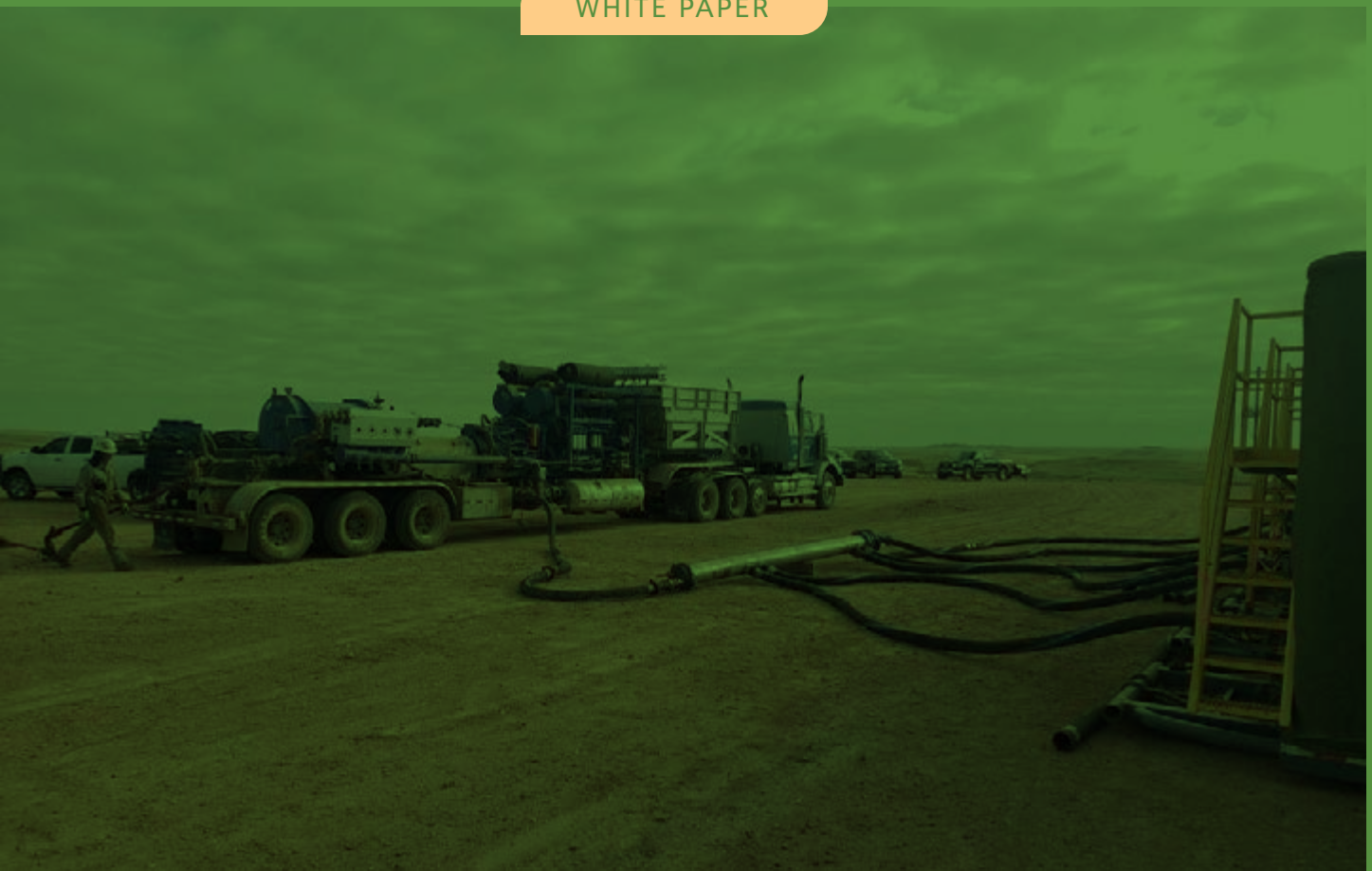
LOCUS Bio-Energy

Unlocking the Oil Left Behind

How Biosurfactant EOR Revives Mature Shale Wells

WHITE PAPER



Executive Summary

U.S. shale operators are entering a phase where maximizing recovery from existing wells is increasingly preferred over drilling new ones. With oil prices limiting capital programs and mature assets declining faster, the industry is shifting toward chemical efficiency as the next lever for production growth. Rigless EOR—especially chemical injection—has gained momentum, but conventional surfactants and solvents consistently underdeliver because they cannot effectively penetrate or persist within the micro- and nanopore networks where most unrecovered hydrocarbons reside.

In mature shale wells, the effectiveness of EOR chemistry is not determined during injection. It is determined after flowback—during dilution, flowback, and sustained contact with the reservoir. This is where most chemical systems fail to deliver lasting recovery. Enhanced oil recovery requires chemistry that maintains molecular-scale impact under real reservoir conditions, long enough to mobilize oil that mechanical interventions cannot reach.

AssurEOR STIM® was engineered to solve exactly this problem. Its ultra-small biosurfactant micelles (3–5 nm) reduce interfacial tension, lower capillary pressure, restore water-wet conditions, and access pore structures conventional chemistries miss. Field deployment in mature Bakken horizontals delivered >70% uplift and >1,700 incremental barrels per well in ~120 days, with <20% water return demonstrating strong reservoir uptake and sustained performance.

In an environment of tight budgets, regulatory scrutiny, and diminishing returns from mechanical optimization, STIM provides a fast-to-deploy, rigless, low-risk EOR pathway that boosts near-term cashflow, extends well life, and materially increases EUR. As refrac economics tighten, operators are increasingly prioritizing rigless chemical EOR pathways that deliver incremental recovery without reopening mechanical risk—or committing new capital.

HIGHLIGHTS

>70% Uplift

Recovery-driven response, not a rate spike

>1,700 bbl Incremental

Mobilized from previously immobile pore-scale oil

No Refrac Required

Rigless chemical EOR via existing infrastructure

<20% Water Return

Evidence of deep reservoir contact

Higher EUR, Flatter Decline

Chemical efficiency changes the recovery curve

Introduction

Mechanical Gains Have Plateaued

The first decade of U.S. shale development was defined by extraordinary gains in mechanical efficiency—longer laterals, precision drilling, advanced pad designs, and increasingly complex hydraulic fracturing programs. These innovations reshaped the global energy landscape. Today, however, those gains have plateaued and shale economics have shifted. WTI price pressure, higher capital costs, and consolidation have forced operators to rethink how recovery is achieved. Drilling new wells is no longer the default; maximizing the value of existing assets has become the priority. This shift raises a critical question: can chemistry deliver recovery gains that persist after initial flowback? In mature shale wells, recovery is now governed less by access and more by whether chemical effects endure at the pore scale.

> "The next wave of shale productivity will not be driven by drilling more wells, but by recovering more from the reservoirs already developed."

The Unconventional Recovery Problem

Unconventional reservoir architecture creates fundamental limitations. Most shale wells recover only 3–10% of original oil in place, leaving the majority of hydrocarbons behind. Much of this oil resides in micro- and nanopores where capillary forces, wettability constraints, and mixed mineralogy inhibit mobility. These pore-scale forces dominate production behavior once pumping ends, reasserting themselves during flowback and long-term depletion. As a result, production often declines sharply—up to 85 percent within the first three years—highlighting that most hydrocarbons operators have already paid to access remain trapped in the rock. This is fundamentally an enhanced oil recovery challenge, but one classical EOR technologies cannot solve at unconventional scale. Most conventional approaches fail because they cannot sustain interfacial or wettability changes once injection ends. Temporary pressure or flowback improvements do not translate into durable recovery.

Chemical Efficiency Emerges as the New Frontier of EOR

Market analysis, including Bloomberg's "Shale Oil's Next Revolution Should Worry OPEC," reinforces this shift toward a new optimization frontier. The next wave of shale productivity will not come from drilling more wells, but from recovering more from reservoirs already developed. This transition is accelerating as refrac economics tighten and operators seek recovery pathways that avoid mechanical risk and new capital commitments. Historically, EOR in tight rock has been expensive, operationally complex, or ineffective. A new pathway is now emerging: chemical EOR designed specifically for unconventional reservoirs. Chemical efficiency offers a more economical path to improved recovery, lower LOE, and stronger field performance—aligned with today's constrained operating environment.

A New Category of Stimulation Chemistry for Unconventional EOR

Within this context, biosurfactant-based stimulation, specifically AssurEOR STIM®, is emerging as a materially different solution for unconventional wells. Unlike traditional chemistry, STIM's ultra-small micelles penetrate pore networks that conventional systems cannot access, enabling nanopore-scale EOR within existing workflows. Critically, STIM is engineered to maintain interfacial and wettability effects after flowback slows, when most chemical systems lose effectiveness. This white paper examines the recovery challenge facing shale operators, the science behind biosurfactant stimulation, and the business case for deploying AssurEOR STIM® across mature unconventional assets.

Problem Statement

Unconventional Wells Trap Oil in Pore Structures Conventional EOR Cannot Access

Shale reservoirs present structural challenges that conventional EOR, stimulation, and production technologies were never designed to overcome. Their pore networks are dominated by nano- to micropores, which trap oil through capillary forces and wettability constraints. These forces dominate production behavior once pumping stops, reasserting themselves during flowback and long-term depletion. Many previously high-performing wells now produce around twenty barrels per day, reflecting a fundamental limitation in pore-scale hydrocarbon access and sustained mobility that traditional EOR gases and chemicals cannot overcome.

Gas-Only Huff-N-Puff Falls Short as an Unconventional EOR Method

Traditional huff-n-puff EOR using CO_2 or natural gas often produces temporary pressure increases during initial flowback, but little sustained incremental oil once pressure dissipates. Gas alone cannot consistently overcome capillary trapping or alter wettability in tight rock, limiting its effectiveness across shale reservoirs. Without a chemical mechanism that persists at the rock–fluid interface, pressure-driven uplift collapses as soon as initial flowback ends. The industry has learned that these pressure-driven methods do not solve the pore-scale physics responsible for low unconventional recovery. Without persistent chemical interaction at the rock–fluid interface, pressure-based methods deliver rate response—not recovery, and certainly not increased EUR.

Conventional Chemical Systems Are Not Built for EOR in Tight Rock

Conventional acid programs improve near-wellbore permeability but do not mobilize hydrocarbons deeper in the formation. Their impact is localized and transient, diminishing rapidly once acid spends. Solvents introduce safety risks, often producing short-lived results. Commodity surfactant micelles are too large to penetrate nanopores, making their impact largely superficial. Even when initial cleanup is observed, interfacial effects collapse during dilution and flowback, eliminating any meaningful contribution to recovery. For true EOR, operators need chemistry capable of accessing and persistently mobilizing oil where the reservoir actually stores it—in micro- and nanopore networks.

Operators Lack a Rigless, Predictable, Formation-Friendly EOR Pathway

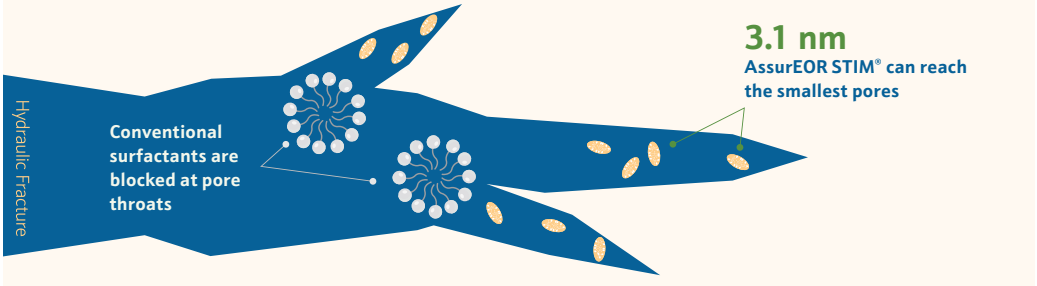
This leaves operators with difficult choices: expensive refracs, new drilling that rarely meets economic thresholds in today's market, or chemical treatments that deliver inconsistent results. Refracs, in particular, introduce mechanical risk, capital exposure, and uncertain recovery outcomes—often for marginal incremental barrels. What has been missing is a rigless, economically viable form of chemical EOR that operates safely, predictably, and effectively after injection, under real unconventional reservoir conditions.

	Cost per Well	Production Uplift	Payback Period
Refrac	**$3.4M avg** (30% of new well)	**Up to 80%** of original peak	1-2 years
EOR	**$350K avg** (10% of refrac)	**30-70%** uplift in field trials	Months

Source: S&P Global Commodity Insights NETL EOR cost appendices

Solution Overview

Nanometer-Scale Micelles Enable Unconventional EOR at the Pore Level

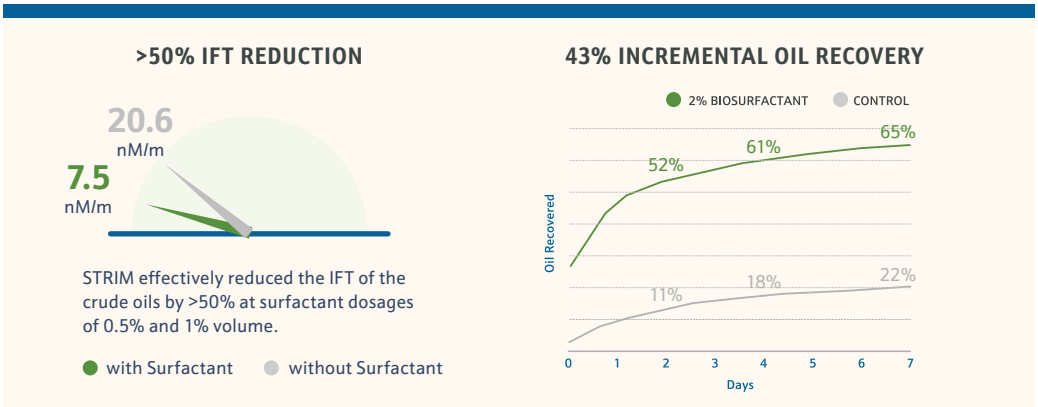


Sustained Performance

STIM remains active as it dilutes in the resevoir – unlike conventional surfactants that lose effectiveness as concentration drops.

AssurEOR STIM® was developed specifically to solve the pore-scale limitations that define unconventional reservoirs. Its ultra-small micelles (3–5 nm) can access pore throats unreachable by conventional surfactants, solvents, or acids. This gives STIM direct contact with immobile hydrocarbons trapped deep in the rock matrix—enabling the kind of pore-level mobilization required for meaningful EOR uplift. Critically, pore-scale access alone is insufficient without sustained molecular performance. AssurEOR STIM® is engineered to maintain interfacial activity and wettability alteration as concentrations fall—where conventional systems fail. This pore-scale access is a prerequisite for altering the interfacial physics that ultimately govern oil mobilization.

Interfacial Tension Reduction and Wettability Shift Drive Sustained EOR Performance



In Lab Tests

Wettability shifts from oil-wet to water-wet, allowing oil to detach and move—not just flow once accessed

Once in the reservoir, STIM delivers interfacial tension (IFT) reduction that persists under dilution and reservoir-relevant conditions. This reduction is crucial for overcoming capillary forces responsible for unconventional flow restriction. STIM also promotes a water-wet environment, enabling more efficient displacement of oil through nanopore and micropore networks. These two mechanisms—IFT reduction and wettability alteration—are the cornerstone of modern chemical EOR but delivered here in a formation-friendly way. This persistence under real reservoir conditions is what differentiates true EOR from short-lived stimulation effects.

EOR Without the Operational Tradeoffs

No Damage

STIM avoids the common failure modes of traditional EOR—no corrosion, no sludge formation, and no risk of formation instability. Reservoir and equipment integrity are preserved while mobilizing trapped hydrocarbons.

No Workflow Disruption

STIM integrates seamlessly into existing unconventional operations. No refracs, no downtime, and no changes to standard completion or production workflows. Because performance persists beyond initial flowback, operators avoid repeated treatments or escalating mechanical intervention.

No Permanent Equipment

Deployed riglessly through existing wellbore infrastructure, STIM requires only short-term pumping equipment for injection—no permanent surface or downhole installations.

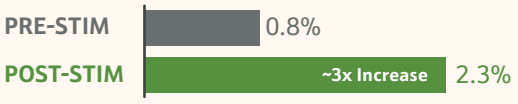
Built for Unconventional Wells

Designed to function within real-world unconventional constraints, STIM delivers chemical EOR performance without introducing operational complexity or long-term risk.

Mobilization of Heavier Hydrocarbons Indicates Deep EOR Access

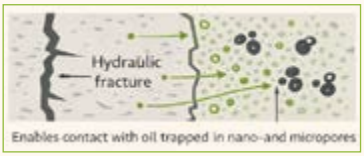
Produced-Fluid Paraffinic Content (Pre- and Post-STIM)

Relative changes in paraffinic hydrocarbon abundance observed during Bakken Huff-n-Puff testing



Paraffinic content reported as percentage of produced crude oil composition.

Chemical access beyond fracture-dominated flow paths



Interpretation based on produced-fluid compositional changes observed in Bakken Huff-n-Puff testing.

Source: Frink well produced-fluid analysis, SPE-220801-MS

Produced-fluid analysis confirms STIM's ability to mobilize heavier hydrocarbon fractions—including paraffins—indicating contact with deeper portions of the reservoir that traditional chemistry cannot reach, rather than limited cleanup of fracture-adjacent fluids. This compositional shift reflects true chemical EOR impact on the composition and volume of recovered hydrocarbons, not merely improved flowback behavior.

Business Case

Historically, achieving high levels of uplift in mature shale wells required refracs or new drilling. Lab and field results demonstrate that chemical EOR can deliver comparable recovery gains without the capital intensity, downtime, or mechanical risk of re-intervention—providing operators with a lower-risk pathway to incremental recovery.

High-Impact EOR Performance in Mature Bakken Wells

In a multi-well Bakken program, baseline production averaged ~20 BOPD. Following AssurEOR STIM® treatment, peak rates exceeded 70 BOPD within five days of returning the wells to production. Over 120 days, uplift remained more than 70% above forecast, yielding over 1,700 incremental barrels per well—recovery outcomes typically associated with far more invasive or capital-intensive interventions.

Consistent EOR Performance Across a Multi-Well Program

Across 15 wells, 11 produced above forecast, demonstrating repeatable performance when placement is achieved. Because deployment is rigless and low-pressure, operators avoided the cost, operational disruption, and risk associated with refracs and other EOR technologies that require significant mechanical modification.

Operational Simplicity and Reservoir Uptake Enable Scalable EOR

STIM was injected through the tubing–casing annulus at >10 bbl/min and <1,500 psi—well within standard field practice. Water return volumes below 20% confirmed strong reservoir uptake and extended residence time, both critical for sustaining interfacial and wettability effects required for EOR in tight rock.

Stronger Well Economics in a Capital-Constrained Market

The economic impact is clear: rapid peak response accelerates payout, sustained uplift increases EUR, and rigless deployment keeps LOE low. In a market defined by constrained capital and tighter margins, STIM provides a scalable pathway to EOR-driven value creation. Compared to gas-only injection, gas–water injection, and gas–surfactant methods, biosurfactant-based chemical EOR delivers faster recovery at lower cost, with comparable or superior returns.

120-DAY TRIAL RESULTS

+2x
ROI

+70%
Uplift

1,700+
Incremental Barrels

5-Day
Peak Response

Conclusion

Unconventional Wells Need a New Path to Real EOR

Steep declines, low recovery factors, and hydrocarbons trapped in nanoscale pore structures have created a recovery ceiling that mechanical improvements alone cannot overcome. With drilling and refrac economics challenged by today's market, operators need a different lever—an EOR lever designed for unconventional reservoirs. The decisive factor is no longer whether chemistry can be injected—but whether its effects persist after injection ends. In unconventional reservoirs, persistence is the proof point of real EOR.

AssurEOR STIM® Delivers a Modern Form of Chemical EOR

By penetrating micro- and nanopores, reducing IFT effectively, altering wettability, and mobilizing heavier hydrocarbons, STIM delivers production responses previously unattainable with conventional chemical systems. The Bakken results demonstrate that nanopore-scale stimulation is both technically validated and commercially viable as an EOR strategy.

Chemical Efficiency Is the Future of Unconventional EOR

The strategic narrative is clear: chemical efficiency—not mechanical complexity—will define the next decade of unconventional recovery and EOR. Biosurfactants are the enabling technology that makes this shift possible. The key advantage is speed and cost-effectiveness: biosurfactant EOR delivers results faster and at lower cost than traditional gas injection methods.

NEXT STEPS

Increase Recovery—Without Rebuilding Your Field.

AssurEOR STIM® delivers measurable EOR gains using existing well infrastructure—no capital projects, no operational disruption.

Schedule a Technical Consultation

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AssurEOR FLOW®

Extend production from frac to flowback and beyond.

As operators seek full-lifecycle optimization, STIM addresses the EOR challenge of mobilizing trapped hydrocarbons. AssurEOR FLOW®, improves near-wellbore connectivity and flow efficiency—completing the chemical pathway to stronger, more predictable recovery across mature unconventional wells.