Energy Geosciences
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Preliminary Simulations of an Onshore and Offshore CO_2 Well Blowout

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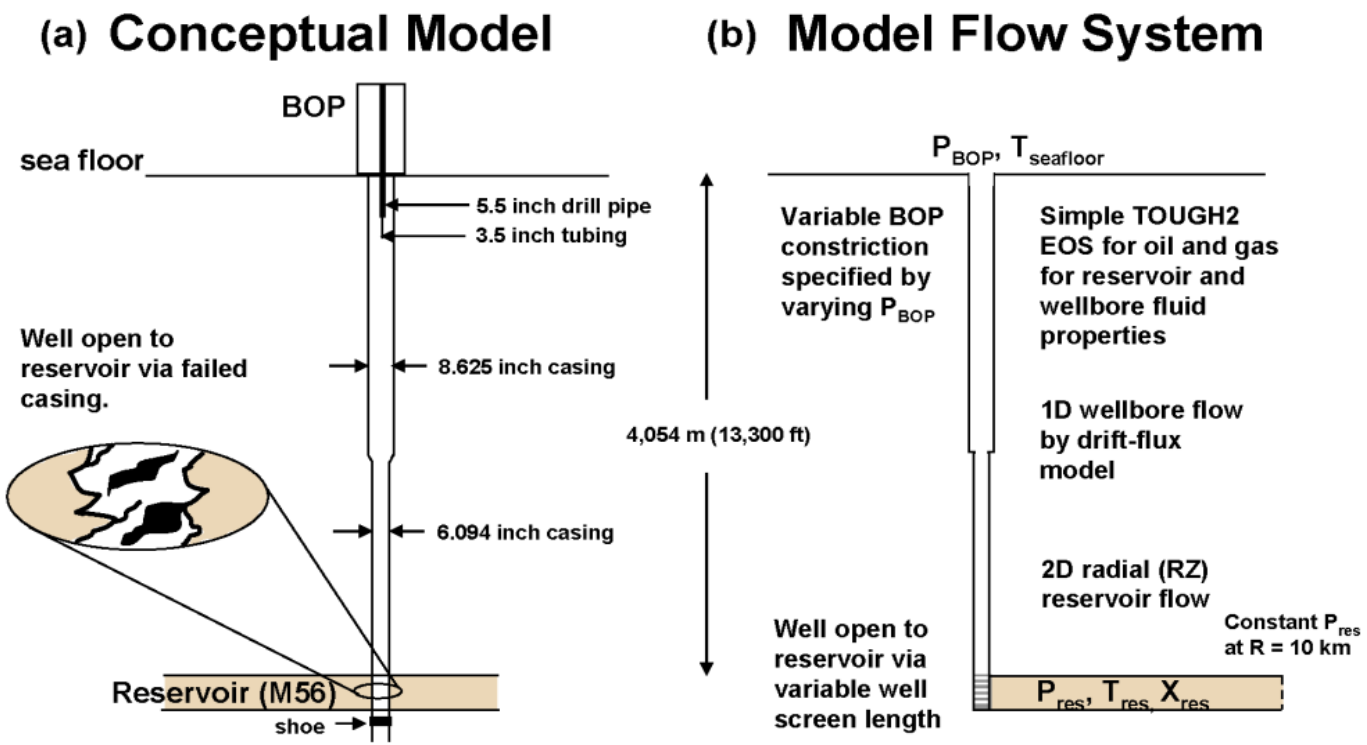
Introduction

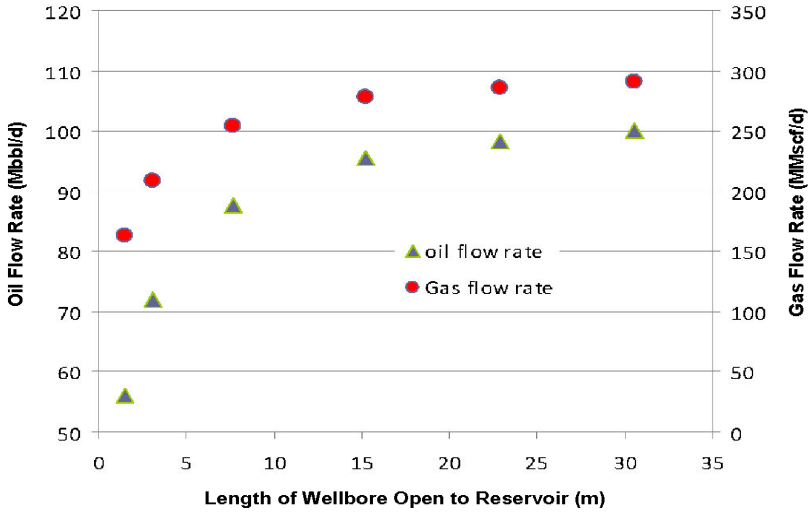
- LBNL has experience and capability in simulating hydrocarbon well blowouts
- We use LBNL's T2Well code to couple reservior and well flow

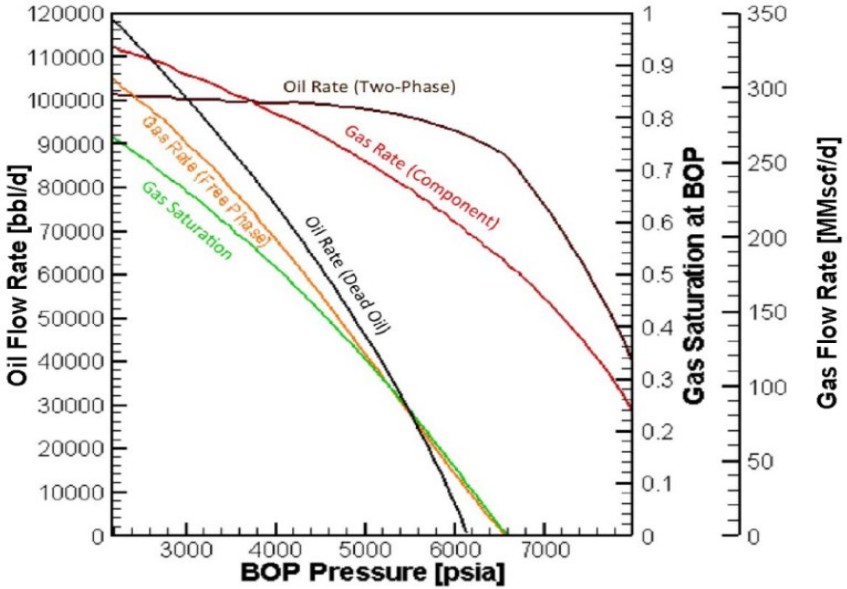
We used T2Well to estimate the 2010 Macondo leakage rate



Effects of unknown properties of the system can be investigated by modeling with T2Well

Effects of size of opening in damaged well and effects of gas exsolution in the wellbore for various BOP pressures.





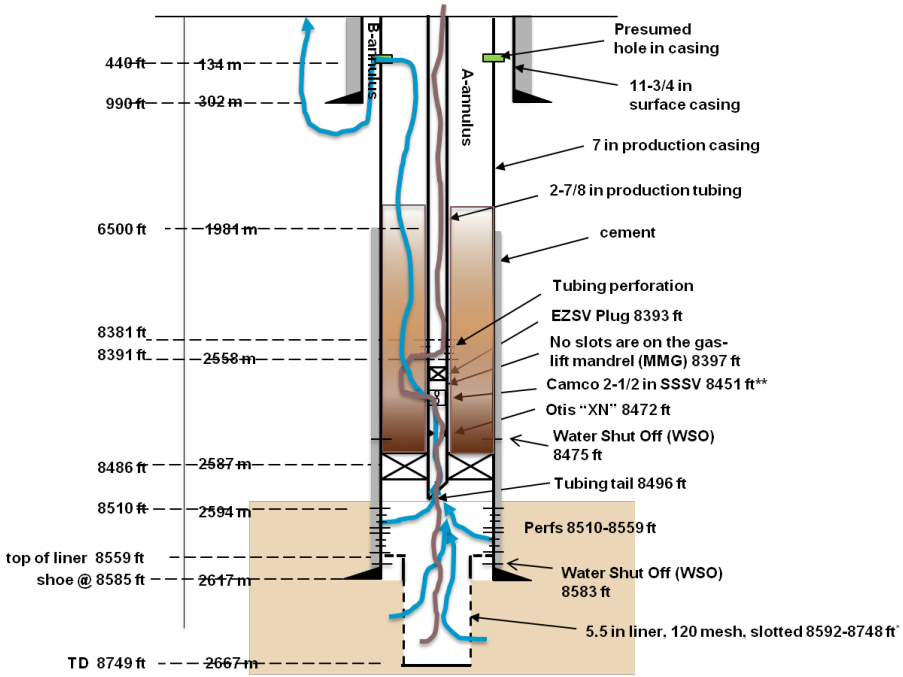
Oil flow rate is also sensitive to the pressure at the bottom of the BOP, with gas exsolution moderating oil flow for lower P_{BOP}. .

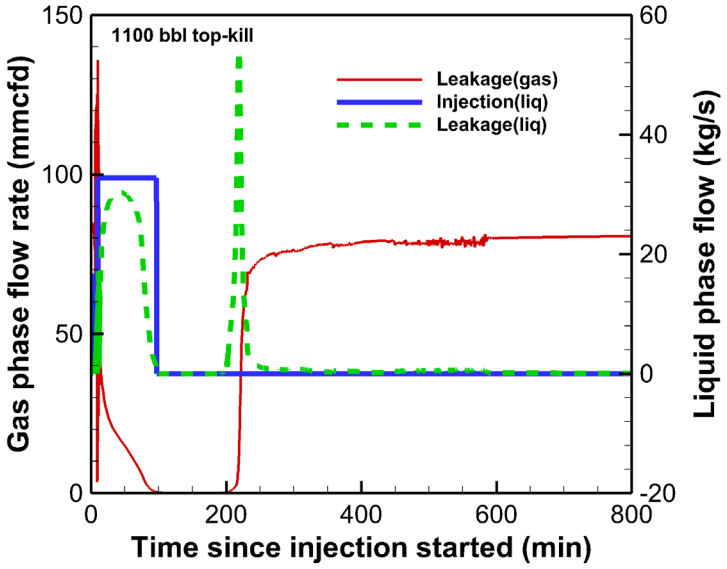
(Oldenburg et al., Proc. National Acad. Sci., 2011).

We used T2Well to understand why the 2015 Aliso Canyon underground gas storage well blowout was hard to kill

http://ktla.com/2016/02/18/socal-gas-porter-ranch-leaking-well-announcement/

The SS-25 well at Aliso Canyon had a complicated flow geometry that made it difficult to accumulate kill fluid in the bottom of the well

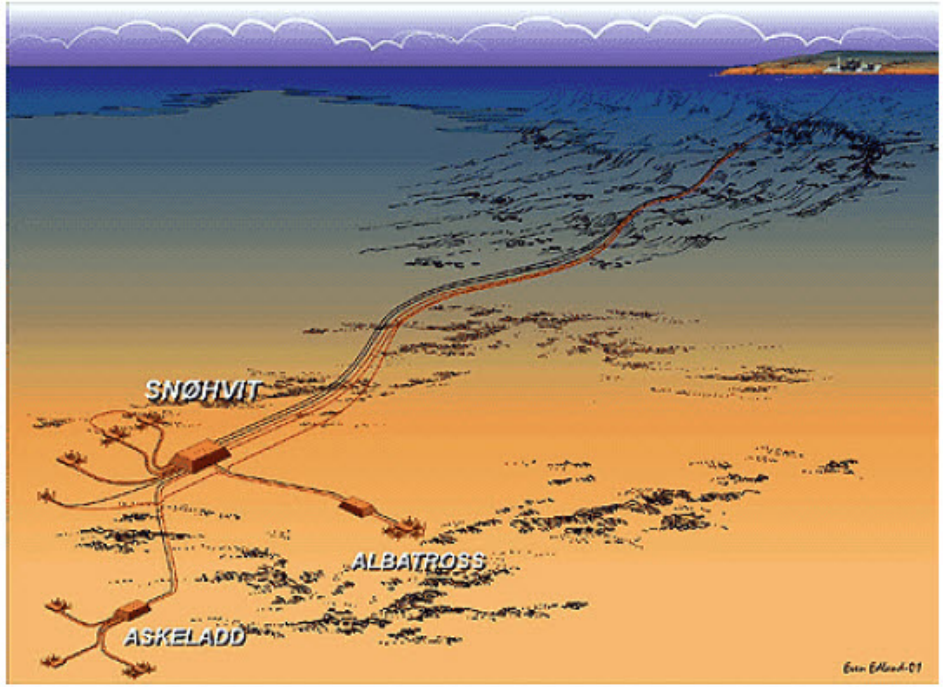




- **1100 bbl top-Kill – the well lays down briefly after 1100 bbl of fluid are injected and then erupts like a geyser.**

Pan, L., Oldenburg, C.M., Freifeld, B.M. and Jordan, P.D., 2018. Modeling the Aliso Canyon underground gas storage well blowout and kill operations using the coupled well-reservoir simulator T2Well. *Journal of Petroleum Science and Engineering*, *161*, pp.158-174.

Offshore CO_2 wells have overpressure at wellhead provided by the water column

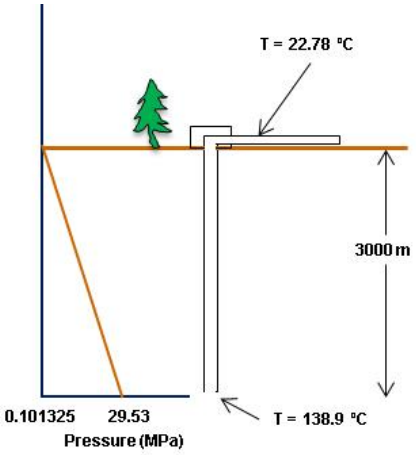


https://hub.globalccsinstitute.com/publications/assessment-capture-and-storage-potential-co2-co-produced-natural-gas-south-east-asia/22-sn%C3%B8hvit

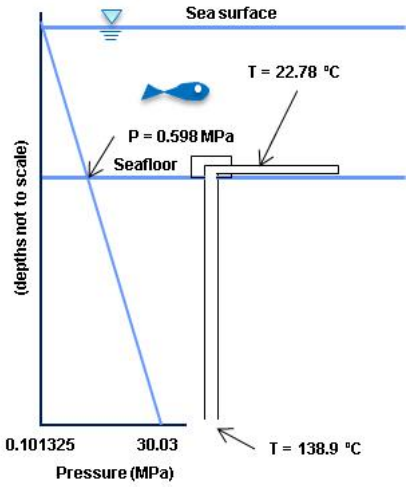
Progress for GoMCarb

- For GoMCarb, we simulated onshore and offshore blowouts of a CO_2 injection well
- The purpose of the study is to understand dynamic multi-phase non-isothermal flow phenomena in CO_2 wells to inform risk assessment studies
- Scenario consists of a vertical CO_2 injection well of 3050 m length
- At time zero, a surface pipe is breached producing a 2-inch diameter hole
- Onshore, CO_2 enters ambient air at 0.101325 MPa and 22.78 C
- Offshore, the blowout is into the water column at a depth of 50 m

We simulated a blowout for the same well-pipeline combination in onshore and offshore environments



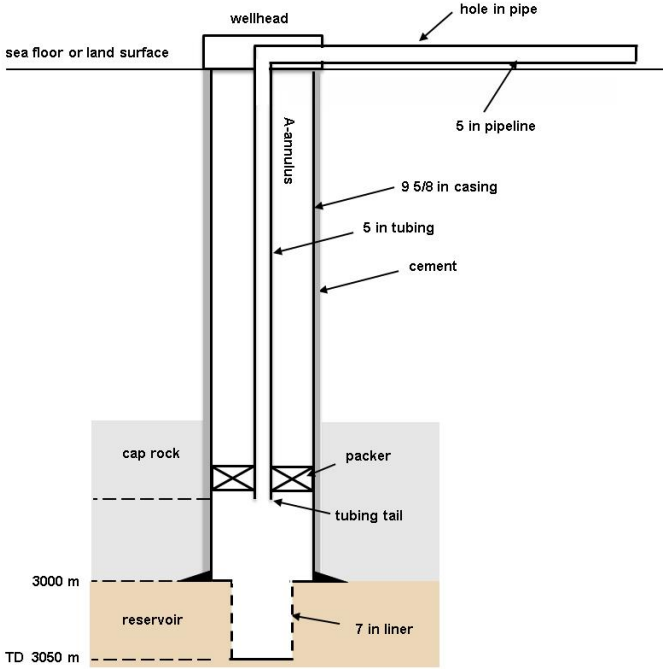
Onshore

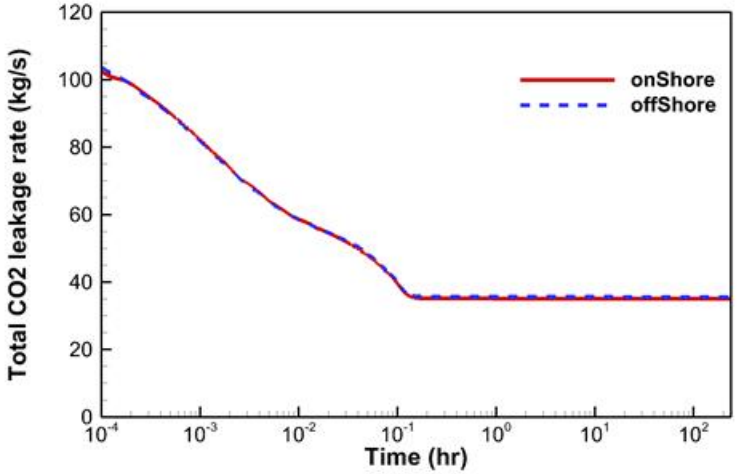


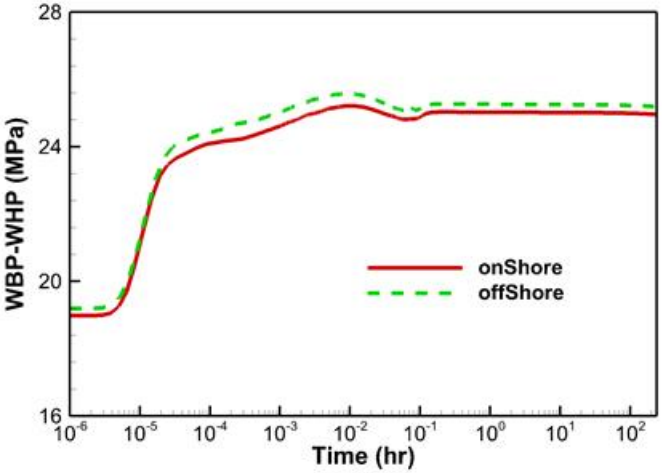
Offshore

Pressures at the wellhead, hole in pipe, and reservoir are the only differences between the two scenarios.

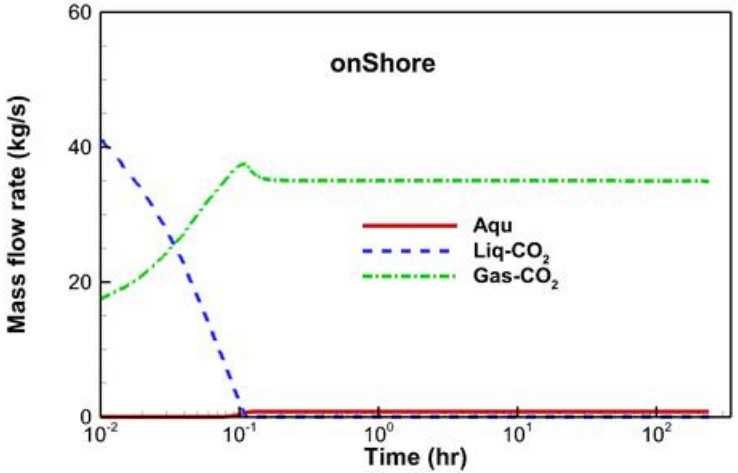
Well detail

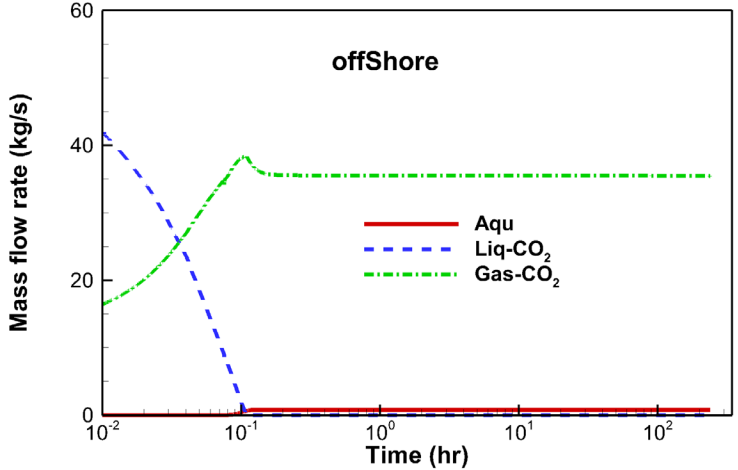






- **The CO_2 blowout flow rate at the 2-in hole is very large early and then plateaus.**
- **The onshore and offshore scenarios are very similar in flow rate and ΔP.**





- The overall leakage is dominated by gas-like CO_2 after a short period (~0.1 hour) of two-phase CO_2 (gas and liquid) conditions, the liquid CO_2 arising from decompression cooling.
- Note there is also a small amount of aqueous phase that travels up the well dissolved in CO_2 which then exsolves near the hole.
- The first-order conclusion of our simulations as shown is that the blowout flow rates for the onshore and offshore scenarios are very similar.

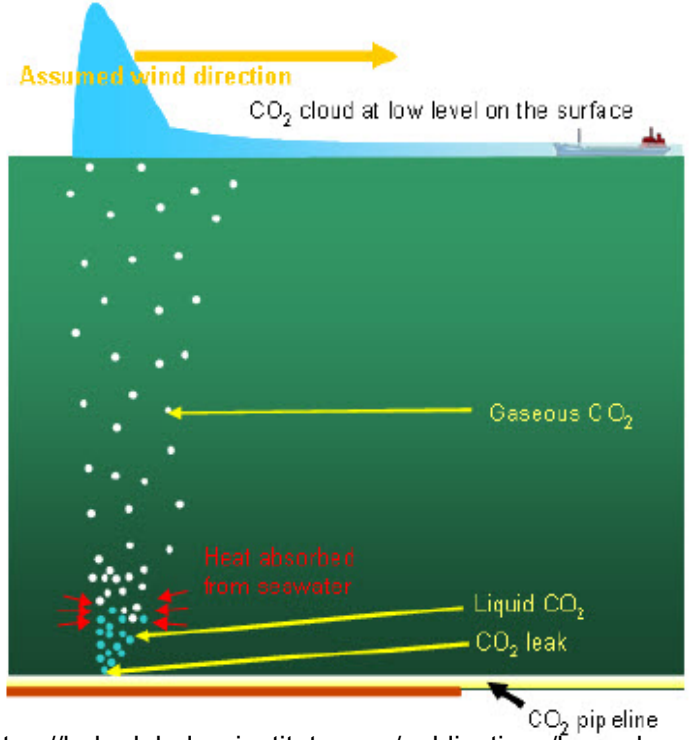
Conclusions

- The simulations show that the overall CO_2 leakage rates are very similar for the onshore and offshore scenarios
- Subtle differences in flow rates of various phases arise from differences in pressure at the leakage point.
- Overall, the main differences between onshore and offshore CO_2 blowouts are expected to arise mostly after discharge due to differences between how CO_2 disperses in ambient air versus in the water column

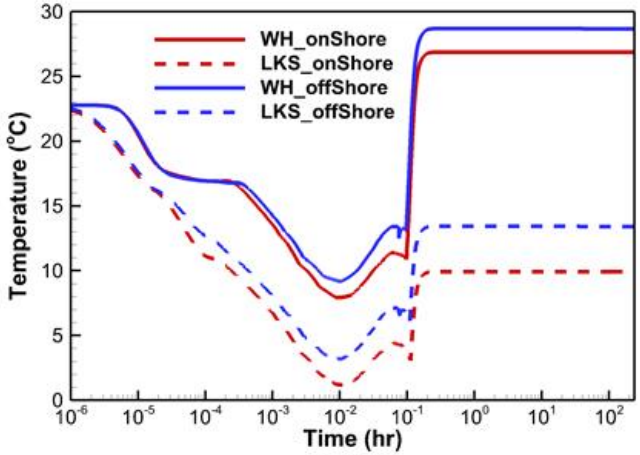
Acknowledgments

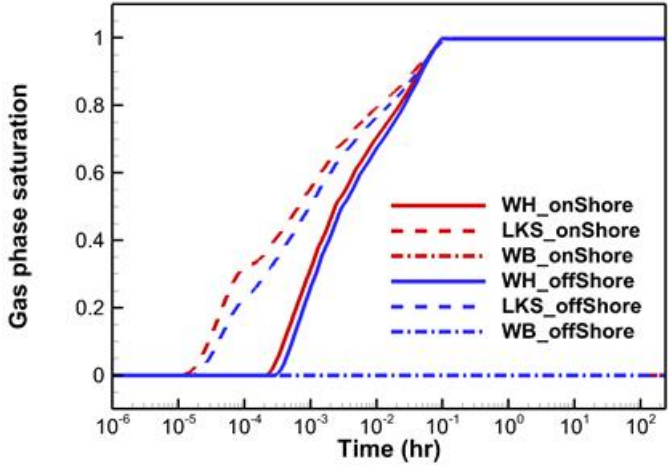
This work was supported by the GoMCarb Project funded by the Assistant Secretary for Fossil Energy (DOE), Office of Clean Coal and Carbon Management, through the National Energy Technology Laboratory (NETL), and by Lawrence Berkeley National Laboratory under Department of Energy Contract No. DE-AC02-05CH11231 .

Sea water column provides overpressure and a vast heat and mass reservoir that affects leaking CO_2



https://hub.globalccsinstitute.com/publications/hazard-analysis-offshore-carbon-capture-platforms-and-offshore-pipelines/37-hazards-associated-co2-releases





- Wellhead temperature drops quickly at the start of leakage and then recovers quickly from heating of the surface pipe by conduction from the surrounding air or seawater after liquid CO_2 disappears.
- The temperature at the wellhead is slightly higher in the offshore case than in the onshore case because the back pressure at the LKS is higher in the offshore case which leads to less expansion cooling.
- Saturation of gas-like CO_2 increases slightly faster in the onshore case than in the offshore case most likely because the pressure is slighty lower in ambient air versus at 50 m water depth.

Properties of the two cases are identical except for wellhead and wellbottom pressure

Table 1.Well component dimensions.

Model element	Value
Surface pipe	ID = 0.10556 m (5 inch tubing), horizontal, with hole located 10 m away from the wellhead
Tubing	ID = 0.10556 m (5 inch tubing), vertical, (0-2900 m)
Casing	ID = 0.2205 m (9 5/8 inch casing, 0 – 3000 m, simulated 2900-3000 m)
Liner	ID = 0.15037 (7 inch liner, 3000-3050 m from surface or seafloor, perforated)
Break in pipe (hole in pipe)	Effective ID = 0.0508 m (2 in) (10 m away from the center of well)
Tubing and pipeline wall roughness	45.72×10^{-6} m

Table 2. Reservoir properties.

Reservoir Properties	
Thickness	50 m
Depth of lowermost cap rock	3000 m
Porosity (ϕ)	0.20
Permeability (k)	1.0×10^{-12} m^2
Compressibility of reservoir formation	8.5×10^{-10} Pa^{-1}
Thermal conductivity of reservoir saturated reservoir formation[4]	2.50 W/(m K)
Heat capacity (C_P) of saturated reservoir	1000 J/(kg K)
Capillary Pressure (P_{cap}) and Relative Permeability (k_r) *Terminology:* m = 1-1/n = power in expressions for P_{cap} and k_r S_{ar} = aqueous-phase residual saturation S_{gr} = gas-phase residual saturation P_{c0} = capillary pressure strength between aqueous and gas phases P_{cmax} = maximum possible value of P_{cap}	van Genuchten[1] P_c and k_r with Corey[2] relative permeability for gas $m_{vG} = 0.457$ $S_{ar} = 0.30$ for P_{cap}, 0.36 for k_r $S_{gr} = 0.05$ $P_{c0} = 1.25 \times 10^4$ Pa $P_{cmax} = 1 \times 10^7$ Pa
Initial pressure	29.53 MPa onshore case; 30.03 MPa in offshore case
Initial temperature	138.9 C Geothermal gradient 38.39 C/km Onshore land surface T = 22.78 °C; Offshore seafloor T = 22.78 °C
Initial saturation	0.1 aqueous saturation; 0.90 CO_2 saturation

[1]van Genuchten (1980)
[2]Corey (1954)

The coupled well-reservoir system is simulated using T2Well which models flow in the well using a three-phase drift-flux model and flow in the reservoir by multiphase Darcy's law.

Pan, L., and C.M. Oldenburg. "T2Well—An integrated wellbore–reservoir simulator." Computers & Geosciences 65 (2014), 46-55.