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Stanford | Doerr School of Sustainability
Energy Science & Engineering

California: State and Focused Project

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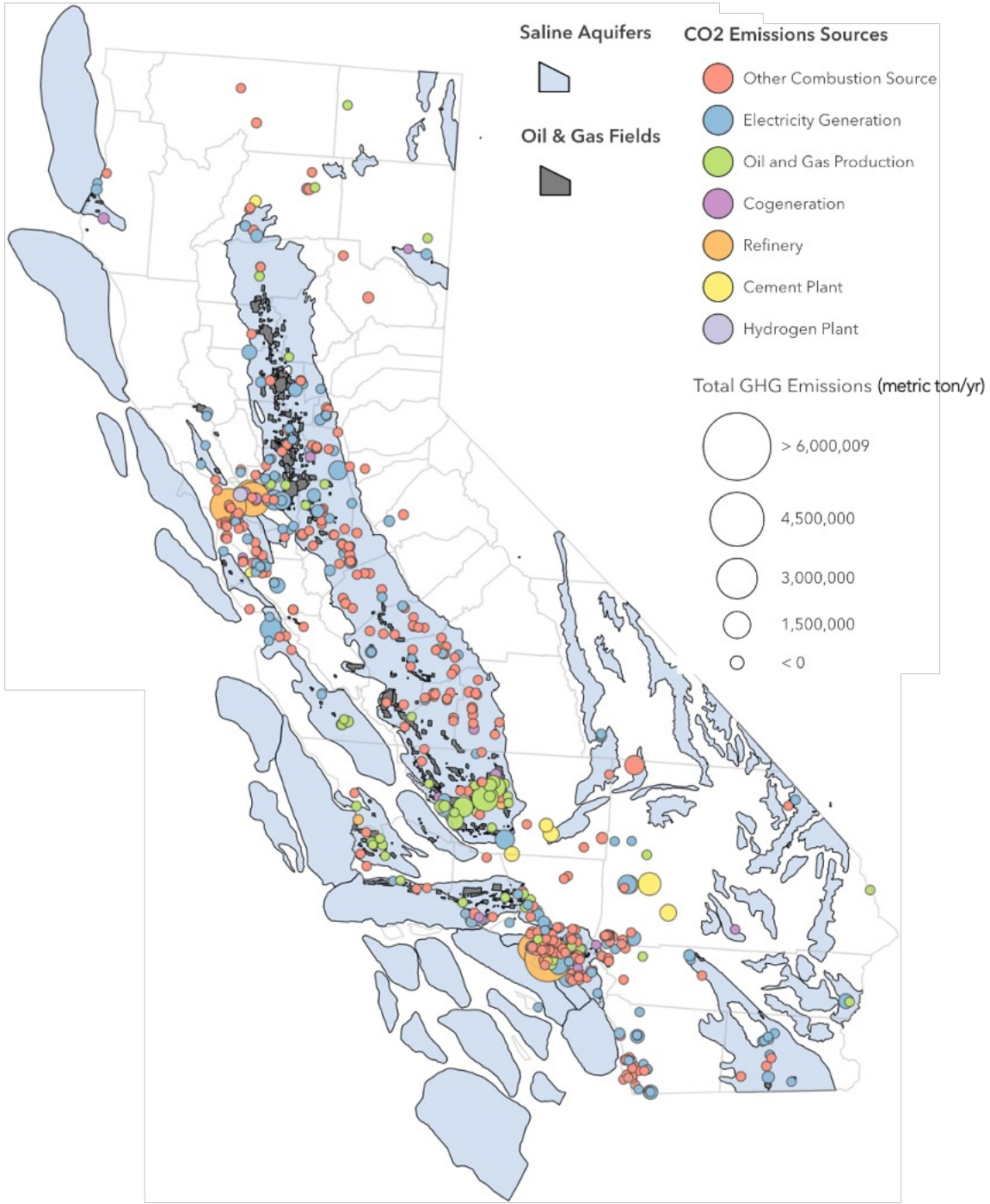
Project Management

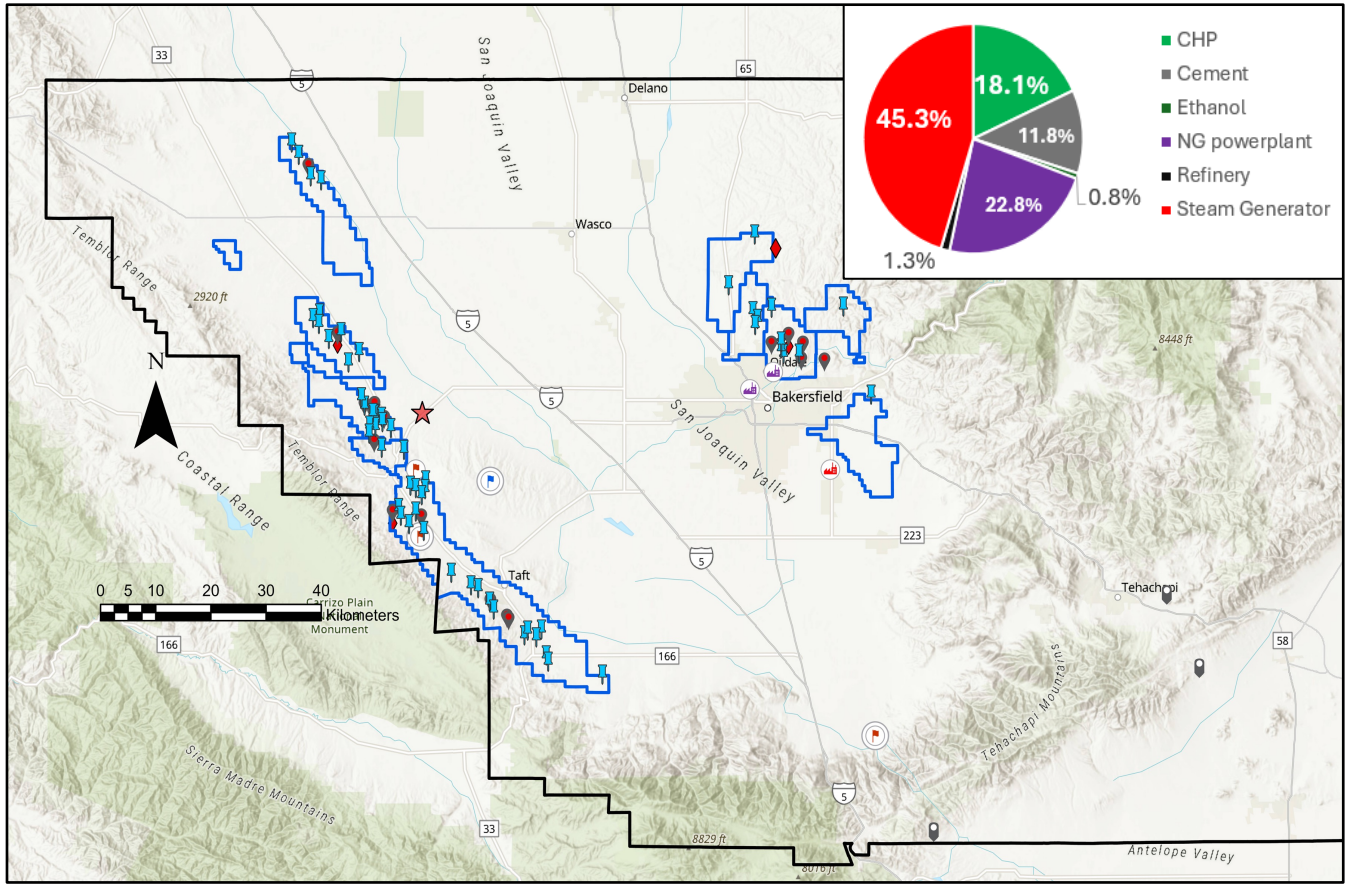
- California General (100%)
  - statewide data collection and technoeconomics
  - data analysis (targets of opportunity)
  - stakeholder engagement
- Focused Project (96%)
  - provide technical and economic analysis to support a first-of-its-kind capture and storage project aimed at reducing emissions from upstream oil production operations
  - add certainty to storage volumes and dynamic storage capacity of relatively poorly characterized saline formations in the SJV
  - lay the foundations of a regional storage hub

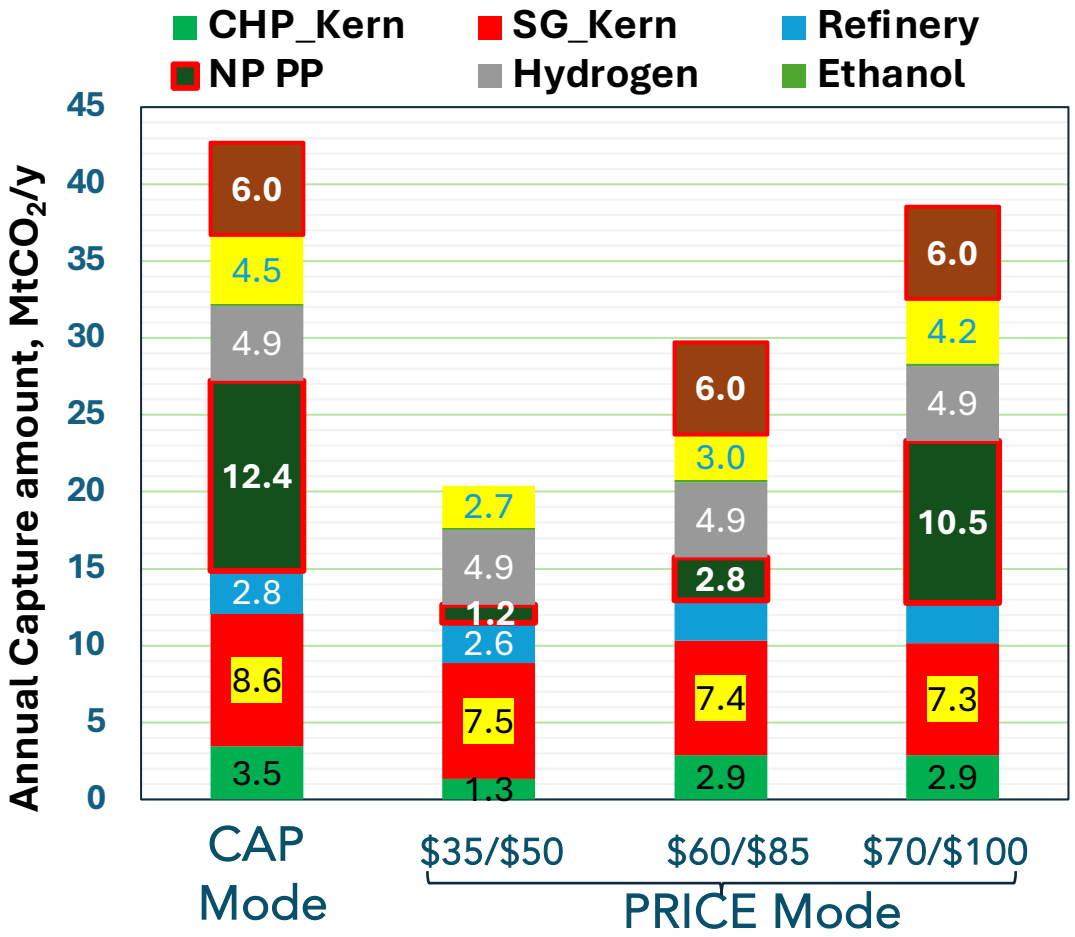
Outline

1. Project management
2. Geolocation of distributed emitters
3. Subsurface model
4. Storage assessment
5. Plume migration
6. Field project
7. Risk assessment
8. Industrial engagement
9. Forward looking scenarios



Geolocation of distributed emitters in Kern Co.



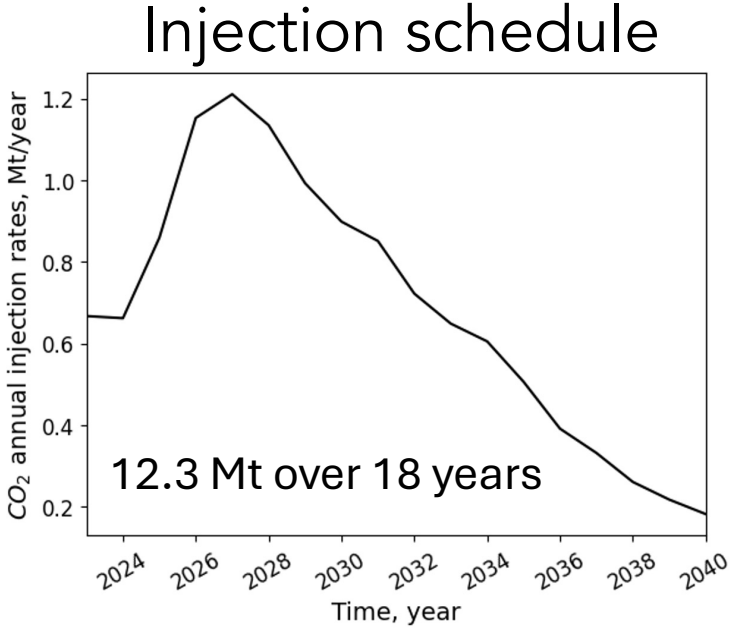


- 19.1 $MtCO_2/y$ in Kern Co
- 12.1 $MtCO_2/y$ thermal EOR

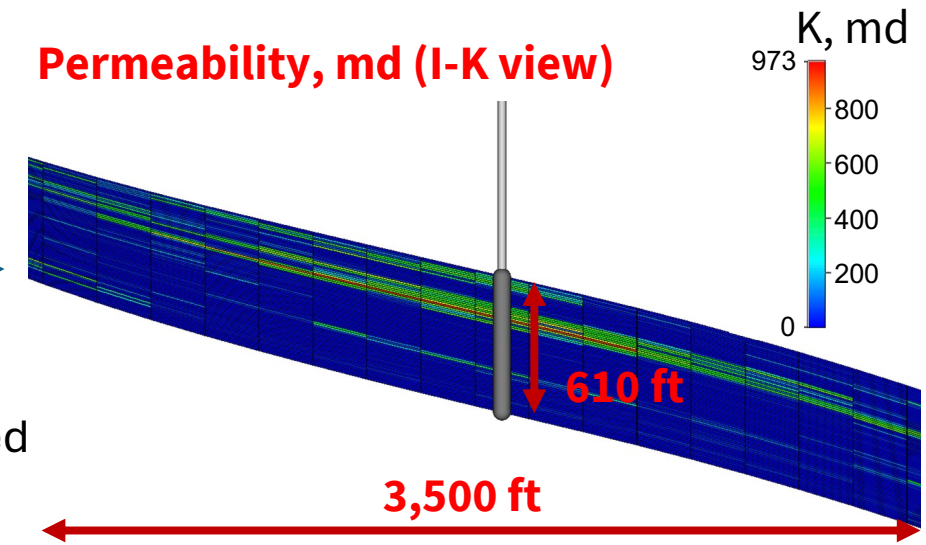
- SIMCCS affirms significant capture potential and economic value

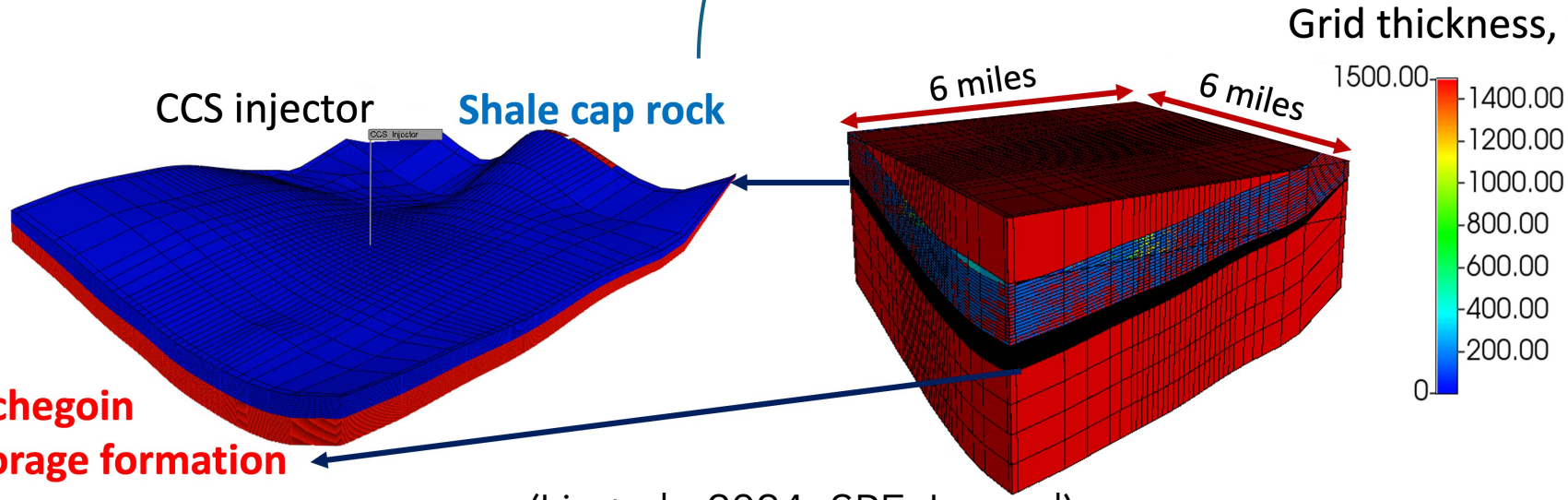
(Kim et al., 2023, IJGGC)

Subsurface model of Western Kern Co. site



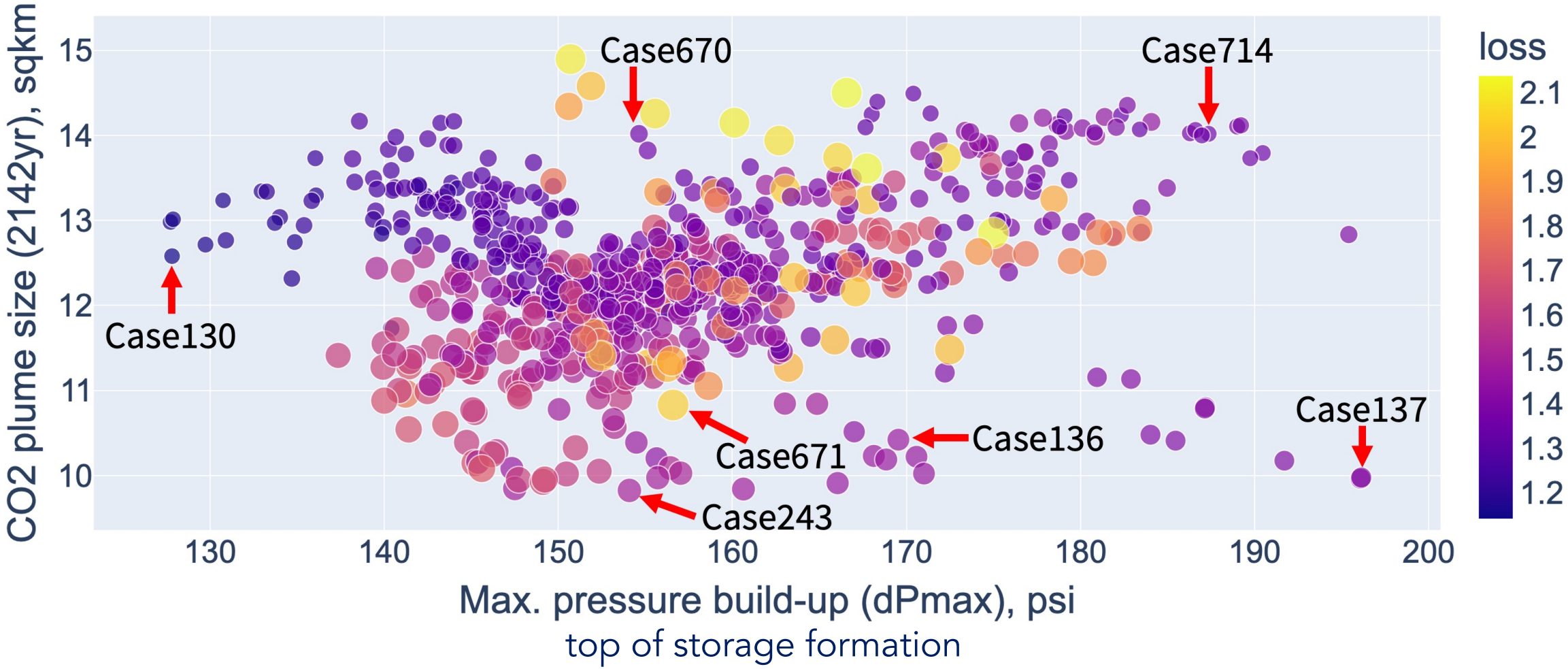
2-way coupled flow and mechanics





(Li et al., 2024, SPE Journal)

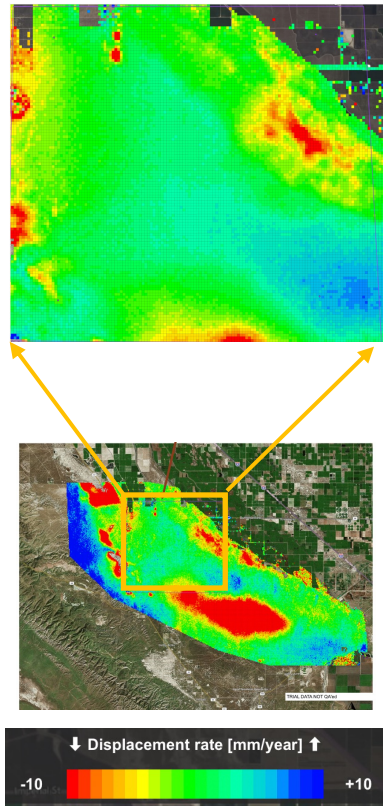
Storage site assessment—injector design



(Li et al., 2024, SPE Journal)

Plume migration and land uplift for MMV

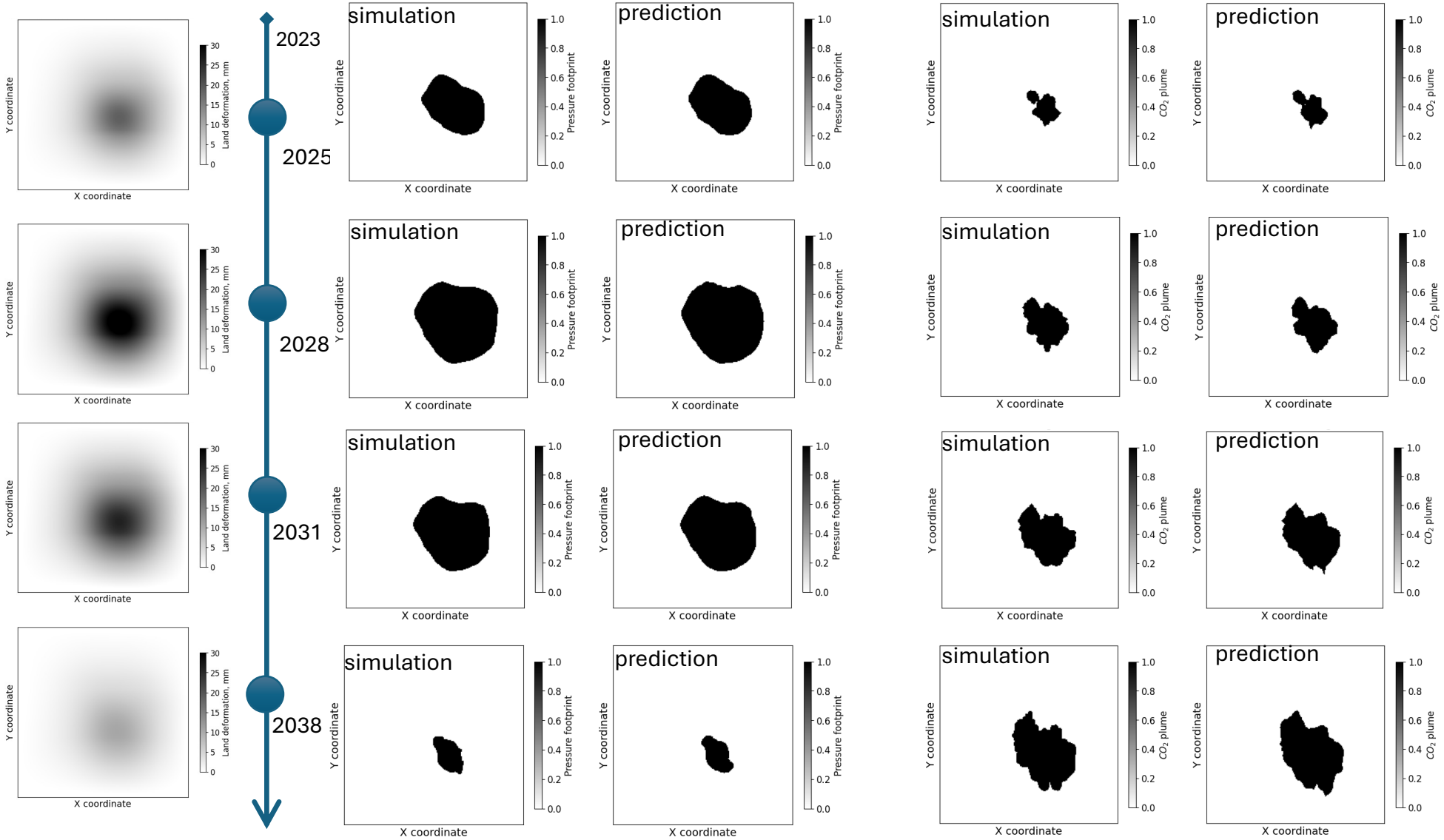
InSAR observation



Land uplift

Pressure footprint

CO_2 plume



Site Specific Scenarios

Carbon Solutions ran **12** unique scenarios using the proposed storage location as the only storage option

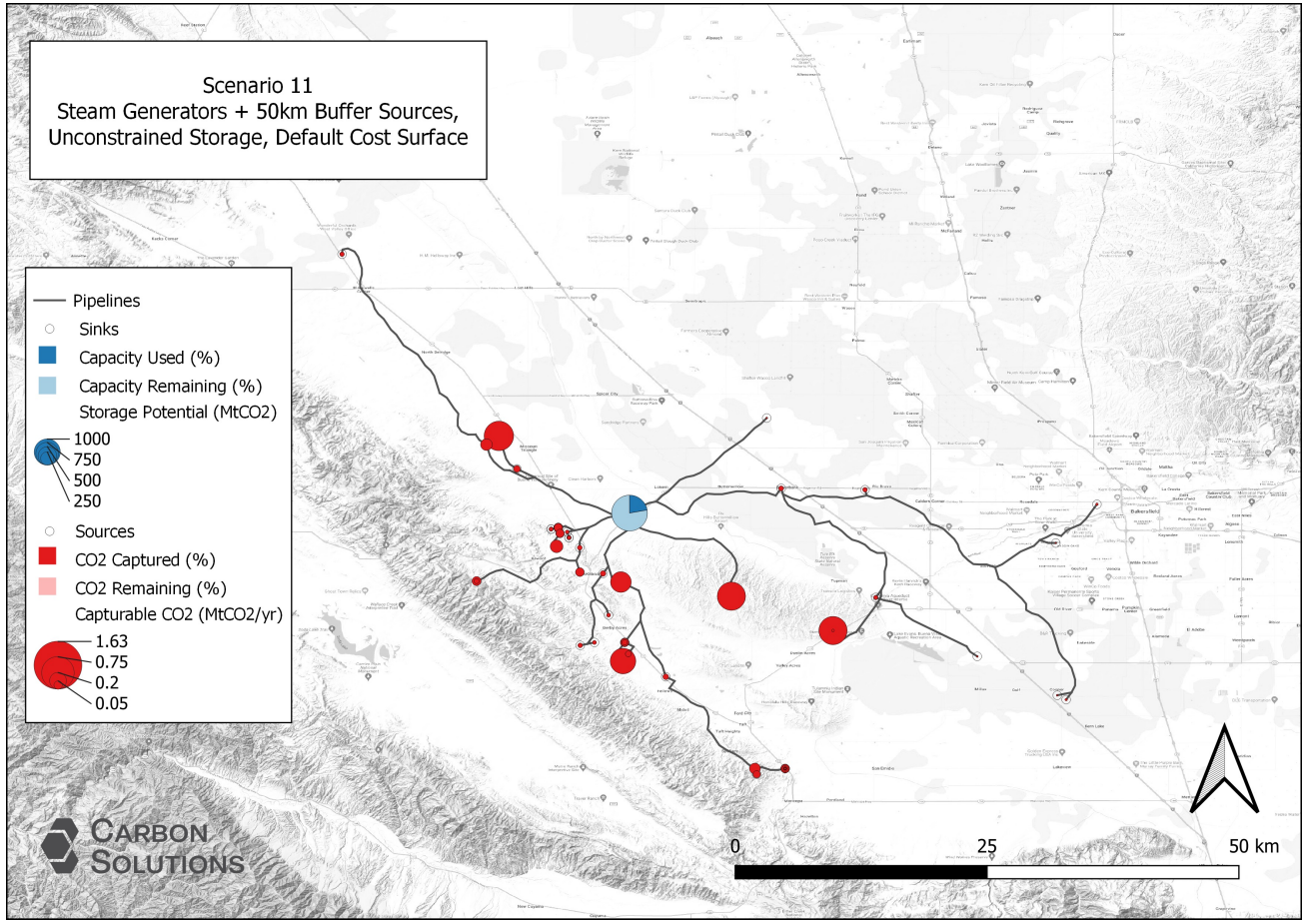
- Two different sets of scenarios using constrained and unconstrained storage capacity

For each sets of storage scenarios different sets of sources:

- Steam generators only
- Steam generators + sources in different buffer ranges (10km – 65km)

A 30-year project duration for storage capacity and 10-year financing were used

Good potential for regional storage hub

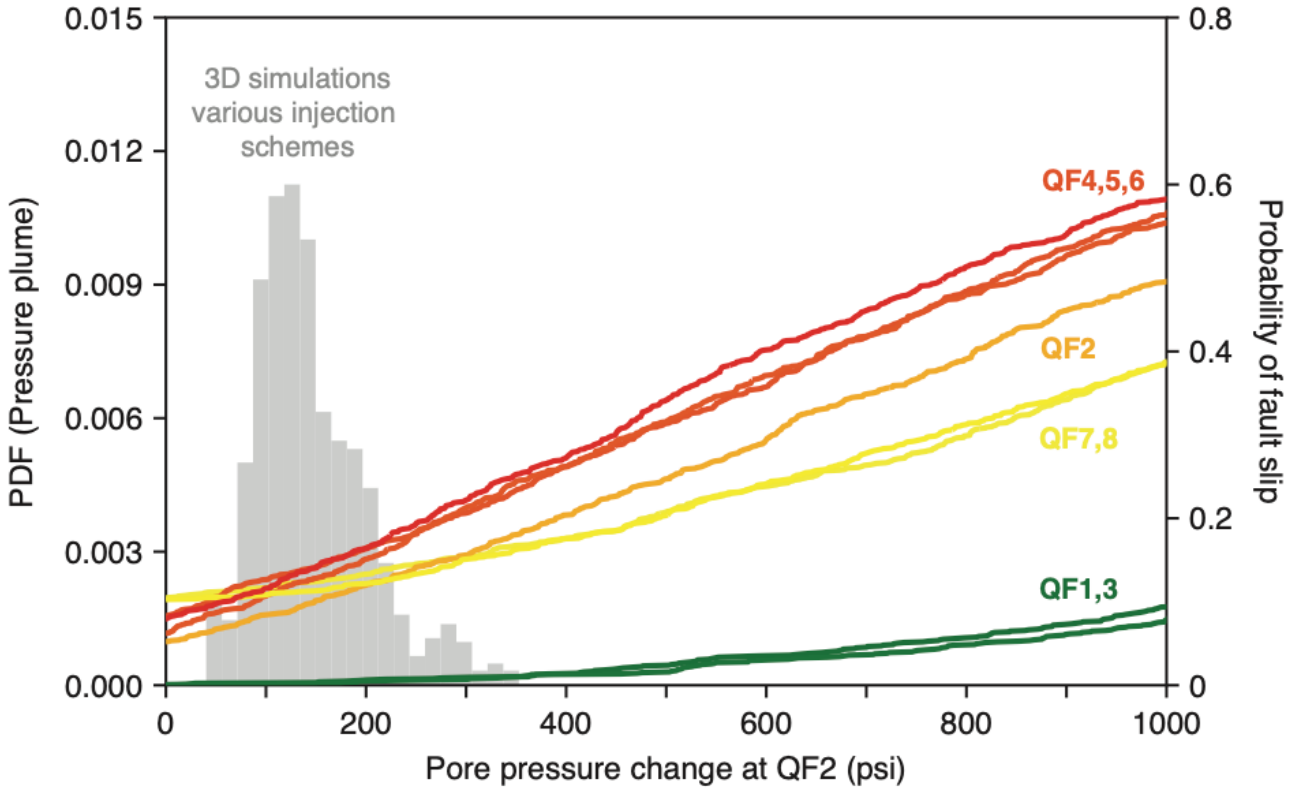


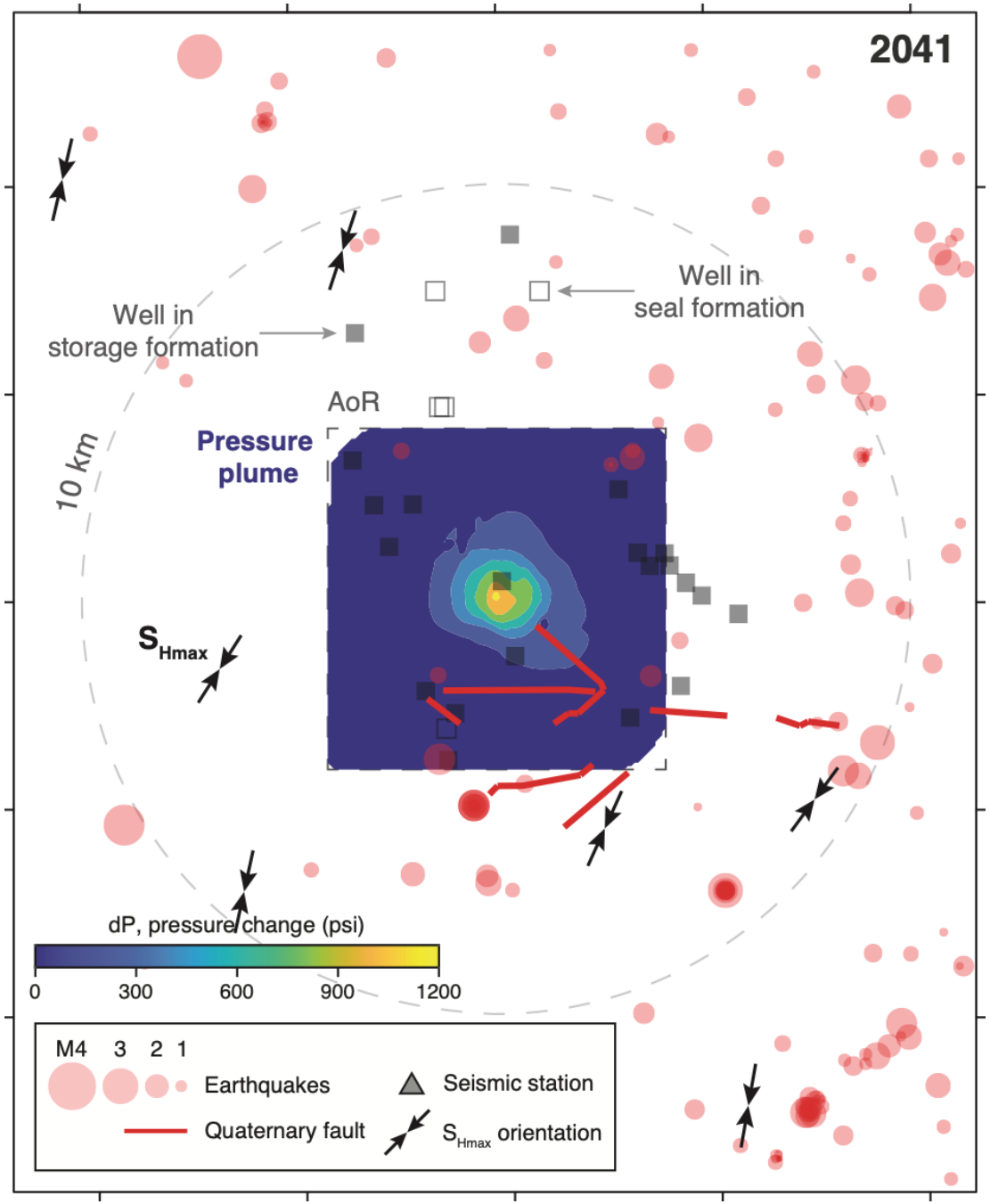
Site Specific Scenario Summary

Scenario	Project	Capital Recovery Factor	Annual CO_2 Stored ($MtCO_2$/yr)	Number of Captured Facilities	Number of Utilized Sinks	Length of Pipeline (km)	Capture Unit Cost ($/t$CO_2$)	Transport Unit Cost ($/t$CO_2$)	Storage Unit Cost ($/t$CO_2$)	Unit Cost ($/t$CO_2$)
1	30	0.1627	0.78	11	1	44.36	64.95	7.23	5.30	77.48
2	30	0.1627	0.79	1	1	17.69	64.45	4.58	5.30	74.34
3	30	0.1627	0.79	1	1	17.69	64.45	4.58	5.30	74.34
4	30	0.1627	0.79	1	1	17.69	64.45	4.58	5.30	74.34
5	30	0.1627	0.79	1	1	17.69	64.45	4.58	5.30	74.34
6	30	0.1627	0.79	1	1	17.69	64.45	4.58	5.30	74.34
7	30	0.1627	0.78	11	1	82.09	64.96	4.18	5.30	74.45
8	30	0.1627	5.67	28	1	132.49	66.27	3.67	5.30	75.25
9	30	0.1627	7.35	39	1	190.82	66.05	4.26	5.30	75.62
10	30	0.1627	7.39	42	1	251.45	66.06	5.40	5.30	76.78
11	30	0.1627	7.42	46	1	300.66	66.04	6.62	5.30	77.97
12	30	0.1627	8.83	67	1	509.11	65.96	9.52	5.30	80.78

Risk Assessment: Induced Seismicity

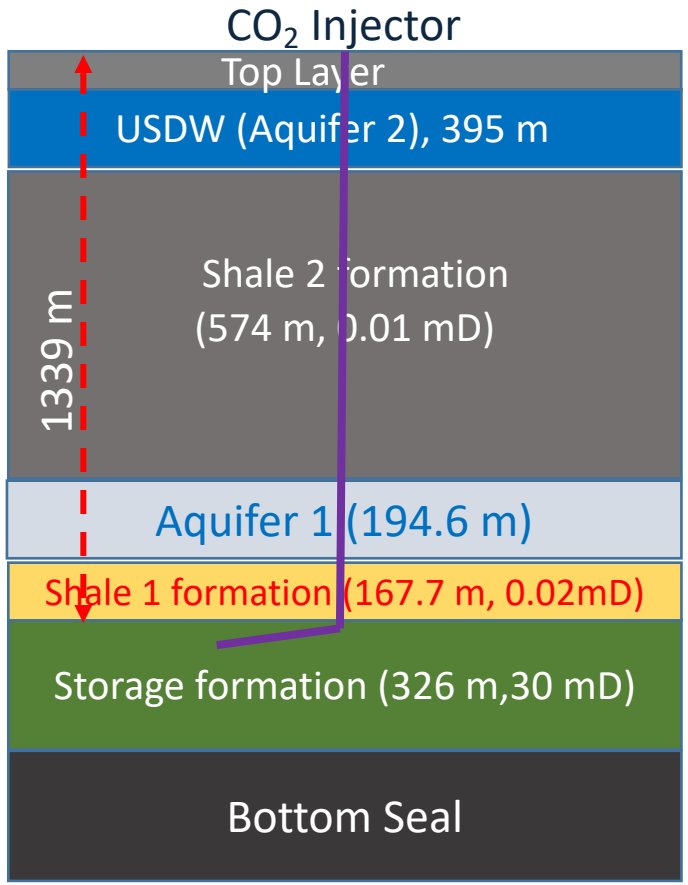
- Mapped faults, earthquakes and stress data
- Built stress model for storage reservoir at depth
- Probability of slip <0.2 on closest active fault (QF2)
- Metrics to distinguish natural vs induced earthquakes



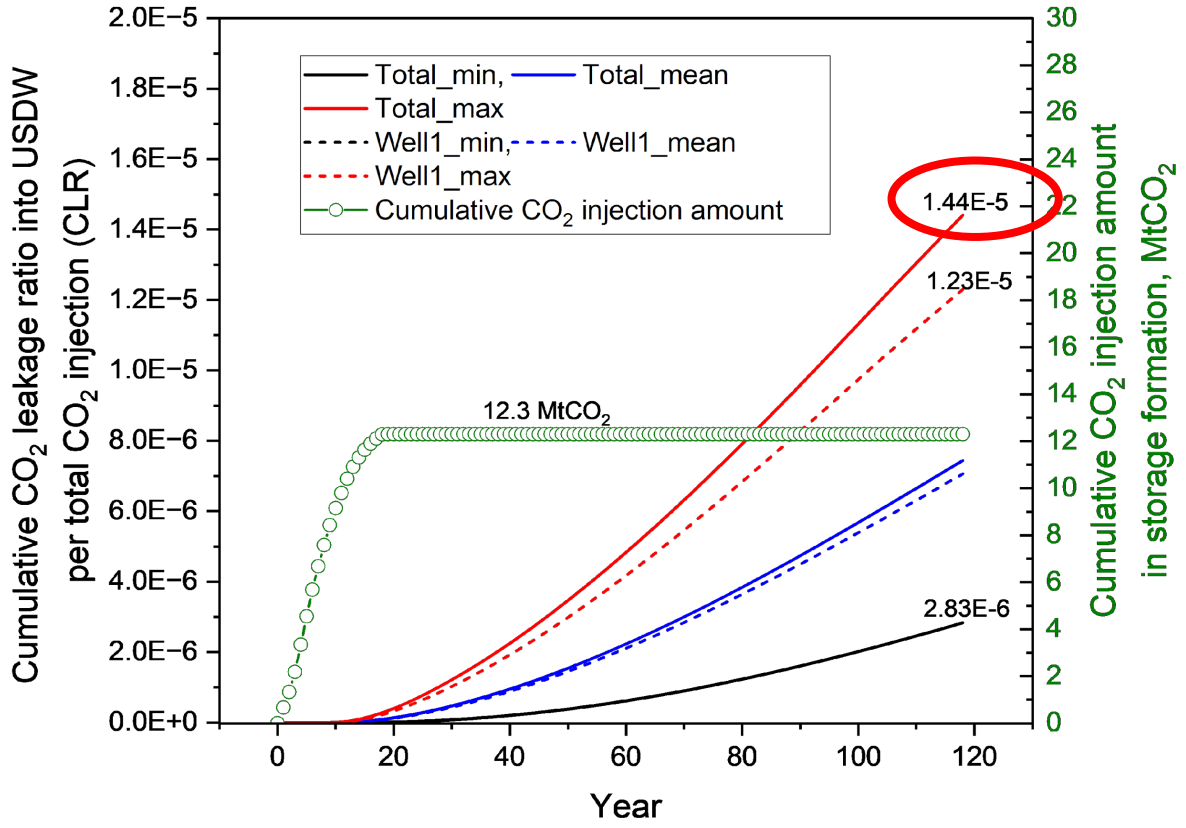


Risk Assessment: Leakage Risk

- NRAP-OPN-IAM Tool & Optimized simulation results w/deviated injector
- Assess leakage rates of CO_2 and brine into the USDW
- Main leakage path: Existing wellbores1 and 2 (Wellbore Perm.: 1- 10 mD)
- CO_2 leakage through QF was negligible



$$CLR = \frac{Cumulative\ leakage\ of\ CO_{2,mass}\ into\ USDW}{Total\ injected\ CO_{2,mass}\ in\ storage\ formation}$$



(Kim et al., 2024)

Industrial engagement

- 22 project meetings with partner Sentinel Peak Resources
- 4 Society of Petroleum Engineers proceedings papers and presentations
- Presented project at 2023 Energy Solutions Week, Stanford University
- Moderated the panel session ‘GHG Mitigation in the upstream oil and gas industry’ at the 2022 Society of Petroleum Engineers Western Regional Meeting in Bakersfield CA on April 27

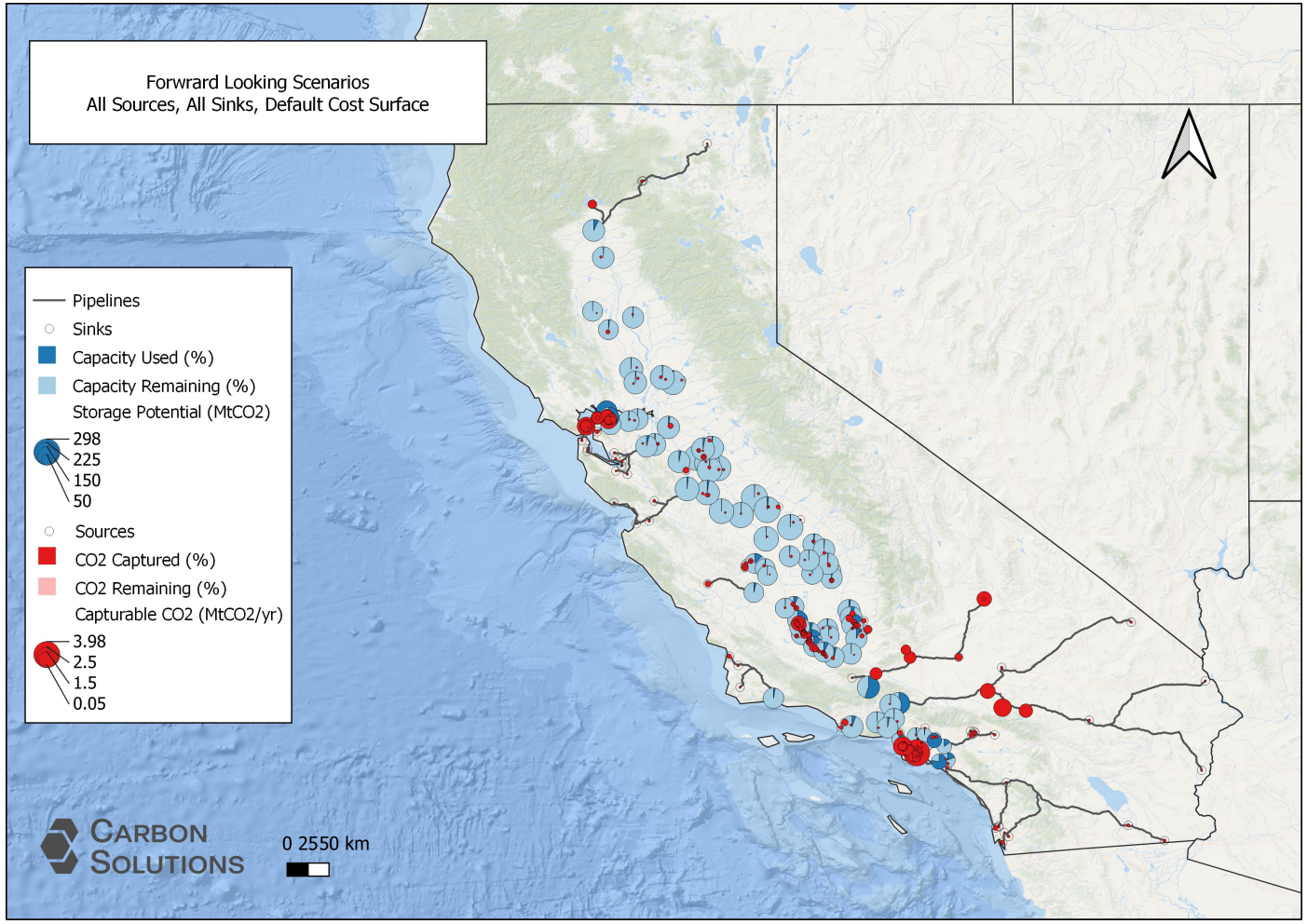
Forward Looking Scenarios

Explore CCS networks that use either distributed or hub storage options in California

Scenarios exploring capturing from all sources of CO_2 and using only steam generators located in Kern County

A 30-year project duration for storage capacity and 10-year financing were used

Future work evaluating what percent of CCS networks interacts with environmental justice communities



Forward Looking Scenario Summary

Scenario	Project Length	Capital Recovery Factor	Annual CO_2 Stored ($MtCO_2/yr$)	Number of Captured Facilities	Number of Utilized Sinks	Length of Pipeline (km)	Capture Unit Cost ($/tCO_2$)	Transport Unit Cost ($/tCO_2$)	Storage Unit Cost ($/tCO_2$)	Unit Cost ($/tCO_2$)
Distributed Sinks/ All Sources	30	0.1627	51.55	246	80	3358.49	68.29	26.81	6.91	102.01
Distributed Sinks/ Steam generators	30	0.1627	8.64	63	13	218.10	64.38	3.87	6.88	75.13
Hub Sinks/ All Sources	30	0.1627	51.55	246	3	5143.38	68.29	33.79	6.63	108.71
Hub Sinks/ Steam Generators	30	0.1627	8.64	63	1	616.78	64.38	10.75	6.85	81.98

Papers and Presentations

- Li, Y, O,Neal, R., Whitezell, M., & Kovscek, A. R. (2024). Optimizing Injection Well Trajectory To Maximize Storage Security and Minimize Geomechanical Risk. SPE Western Regional Meeting, Palo Alto CA. To appear *SPE Journal*.
- Kohli, A., Kim, T. W., Li, Y, & Kovscek, A. R. (2024). 3D Seismic Hazard And Leakage Assessment For A Potential CO2 Storage Site In The Southern San Joaquin Basin, CA. SPE Western Regional Meeting, Palo Alto CA.
- Li, Y., Dodds, N., Leezenberg, P., & Kovscek, A. R. (2024, April). Spatial Monitoring of Geological Carbon Storage Progress Using Time-Lapse Satellite Images. In SPE Western Regional Meeting (p. D031S014R004). SPE
- Y. Li. 2024. Dynamic Modeling and Monitoring of Geological Carbon Sequestration Assets. PhD Thesis, Stanford University
- Kim, T. W., Yaw, S., & Kovscek, A. R. (2023). Scoring, ranking, and technoeconomics of carbon capture and storage opportunities in the central valley of California. *International Journal of Greenhouse Gas Control*, *128*, 103968.
- Kohli, A. H., Li, Y., Kim, T. W., & Kovscek, A. R. (2023, December). Risk assessment of leakage and induced seismicity at a prospective CO2 storage site in the southern San Joaquin Basin, CA. In *AGU Fall Meeting Abstracts* (Vol. 2023, pp. H53H-09).
- Li, Y., & Kovscek, A. R. (2023, December). Pilot Scale Geological Carbon Storage and Injection Well Design Optimization. In AGU Fall Meeting Abstracts (Vol. 2023, No. 145, pp. H51X-145).
- Kovscek, A. R., Kim, T. W., Li, Y., & Kohli, A. H. (2023, December). Navigating Subsurface Risk During Geological Carbon Storage: A Case Study from the Southern San Joaquin Basin, California. In AGU Fall Meeting Abstracts (Vol. 2023, pp. H53H-01).
- Kohli, A., Li, Y., Kim, T. W., & Kovscek, A. R. (2023). Induced Seismicity Hazard Assessment for a Potential CO2 Storage Site in the Southern San Joaquin Basin, CA. *GeoHazards*, *4*(4), 421-436.
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- Kim, T. W., Callas, C., Saltzer, S. D., & Kovscek, A. R. (2022). Assessment of oil and gas fields in California as potential CO2 storage sites. *International Journal of Greenhouse Gas Control*, *114*, 103579.
- Kim, T. W., Yaw, S., & Kovscek, A. R. (2022, April). Evaluation of Geological Carbon Storage Opportunities in California and a Deep Look in the Vicinity of Kern County. In *SPE Western Regional Meeting* (p. D011S005R001). SPE.

Acknowledgements

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