SECURe
Subsurface Evaluation of CCS and Unconventional Risks

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GOOD PRACTICE AND RISK MITIGATION
FACTSHEET #2

Carbon capture and storage:

Release of CO_2/formation waters from the storage complex through wells

The SECURe project employed the Bow Tie risk assessment approach, which identifies a series of barriers that prevent a principal hazard ("top event") from occurring. This factsheet outlines recommendations, which address a single top event that can occur if control of a hazard is lost: the release of carbon dioxide (CO_2)/formation waters from the storage complex through wells. It should be read in conjunction with the Participatory Monitoring Factsheet, which provides overall guidance on project construction.

The issue

Although unlikely, the potential release of CO_2 at pressure from a well must be fully assessed in most CO_2 storage projects. Such releases could result in CO_2 emissions to the atmosphere, releases to seabed and seawater, and/or impacts to ecosystems and people. Release of CO_2 and/or formation waters could occur through abandoned monitoring or verification wells. These releases could occur via the well annulus (a small gap), through cements or casing/production liners or along tubing. A range of well engineering assessments, appropriate material selection and monitoring provide effective barriers to prevent CO_2 release. If release were to occur, then remediation options include monitoring, operational responses, well engineering interventions, and the use of natural geological properties to slow the release. These barriers and preventative and remedial actions are listed in detail in the SECURe report BGS-01-R-12.

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Risk mitigation recommendations

Maintaining borehole integrity

- Operators should use **cement formulations that minimise shrinkage**, when possible. Cement shrinkage can significantly increase the probability of failure for the CO_2 injection well. Appropriate cement properties and operating conditions can be selected to reduce well failure risks by using the modelling and relationships demonstrated in D2.6. Cement formulations that lead to softer, more flexible (i.e. more ductile) cement are recommended.
- Microannuli, or small gaps, along the well, and radial fractures emanating from the casing through the cement should be considered in **leakage mitigation strategies**. Any individual fracture may dramatically increase the leakage risk, but fracture networks do not necessarily lead to a continuous, high permeability path along the wells (D2.6). Under the right conditions, **re-purposing existing wells for CO_2 injection** can be done with minimal damage to the cement provided the status of wells are known and properties of cement are well characterised.
- **Reducing the temperature shock of the cold CO_2** is the most effective way to reduce cement failure risks (D2.6).
- Basic **geophysical logging to confirm the quality of the well completion** is essential in all accessible wells, even when closely spaced, to avoid leakage/failure (D6.8).
- Many plastic well casings and wellheads used for water wells are not gas tight and therefore may allow small amounts of leakage into the well annulus or around the well head cap – at least **part of the completion in monitoring wells should be cement** to mitigate slow leakage through casing joins (described in D6.8). This risk of leakage through non gas-tight casings and well caps from legacy wells should also be considered.
- In monitoring or instrumented wells, D6.8 explains that **reducing the number of sensors on the outside of casing reduces leakage risk and reduces interference with deployment of other monitoring tools** (e.g. metal sensors outside plastic casing can interfere with later geophysical electrical logging programmes).
- We recommend the use of the more readily available and more widely accepted Portland cement for remediation treatments, where the strategy is to have a single slurry capable of curing in the cement sheath and in low-permeability fractures (D5.4). Although guidelines for remediation treatments have not been defined by the SECURe team, we have established several test methodologies that we think satisfactorily represent more diverse and more realistic field situations.

Monitoring approach

- **Use dissolved gases as tracers** to identify potential transport pathways (D3.3).
- **Carry out a comparison of baseline and operational phase data** for soil gas and carbon isotopes to verify there is no evidence for CO_2 leakage (D3.3).
- **Adaptive monitoring** is required from baseline characterisation to operational and post-operational stages of the life cycle, to be able to detect any contamination events (D3.6).
- **Thresholds should be set** for hydro-chemical parameters that could indicate contamination in the future (D3.6). Thresholds should be established using the environmental baseline data to calculate concentrations of parameters that would indicate excessive natural temporal variation.
- **Hydrochemical parameters used as indicators of contamination should be selected** based on the mineralogy of the aquifer, the characteristics of the potential contaminant (for example, CO_2/ formation water release), and the nature of any likely reaction between the two (for example, decreased pH) (D3.6).

Risk mitigation recommendations (cont.)

Use of models

- Effective modelling of the CO_2 containment system should be undertaken, with model forecasts of well integrity to be based on a **thorough understanding of controlling processes associated with CCS operations** (D2.6).
- Laboratory experiments, as outlined in D2.6, **can be used to test cement integrity for realistic stress states and well materials** and to assess fracturing of the cement sheath operating limits for well pressure.
- Developing a risk assessment specifically tackling the opportunities for catastrophic failure (e.g. well blowout) should be developed early in the project to guide site works (see D6.8).

Development of technology

- **A three-tiered methodology to compare candidate remediation fluids is proposed** (D5.4):
    - The first tier is the core flooding approach, evaluating performance of the remediation fluid in a well-described slit in a (nearly) impermeable plug;
    - The second tier is still focusing on a single fracture, but this time the topology of the fracture is relaxed and therefore more field-realistic. The fracture is stress-induced, opening mainly in tensile mode;
    - The third tier is to adopt geometry and complexity comparable to the field, but in a scaled down and more controllable setting. In SECURe, this was achieved by using the ECCSEL mini-wellbore assembly.
- This methodology helps the industry to balance advantages and drawbacks, which might be at different tiers for the candidate competing fluids. This approach also caters for the R&D community when developing new formulations. An obvious starting place is testing under tier one.
- **When developing remediation fluids to control permeability, specific tests should be designed for specific problems.** This is because the method by which the candidate remediation fluids are tested influences the performance of the fluid (D5.4). Key questions to consider include: is the remediation fluid intended for consolidation and eventual blockage of a permeable formation, thus limiting well fluid leakage away from the well? Or should the fluid remediate fractures already in the cement sheath around the well and discrete fractures extending into the formation beyond? Which type of formation is to be remediated - permeable or impermeable and fractured, such as a caprock shale?

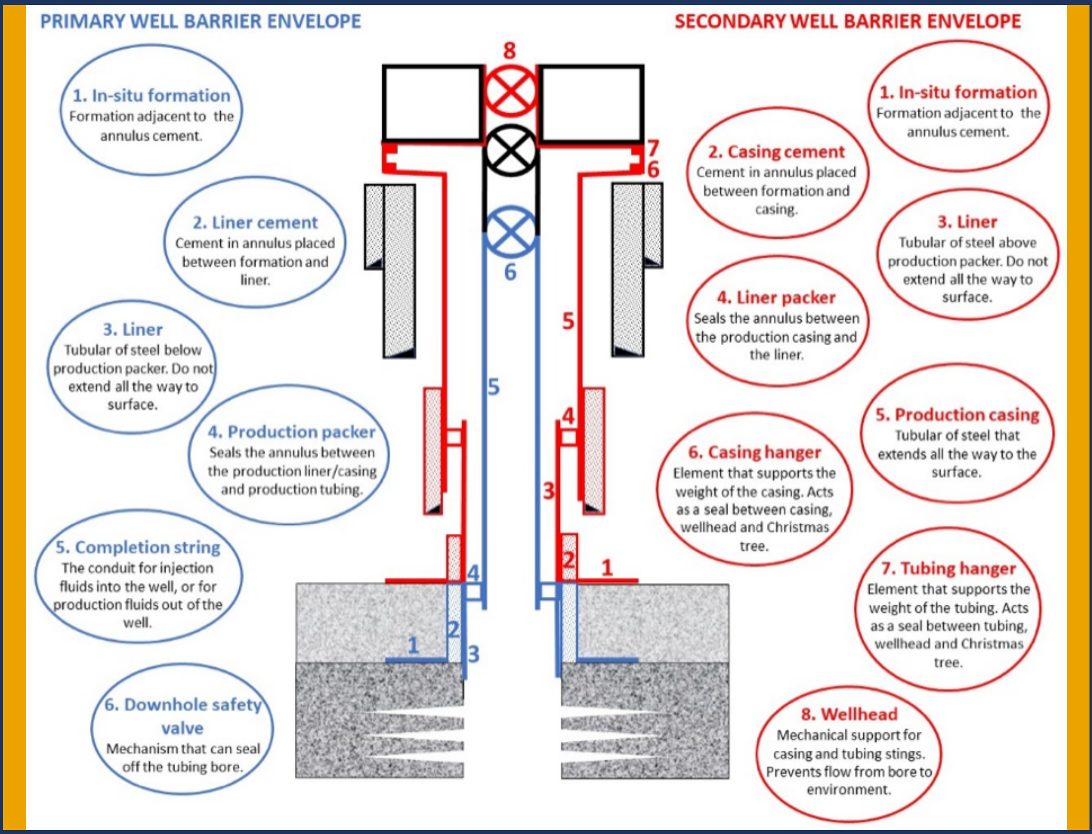

Figure 1: Simplified illustration of well barriers for a typical active CO_2 well. Primary well barrier envelope in blue and secondary well barrier envelope in red (from D5.3).

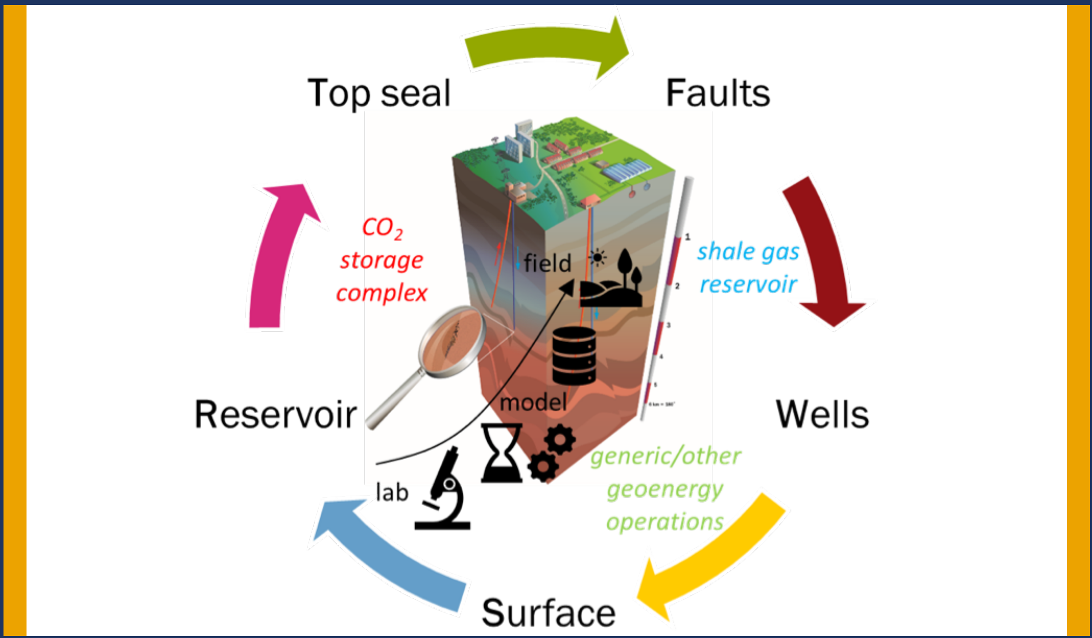

Figure 2: Application domains (CO_2 storage complex, shale gas reservoir and generic/other geoenergy operations), Topics or impact areas/risk receptor (R-Reservoir, T-Top seal, F-Faults, W-Wells, S-Surface), and tools or methods (lab experiments, modelling, field cases - as indicated by symbols and text in figure) for research within WP2 of the SECURe project (from D2.6).