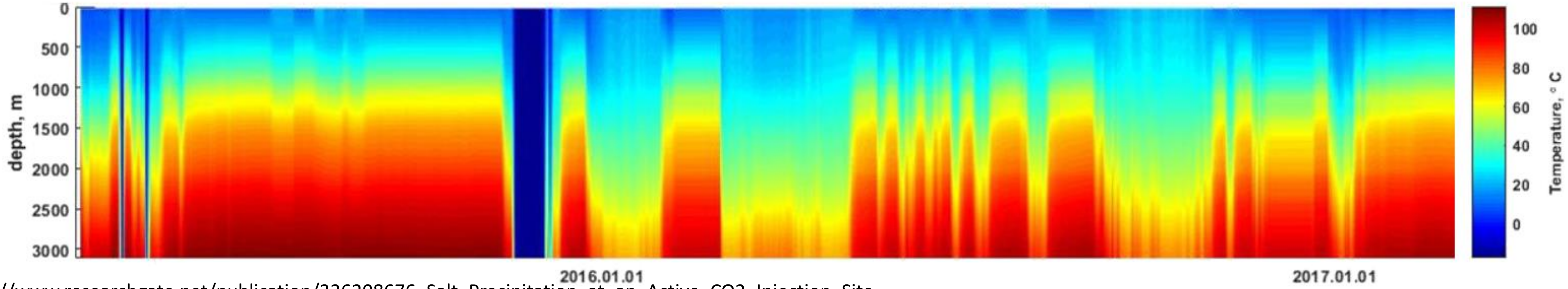
- Hydrate formation: Safety hazard
  - Can form rapidly and travel at high speeds that can result in extensive damage
  - Prevention and risk mitigating measures are commonly implemented

- Sustained casing pressure (SCP), surface casing vent flow (SCVF), and gas migration: Well leakage issues
  - Frequency of these issues vary from region to region (2 - 30 %)
  - Low levels of SCP and SCVF are manageable but high levels can lead to leakage outside the well system

Severity of operation issues based on literature survey

- Asphaltene, wax, salt and scale precipitation: Well injectivity issues
  - CO_2-EOR and CO_2 storage sites have reported these problems
    - Snøhvit, Midale, Ketzin, Aquistore
  - Several preventative and remediation techniques are available

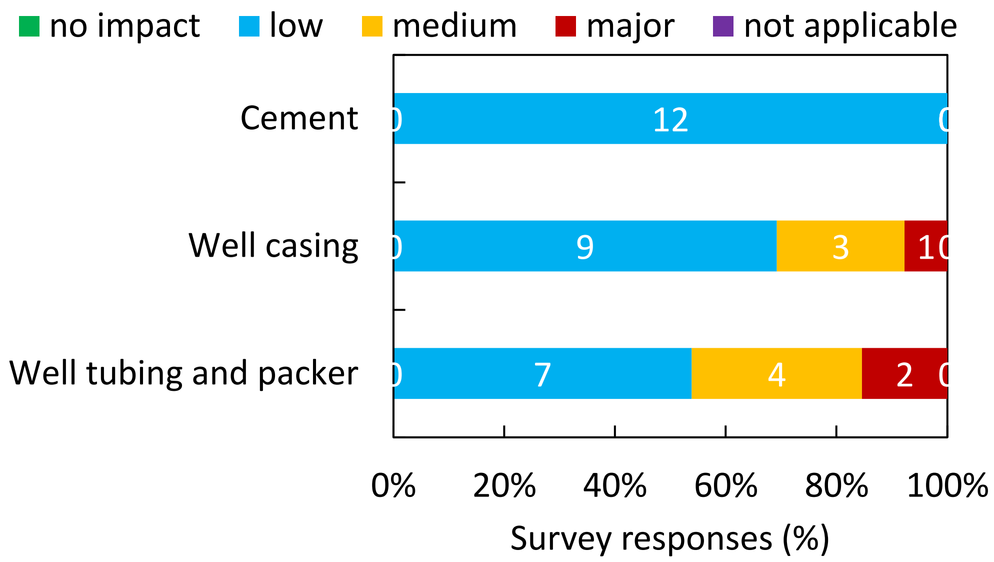
- Thermal cycling: Potential well integrity issues
  - No reported well integrity issues in the field due to thermal cycling
  - Temperature variation due to frequent interruption in injection can degrade strength properties of wellbore materials



https://www.researchgate.net/publication/336208676_Salt_Precipitation_at_an_Active_CO2_Injection_Site

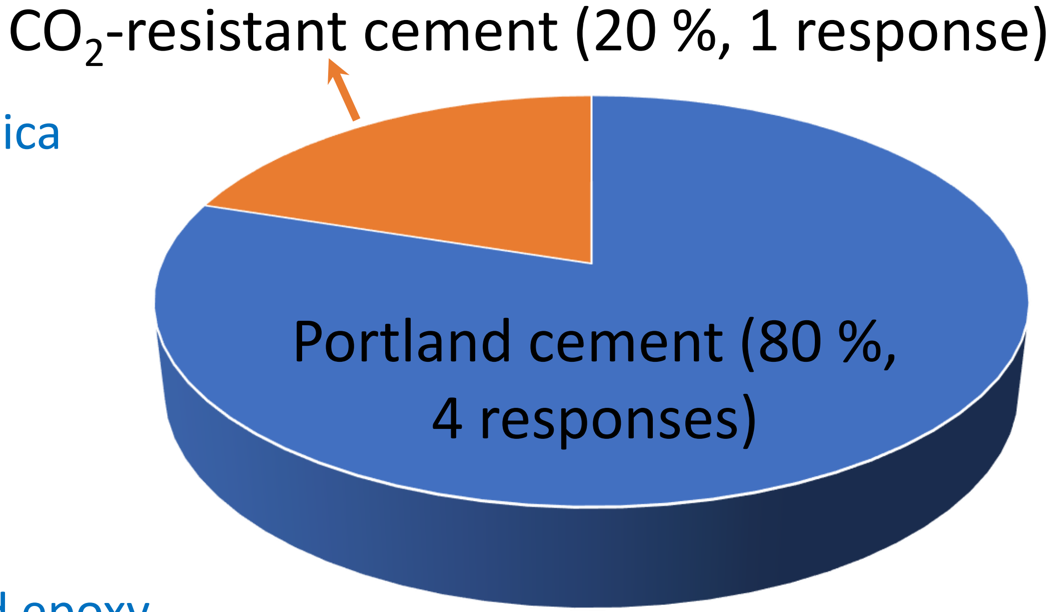
Material degradation

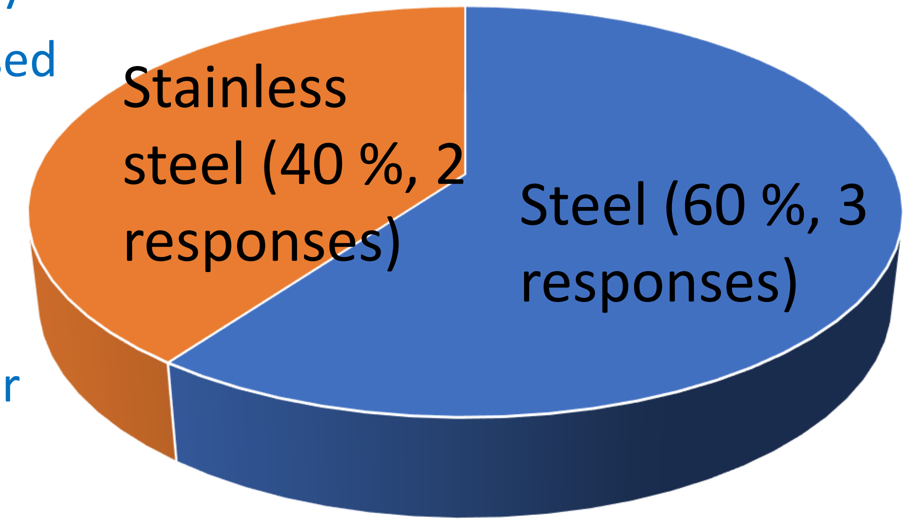
- Cement degradation
  - Cement porosity, permeability and mechanical properties are affected due to reaction with CO_2
  - Impact not adverse if original cement is competent
- Metal corrosion
  - Some field studies have reported extensive damage due to metal corrosion
  - Corrosion rates dependent on variables like ion concentrations
- Rubber degradation
  - Not widely studied



Alternative wellbore materials

- Cement
  - Formulations substituting Portland cement with fly ash, silica fume and other non-reactive material
  - CO_2-resistant cement not commonly used due to cost and adequate performance of conventional cement formulations
- Casing and tubing
  - Carbon steel coated with plastic, epoxy, or glass reinforced epoxy
  - Higher grades of carbon steel or corrosion resistant alloys are used when severe corrosion is expected
- Elastomers and seals
  - Swell resistant materials like hardened, Buta-N and nitrile rubber
  - Teflon and nylon



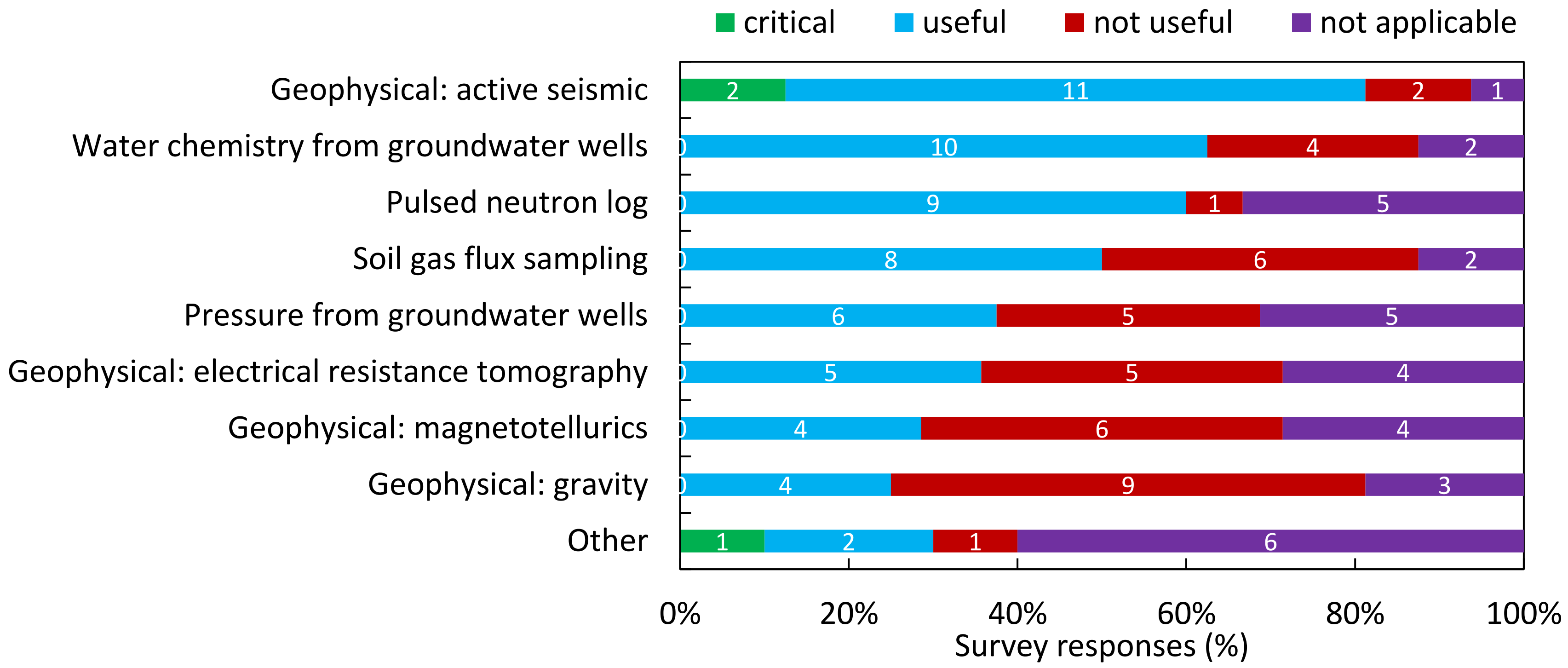


R&D Recommendations

- Material degradation
  - Impact on hydraulic and mechanical properties of cement
  - Impact of different variables on corrosion rates
  - New materials that can resist adverse impact of reactions with CO_2
  - Cost effectiveness in the context of the lifecycle of a well
- Techniques to remediate sustained casing pressure/surface casing vent flow
  - Applicability of methods in the presence of CO_2
- Impact of thermal cycling on well integrity
- Relationship between well construction and well integrity

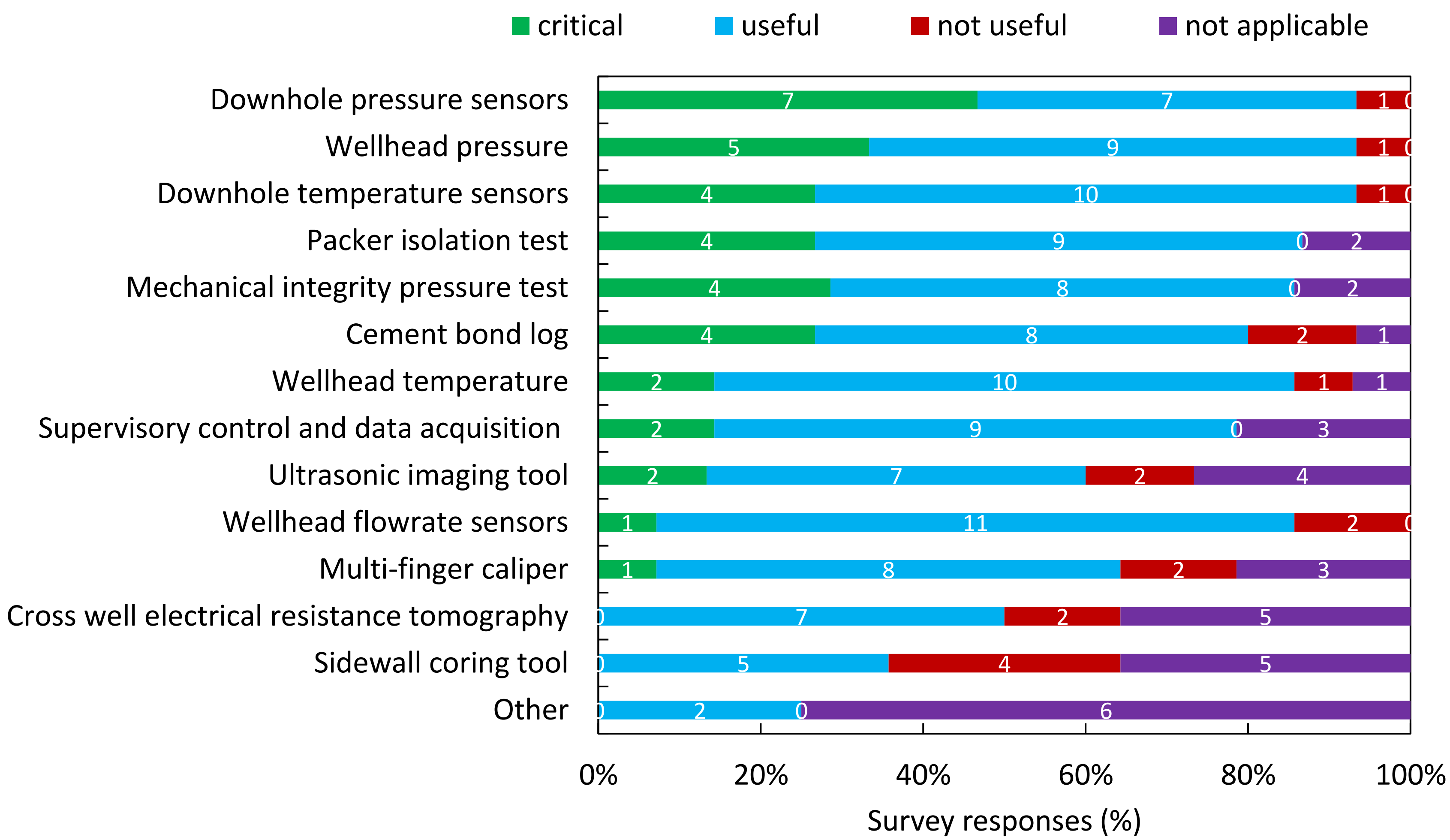
https://the-journal.com/articles/81784

Utility of monitoring methods to detect leakage outside the well



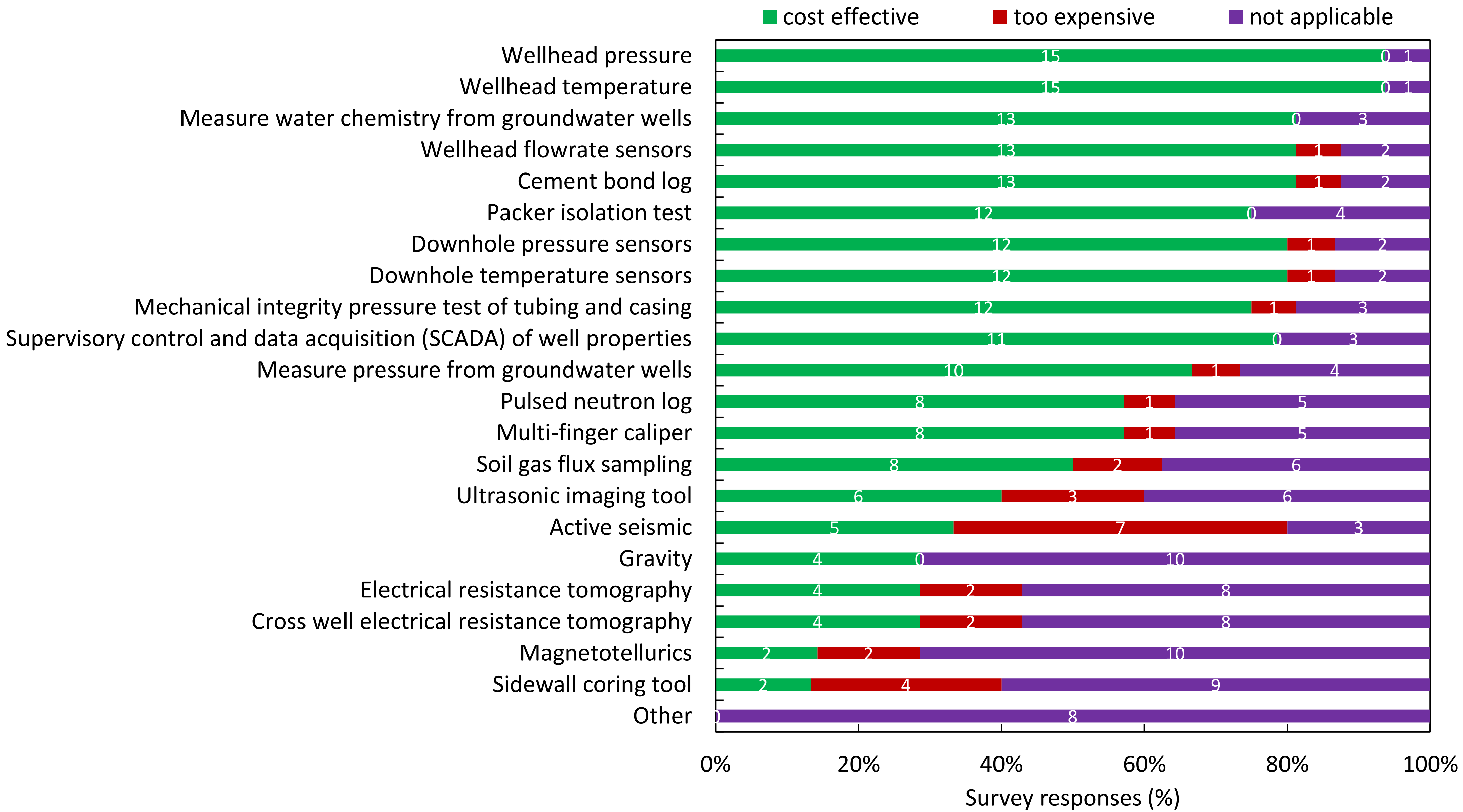
- Active seismic most useful
- Other geophysical techniques aren't considered very useful
  - May be due to limited need for monitoring outside the well in traditional oil and gas operations

Utility of monitoring methods to detect leakage inside the well



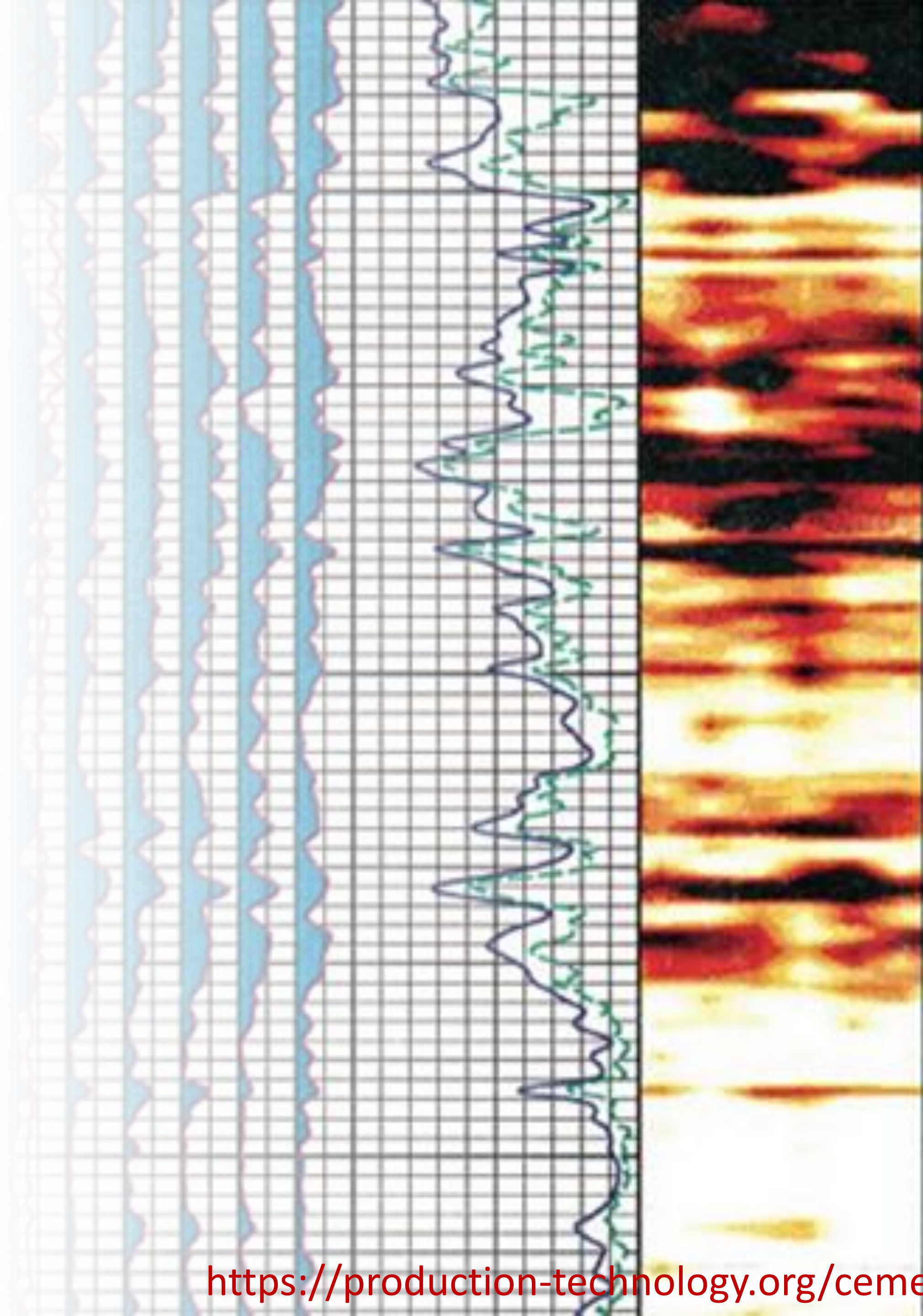
Almost all monitoring methods were considered useful more than 50% of the respondents

Cost effectiveness of monitoring methods



R&D Recommendations

- Advancement of technology for outside well monitoring
- Reducing the cost of important monitoring techniques like active seismic
  - Finding cheaper alternatives



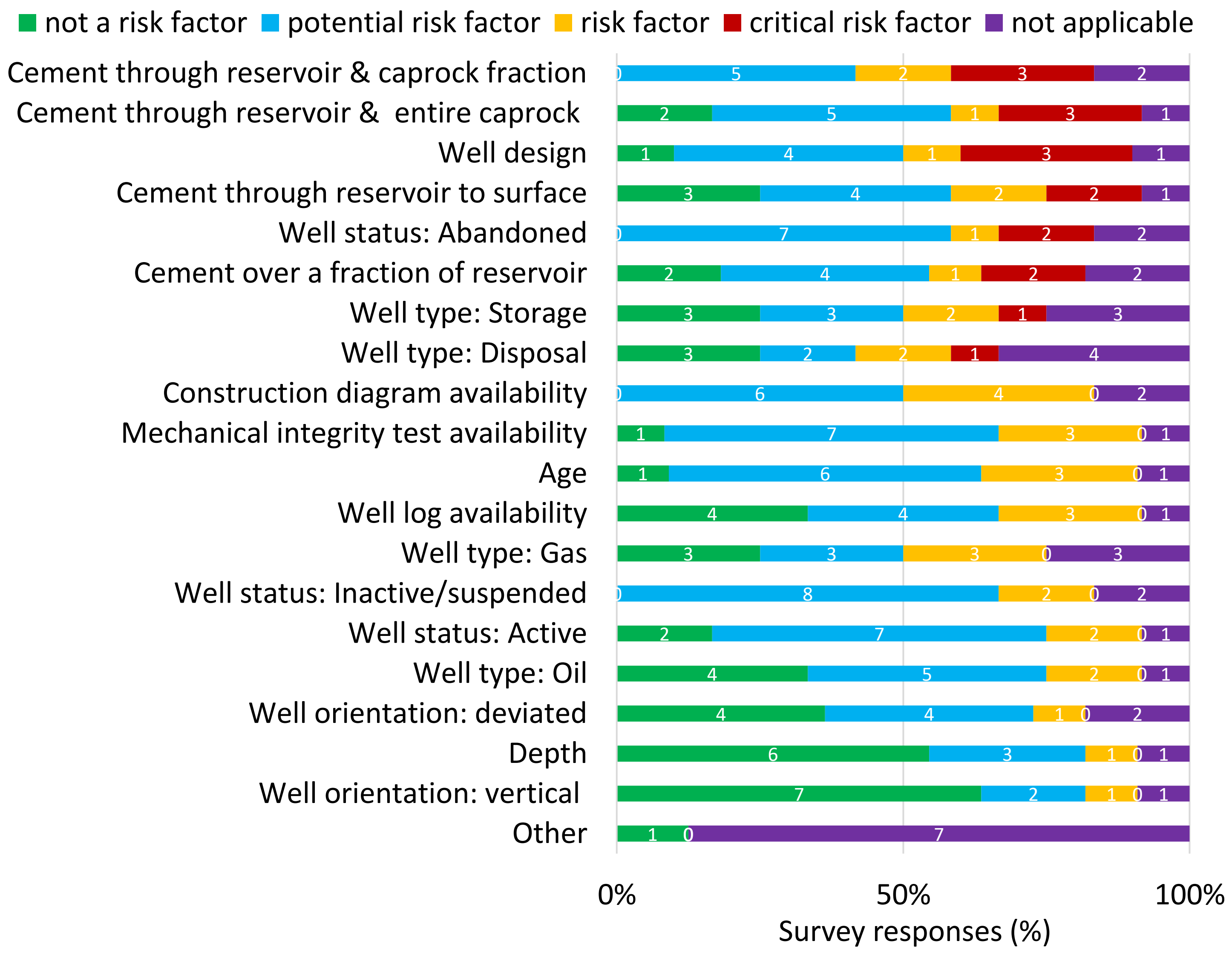
https://production-technology.org/ceme

Risk assessment of legacy wells

- Cement location and well design, status, and type are considered critical

- Well orientation is considered less important
  - Published studies suggest well orientation and age are also important

- Historical well records are considered most relevant for risk assessment
  - Published studies suggest that subsurface conditions should also be considered



R&D Recommendations

- Methods to evaluate well integrity based on well attributes
  - Quantitatively converting well attributes to well risk
  - Quantifying uncertainty when information is unavailable
- Risk assessment combining well attributes and reservoir performance

Concluding remarks

- Loss of well integrity are low frequency events
- Survey did not result in as many responses as we had hoped for
- Well integrity workshop to facilitate candid exchange of information between operators, researchers, regulators, etc.

Project overview

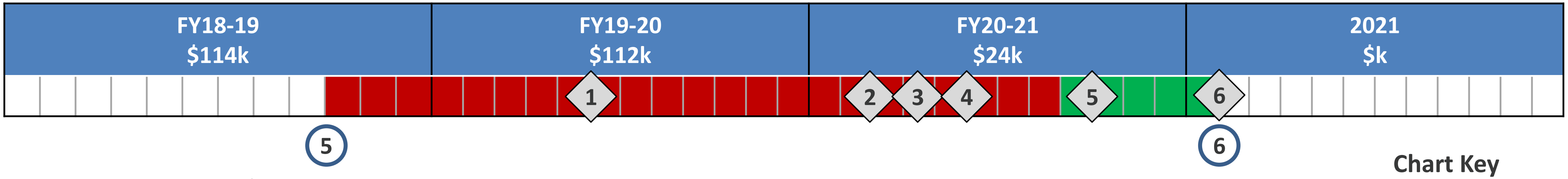


Chart Key

\# TRL Score | Milestone

1. Generate survey for operators
2. Deploy survey for operators
3. Analyze the survey responses
4. Review literature
5. Summarize results into document describing well integrity research needs for CO_2-storage sites
6. Solicit and incorporate expert feedback

Impact

Key Accomplishments/Deliverables	Value Delivered
2019: Field based assessment of issues related to well integrity, monitoring and risk assessment of legacy wells at CO_2 storage/CO_2-EOR sites.	• Guiding document with R&D recommendations regarding well integrity in CO_2 storage and CO_2-EOR sites

Acknowledgments

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- Part of this work was performed by SINTEF with funding from NCCS