LEGACY WELLS UNDER THE TRACER LENS:

SECURING CO_2 STORAGE FOR THE FUTURE

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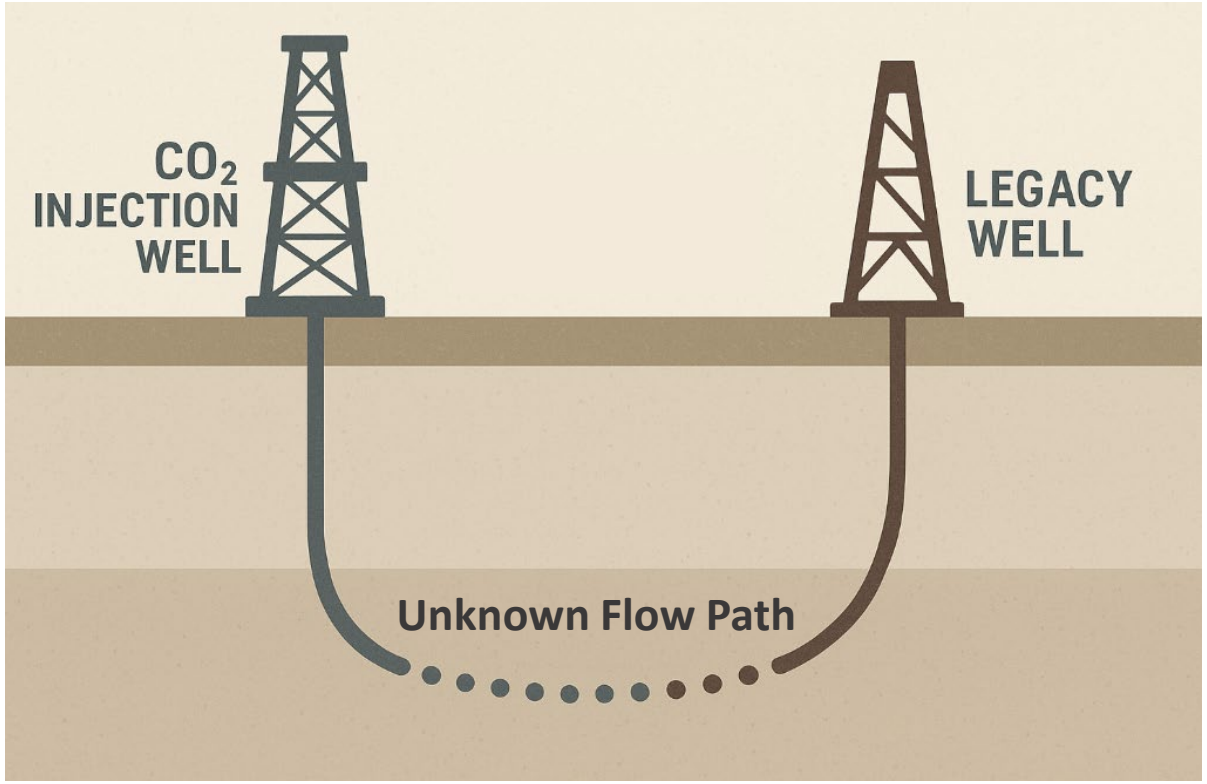
AGENDA

- Problem and Context
- Why Tracers Matter
- Case Studies
- Summary

Why Legacy Wells Are the Blind Spot in CCS



- Unknown Integrity
- Higher Leakage Risk
- Hard to Monitor

Legacy wells are not in the model… but they're in the ground

What Tracers Add to Legacy Well Monitoring

Tracers are organic tags to reservoir fluids

- Follows the flow without impacting transport process
- Fluid from specific source can be identified

Tracer properties

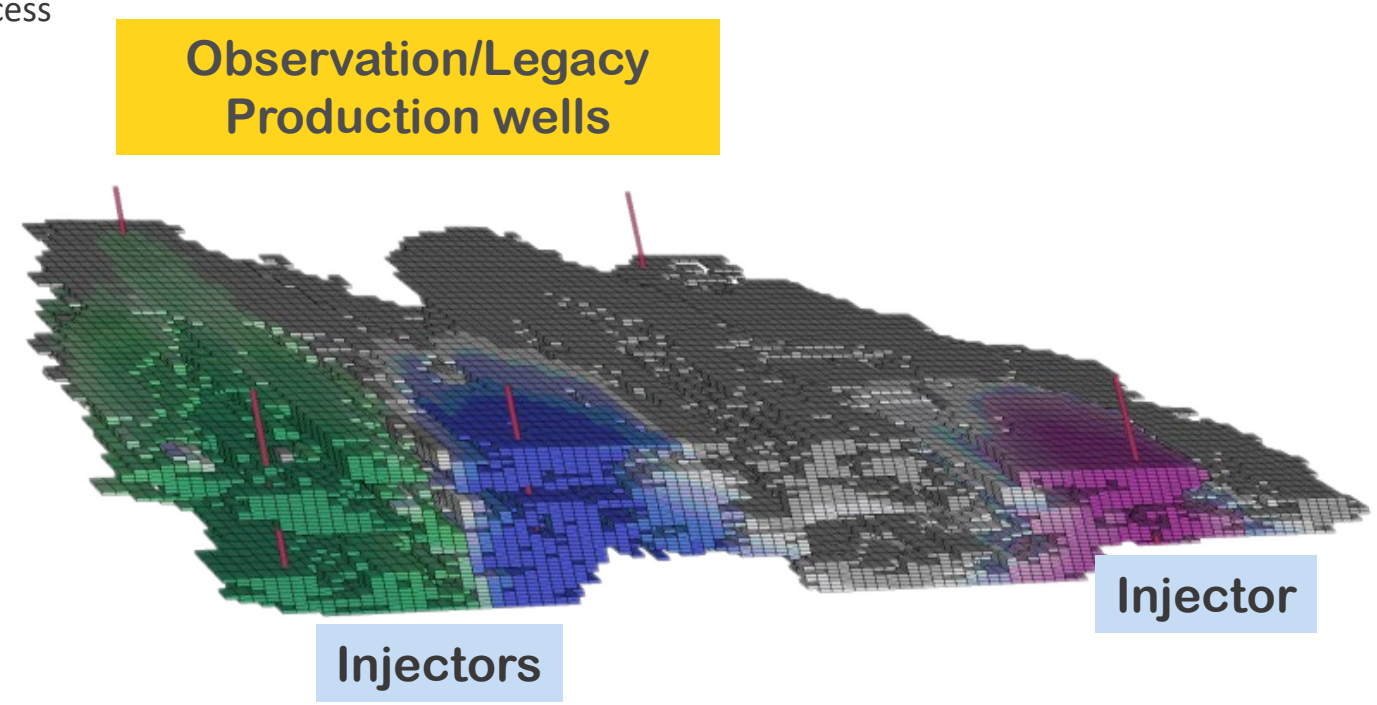
- Inert
- Non-radioactive and low toxicity
- No natural occurrence in reservoir fluids
- No absorption to rock
- Detectable at extremely low concentrations
- Cost effective

Only Proof of mass transport

- Direct Measurement
- Quantifiable data; communication pattern, significance and sweep
- Model calibration

RESMAN CCS tracers have no measurable degradation

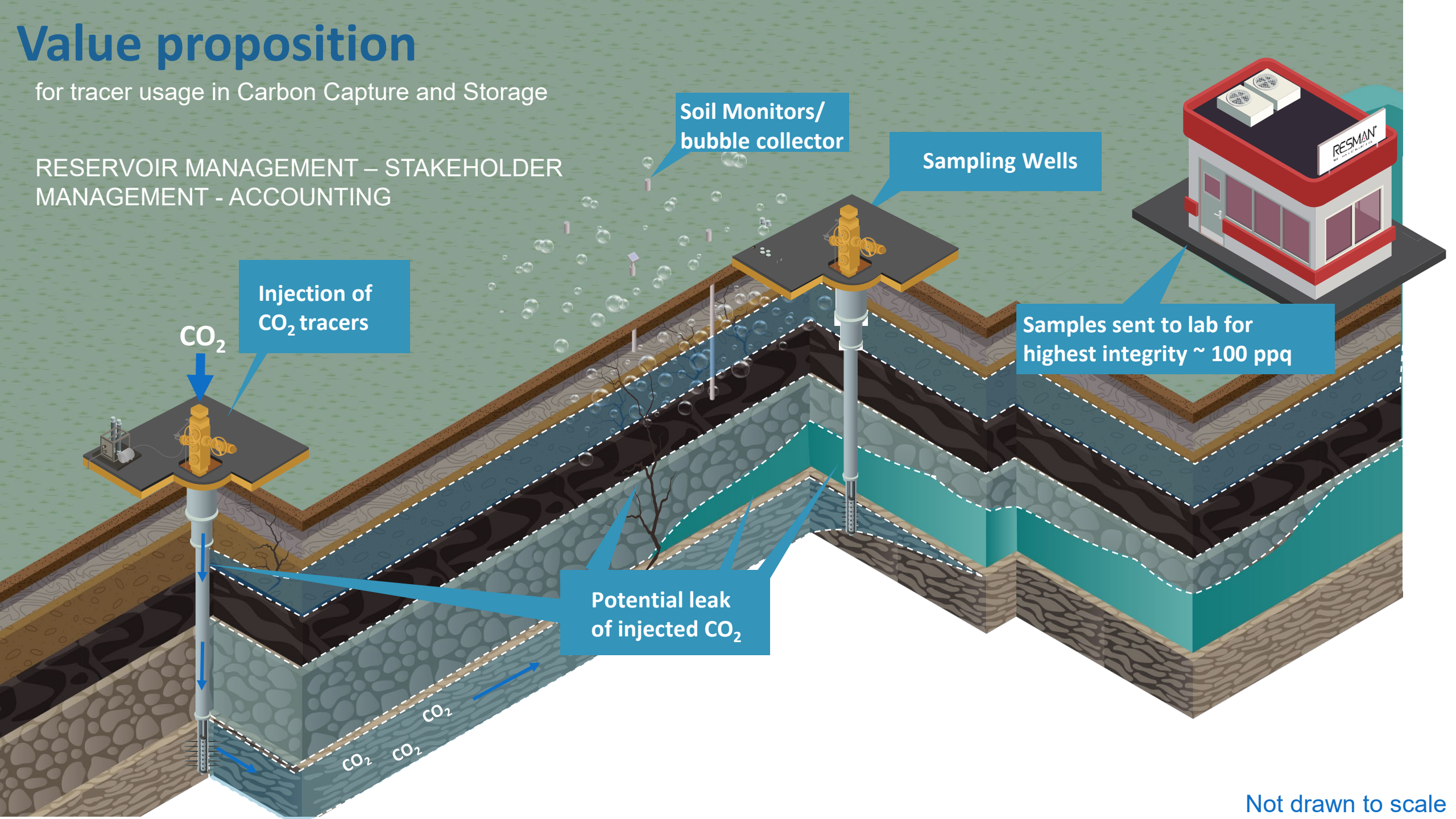
- will last through both injection period
- And the required post-injection monitoring period of multiple decades



Value proposition

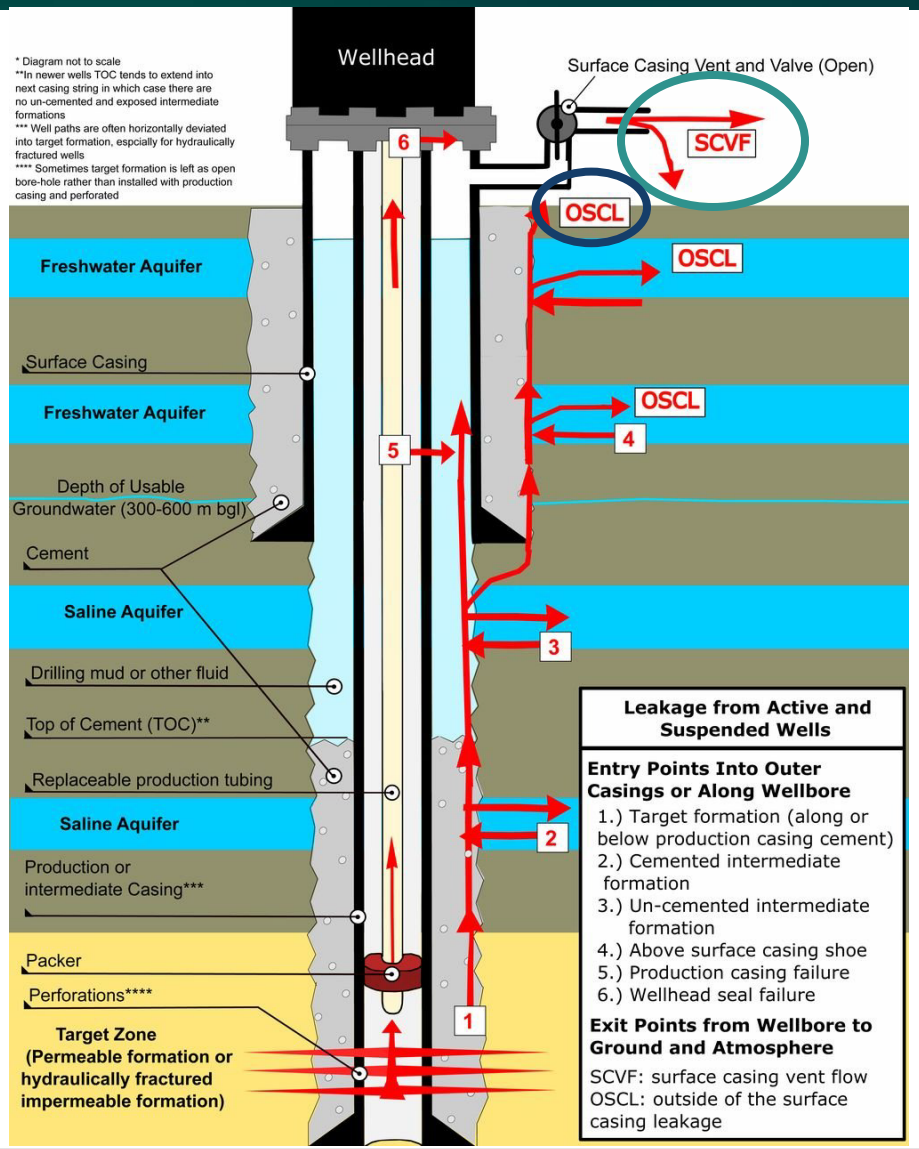
for tracer usage in Carbon Capture and Storage

RESERVOIR MANAGEMENT – STAKEHOLDER MANAGEMENT - ACCOUNTING



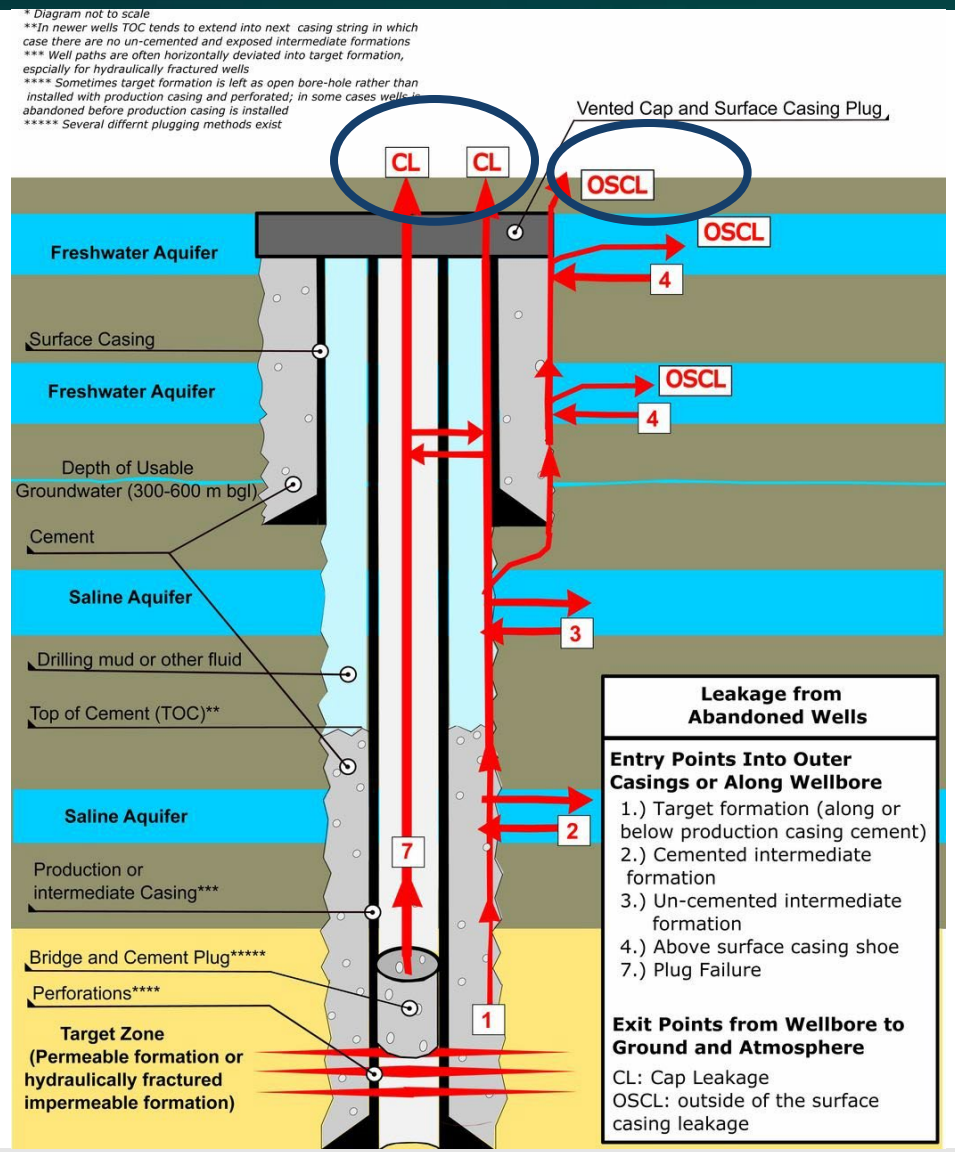
Not drawn to scale

Leak paths and detection methods



Direct gas sample

Soil gas / gas bubble

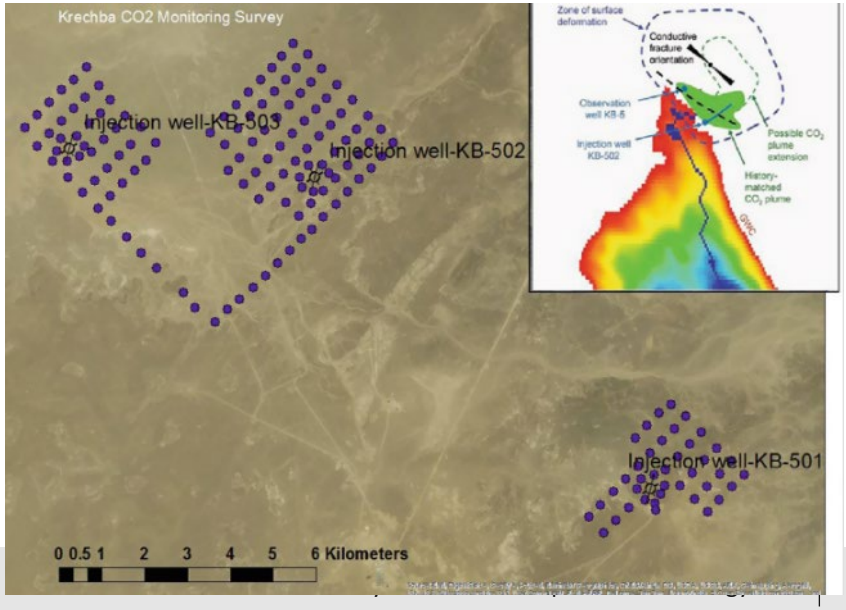


Source: *Wisen et al., 2019* https://doi.org/10.1073/pnas.1817929116

RESMAN High Integrity Detection System RES•HIDS

- Identify possible leakage areas based on geological information
- Place RESMAN gas sampler in sampling well
- Gas sampler will integrate exposure to leakages in the period it is in well
- The sampling well can be fitted from 1m to 5m depth
- Tentative recommended sampling frequency: **Quarterly**
- 33 000 times more sensitive than competing technology
- **Deployed in ADNOC pilot project**

Seabed bubble collectors

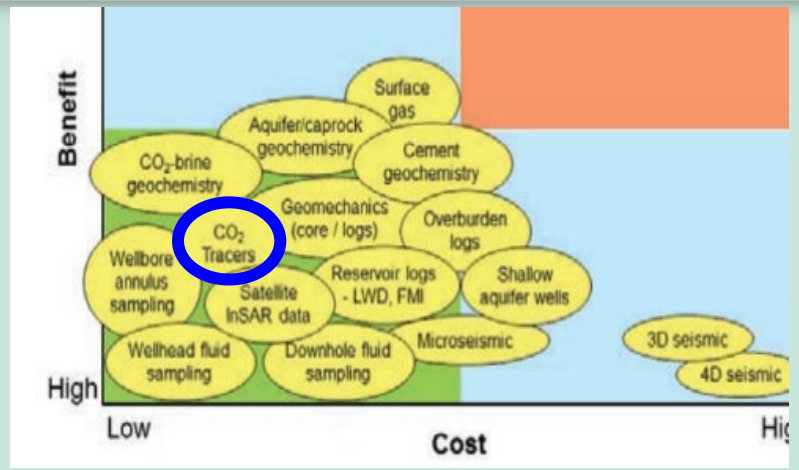


Source: *F Zeboudj and L Bahi «Best Practices in Monitoring CO2 at Krechba Field-Algeria AGI CO2 Tracer Gases Detection Technique» Proceedings of the International Petroleum and PetrochemicalTechnology Conference 2020, pp. 584–599, 2021*

In Salah Publications | Voice of Operators referencing RESMAN's Technology

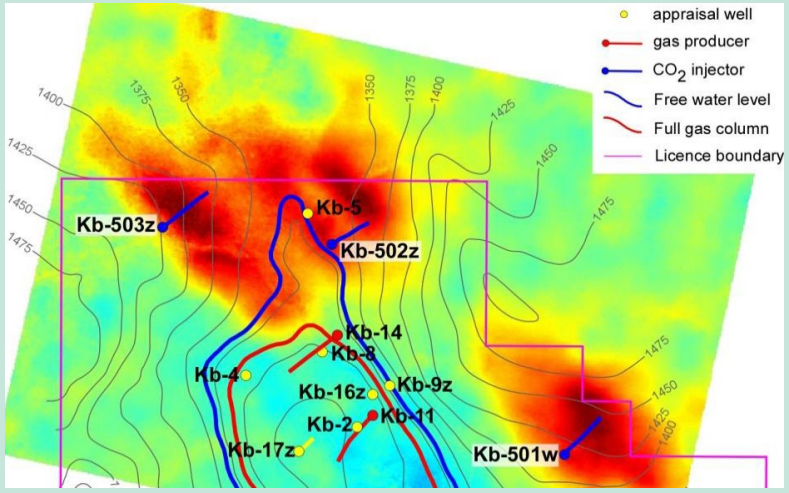
The In Salah CO2 Storage Project: Lessons Learned and Knowledge Transfer

2013



Summary of MMV Technology Applied and Lesson Learned

Tracer in CO2 Injection wells: Valuable and cost-effective

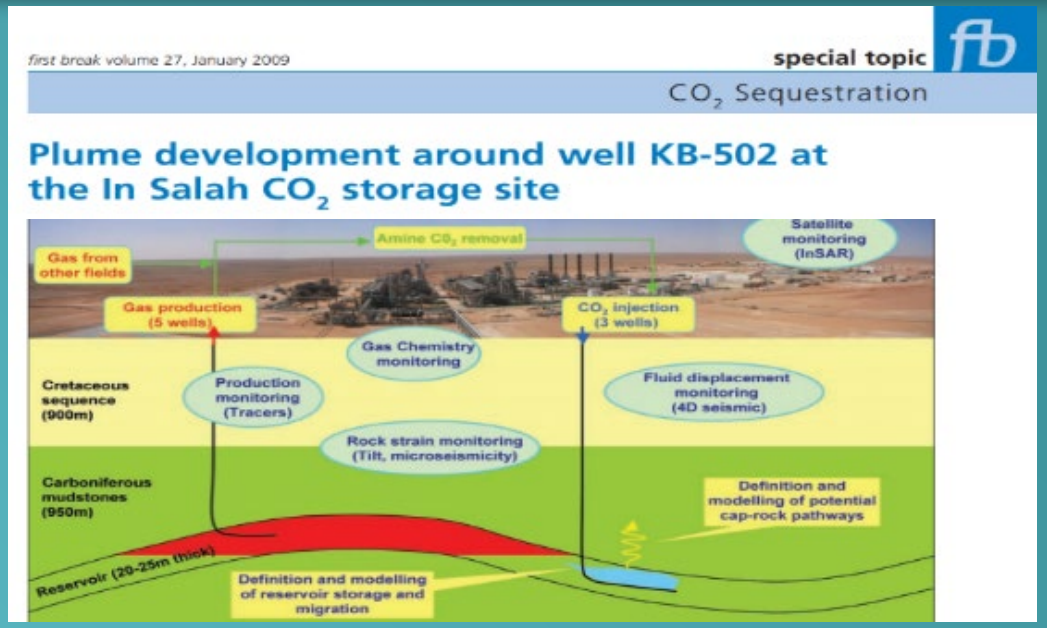


Tracer revealed CO2 break-through from Kb-502 to KB-14 after ~5 years

- Providing source-identification and proof of mass transport
- Not obvious from seismic / InSAR or other data

Plume development around well KB-502 at the In-Salah CO2 Storage Site

2009



Legacy well Integrity issues identified (Kb-5)

A further valuable constraint to the subsurface plume development was gained by the detection of CO2 breakthrough at a suspended appraisal well (KB-5) 1.3 km to the NW of injection well KB-502. Tracer analysis confirmed that the CO2 detected at KB-5 came from KB-502. Reservoir modelling and history matching of the CO2 breakthrough, pressure data, and satellite deformation data have allowed us to build up a detailed picture of the CO2 plume around injection well KB-502

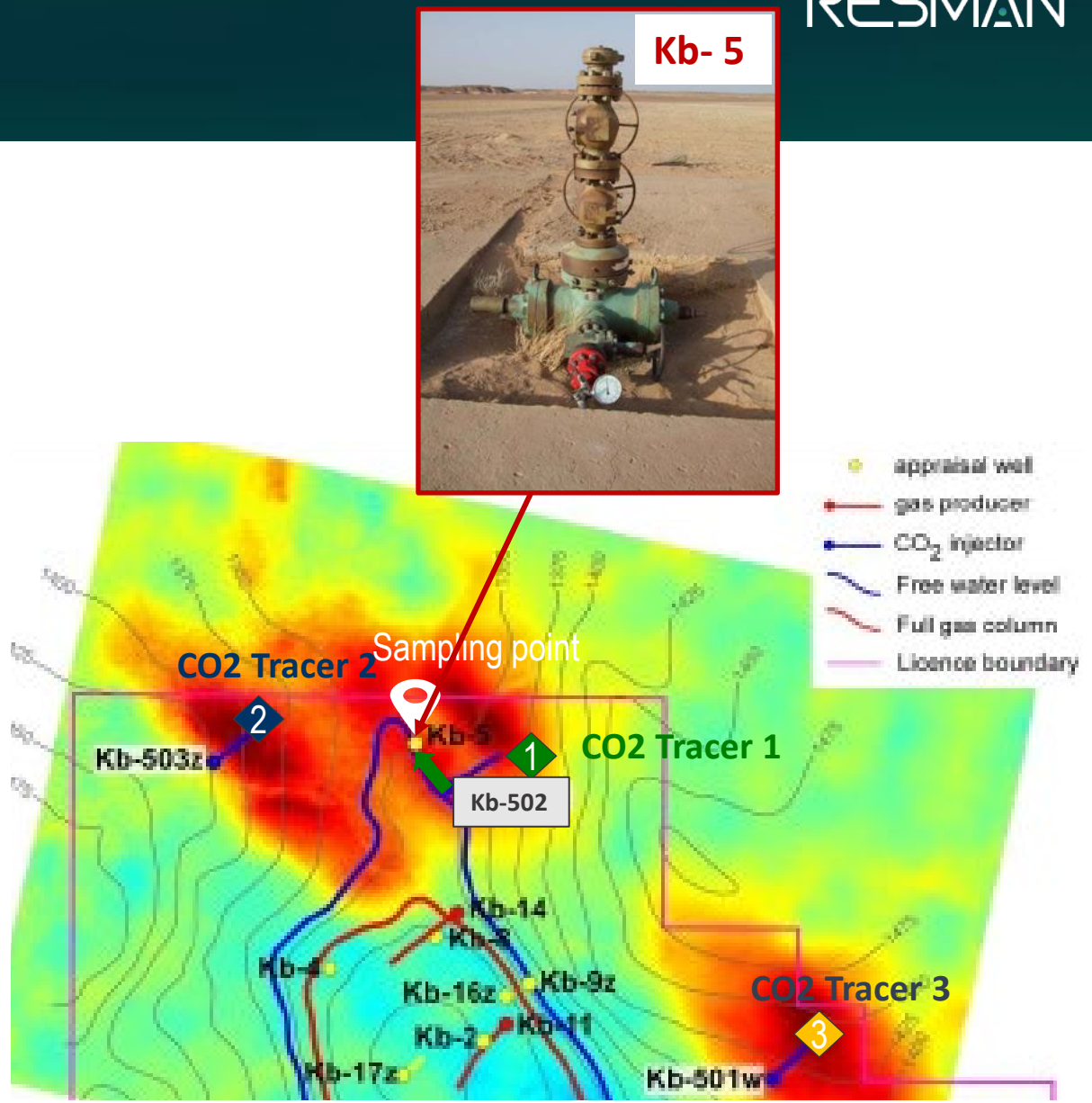
18 years of tracer monitoring – 14 years of post-injection monitoring

CCS Case Experience: Integrity

Legacy well Kb-5 drilled in 1980 and temporarily suspended by 2007

Well and wellhead integrity issues caused CO_2 leak in Kb-5, leak confirmed with tracer and injector (Kb-502) determined by tracer

Well was fully decommissioned with CO_2 resistant cement



Sources: Wright, NFCCC SBSTA CCS Workshop, September 8th 2011, Abu Dhabi

In Salah: Leak from CO2 storage to hydrocarbon gas reservoir

Different CO_2-tracers injected into each of 3 CO_2 injection wells

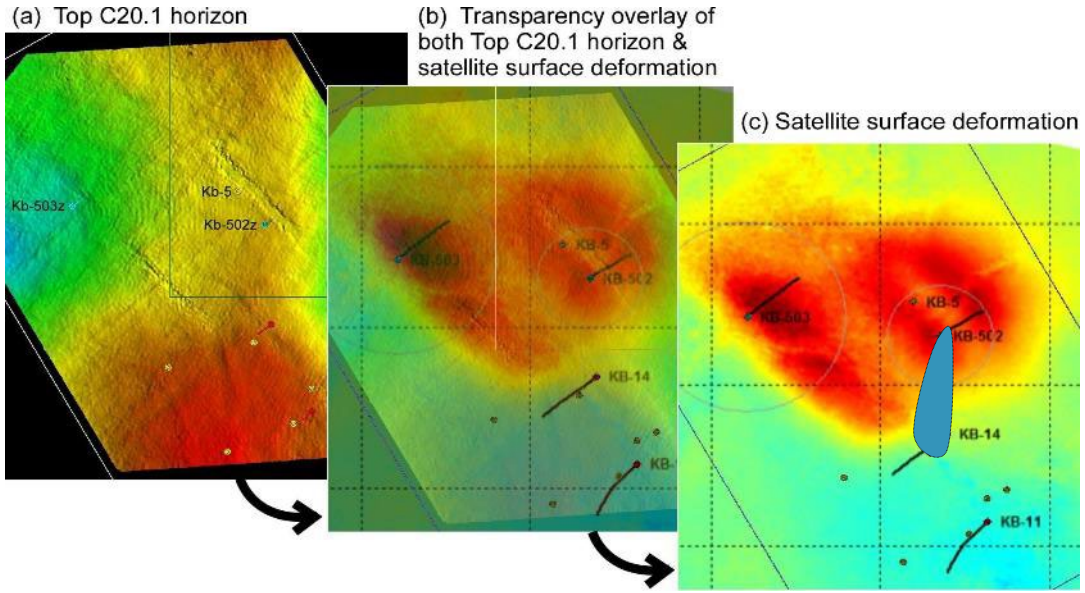
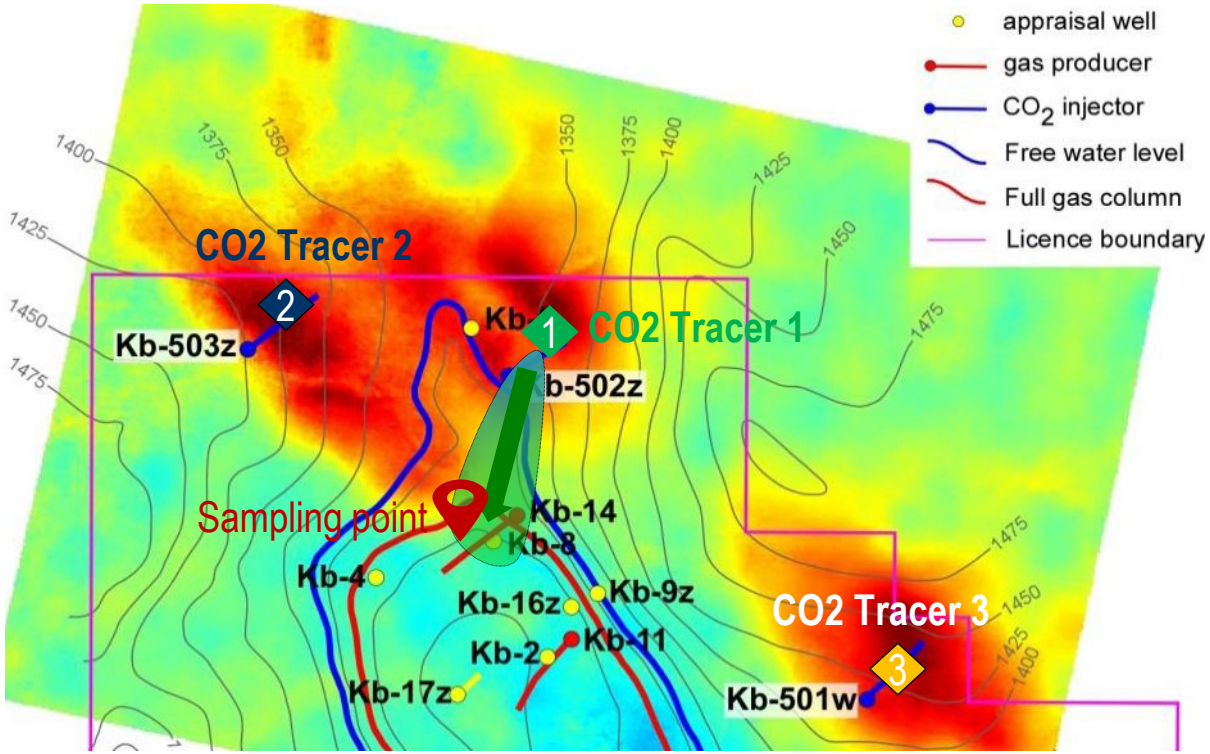


Fig. 4. NW-SE linear features seen on 2009 3D seismic data compared with InSAR surface deformation data.

Source: Ringrose et. al. Energy Procedia 37 (2013) 6226-6236i

Findings

- Tracer saw CO_2 break-through from Kb-502 to KB-14 after ~5 years, provides source identification and proof of mass transport
- Not obvious from seismic or other data



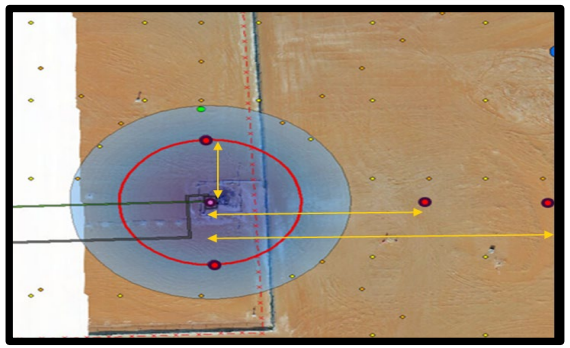
Source: Wright, NFCCC SBSTA CCS Workshop, September 8th 2011, Abu Dhabi

RESMAN®

The highest resolution - lowest carbon footprint technology in market

2024 Adnoc Demonstration Project Detail

- 2024: **First** deployment of RES-HIDS (High Integrity Detection System) in a CCS project for ADNOC in UAE (2024)
- 1st commercial success pilot of Shallow Surface wells monitoring (RES-HIDS)
- Joint SPE Paper w/ Adnoc – SPE-222348-MS
  - *Chemical Tracer for Soil CCS Monitoring Application: Monitoring CO_2 Storage in Saline Aquifers Using Advanced Chemical Tracer and Detection Technology*



Location of CO_2 injection well and 4 soil gas sampling wells at 20/100/200 m radius

Customer Relevance

Summary and Conclusion

- CO_2 tracer technology is an accurate method to understand CO_2: migration, monitoring and early detection CO_2 leakage.
- Tracer technology is a proven technology to have high benefits and relatively low cost in reservoir monitoring and CCS domain.
- The utilized specialized CCS tracer has a high-resolution detection limit (100 ppq = 0.1 ppt). This results in reducing the cost, environmental impact and the carbon footprint dramatically.
- The contractor CCS-tracer is operationally easy to execute and has a small operational footprint.
- Once the pilot has proven successful, this technology will be expanded for other upcoming projects.

*"The CO_2 tracers are considered the **most accurate** method to confirm any CO_2 leakage through the cap rock"*

ADNOC (SPE-222348 presentation, ADIPEC 2024)

Conclusions

- Tracer technology is a no-risk, high-sensitive MMV technology that will enable detection of seeps or leaks of CO_2

- Tracer technology serves multiple MMV objective
  - Legacy well monitoring
  - Cap rock integrity
  - Unique labels to CO_2 plumes
  - Early warning

- Technology is proven during 18 years of monitoring for the In Salah gas project

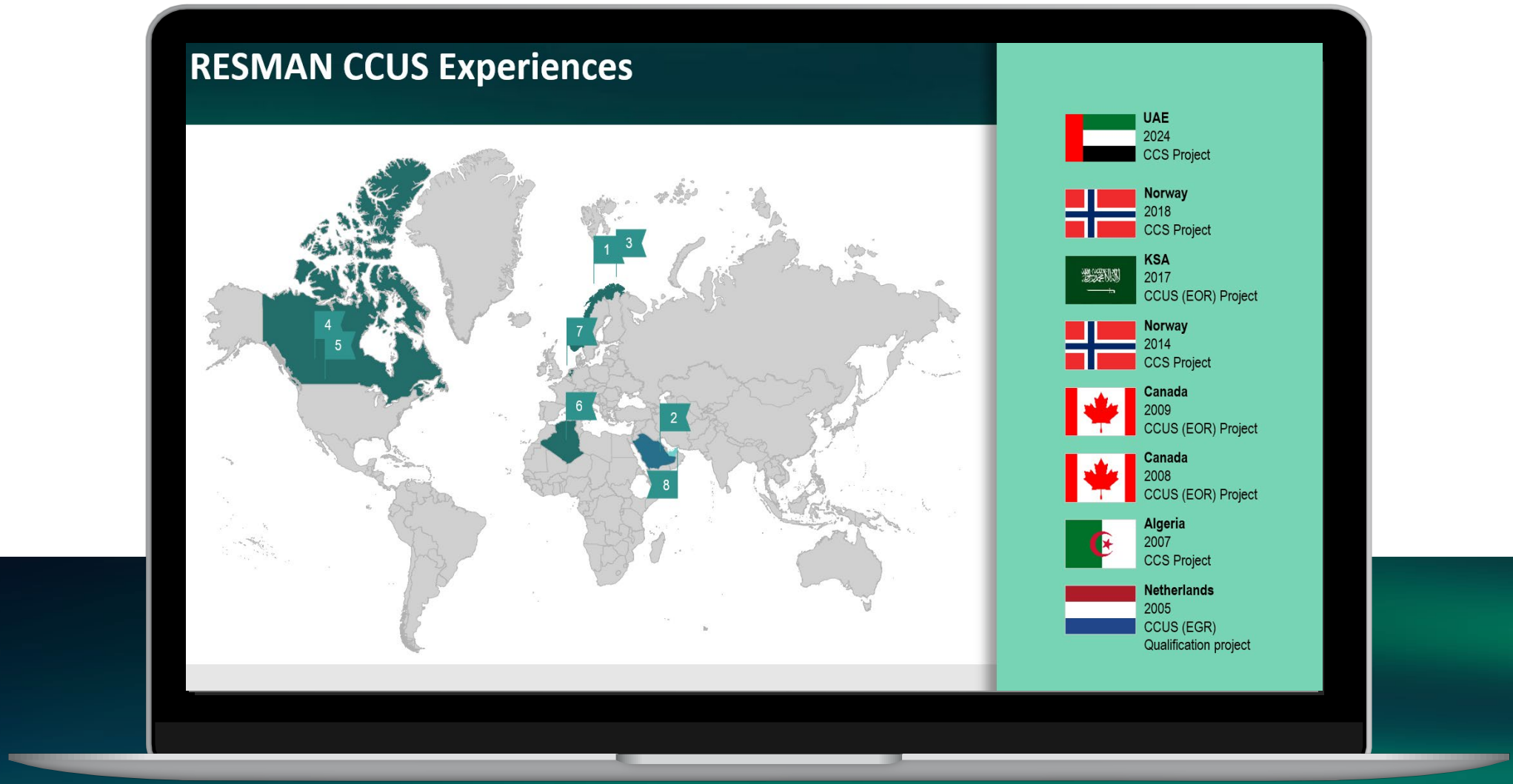
- Technology is scalable for industry scale project of 1-5 Mtpa per well with reasonable tracer amount

Seabed bubble collectors

Active gas samples

Soil sampling wells

Q&A


RESMAN CCUS Experiences
1
3
4
5
7
6
2
8
UAE
2024
CCS Project
Norway
2018
CCS Project
KSA
2017
CCUS (EOR) Project
Norway
2014
CCS Project
Canada
2009
CCUS (EOR) Project
Canada
2008
CCUS (EOR) Project
Algeria
2007
CCS Project
Netherlands
2005
CCUS (EGR)
Qualification project

THANK YOU

SEEING IS BELIEVING

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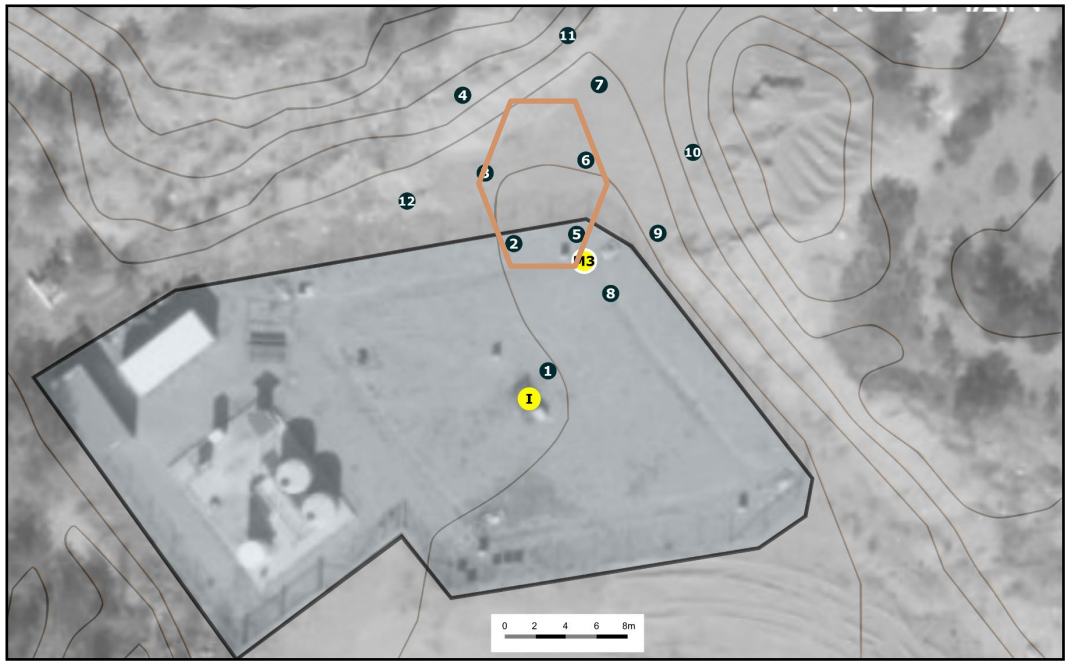
BACKUP SLIDES

SVELVIK TESTLAB (NORWAY) OPERATED BY SINTEF

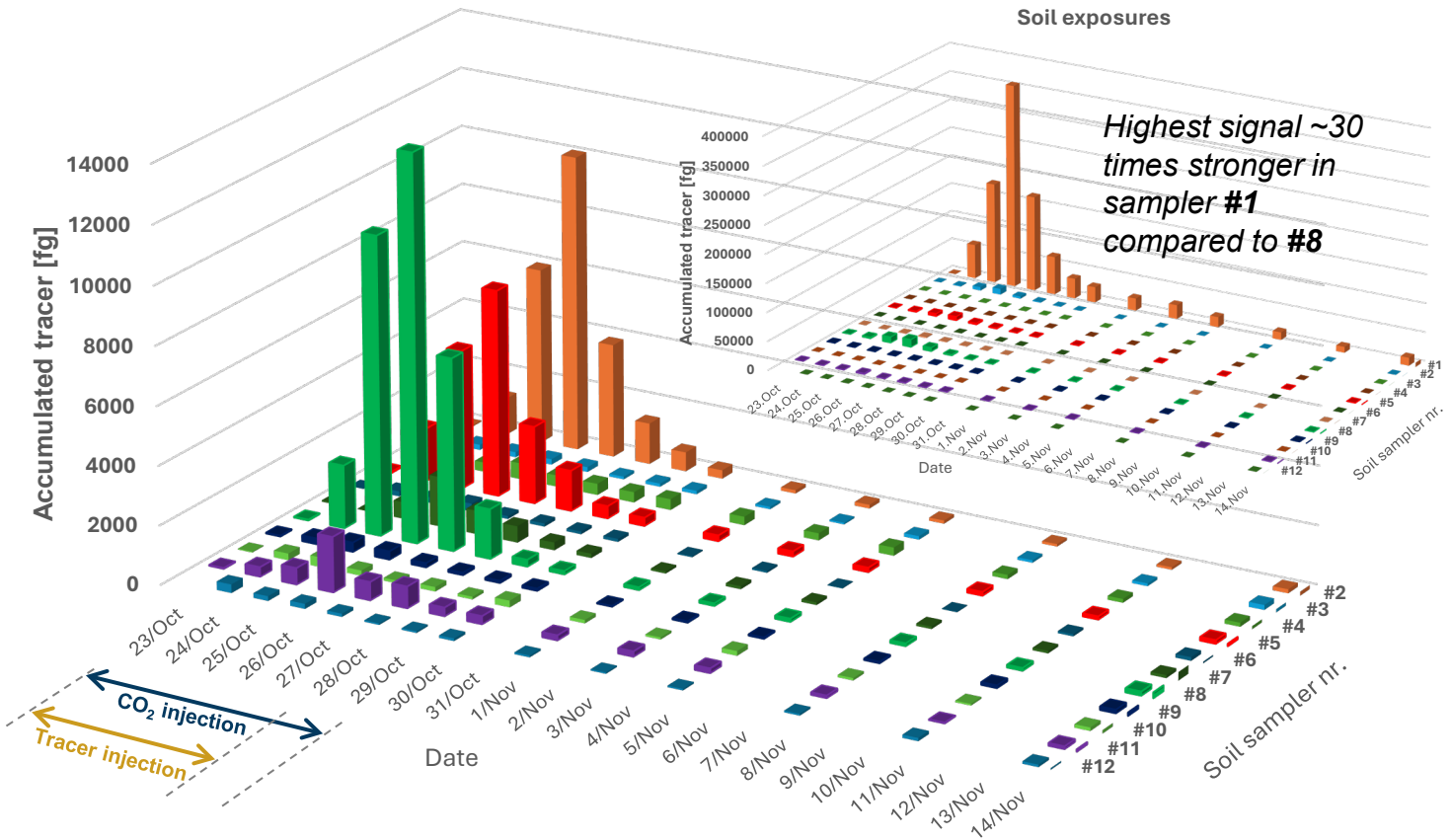


Estimated plume accumulation from previous seismic surveys

- Small scale field lab
  - Well distances ~10 m
  - CO_2 injected at 65 m depth
  - No caprock, glacier deposited sand with some minor mud layers at ~37 m depth
  - Water saturated up to 0.5-1 meter below surface
  - 4 electromagnetic monitoring wells equipped with fiber
- 12 shallow soil sampling wells installed for tracer monitoring, placed based on previous experience of subsurface plume development
- Soil sampling wells perforated just above the water level
- Soil sampling wells equipped with adsorption tubes designed to capture tracer

TRACER DETECTION PATTERN – INITIAL RESPONSE

*The CATs were exchanged according to a pre-planned schedule lasting for **2.5 months**.*



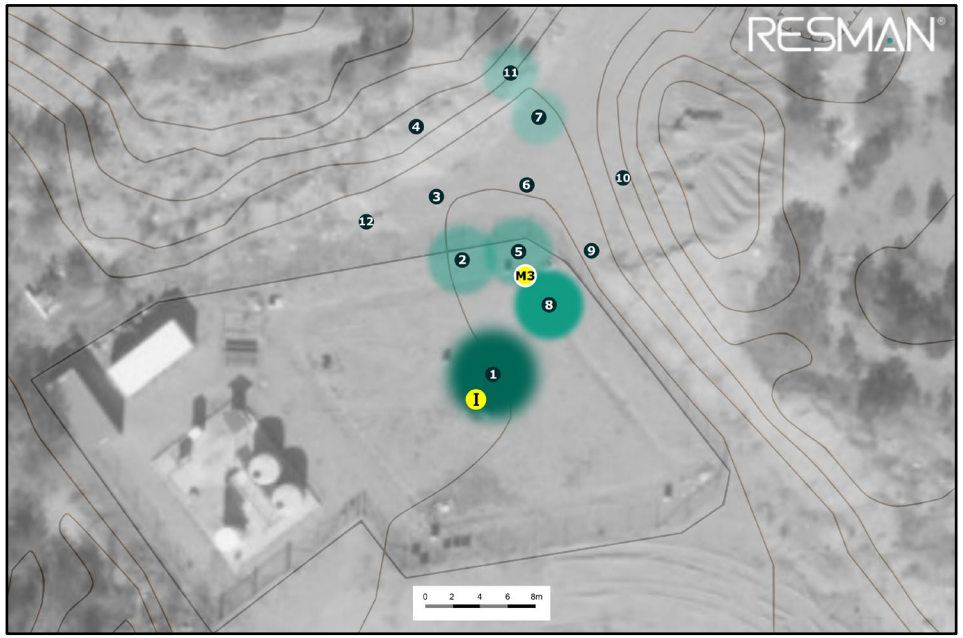


Figure 5. Observed tracer signal as represented by green shadows over the soil sampler positions after 3 days of injection.

- A rapid rise in tracer signal was observed in samplers close to the injection well (**2**, **5** and **8**) peaking after three days of tracer injection
- Soil sampler **#1** directly adjacent to the injection well experienced significantly higher tracer levels compared to the other wells
- Tracer was detected up to 21 m away from the sampling injection well within one day of injection (sampler **#7** and **#11**, fig. 5)