ISUT®

(In-Situ Upgrading Technology)

Making Heavy Oil Competitive

Enhancing Heavy Oil at Its Source

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NanosTech

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ISUT® TECH BRIEF

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Catalytic In-Reservoir Upgrading That Transforms Heavy-Oil Economics

Abstract

Heavy oil must compete in a global market that increasingly favors lighter, cleaner, and more flexible barrels. Long standing reservoir challenges such as poor mobility, high viscosity, and declining performance now directly affect market access, pricing, and carbon intensity. Oil quality is no longer a downstream consideration. It is a core competitive requirement.

ISUT® introduces a reservoir level catalytic approach that improves heavy oil quality and recovery simultaneously. By creating a catalytic upgrading zone within the formation, ISUT® reduces viscosity, increases mobility, and upgrades heavy molecules as fluids move through the reservoir. Lighter products are directed to sales, while heavier fractions are recycled through the catalytic zone, progressively improving sweep efficiency and produced oil quality.

The technology integrates into existing recovery processes without requiring new surface facilities or major operational changes. By reducing diluent demand, lowering operating intensity, and delivering a more stable, higher value crude, ISUT® provides a practical, field ready pathway for heavy oil assets to remain competitive in today's carbon constrained and capital disciplined market.

Introduction

Transforming Heavy-Oil Recovery with In-Reservoir Catalytic Upgrading

Heavy-oil producers operate under intensifying economic and regulatory pressure. Product quality, carbon intensity, and operating efficiency now directly determine market access and long-term asset viability. Yet despite decades of optimization, both thermal and non-thermal developments continue to face structural challenges: rising diluent demand, constrained pipeline capacity, and declining reservoir quality as assets mature.

With a large share of the world's remaining oil resources in heavy reservoirs, improving recovery from existing developments is a critical pathway to meeting future supply needs. Improving production from these reservoirs requires solutions that act where the constraints originate: inside the reservoir.

Unlike surface upgrading, ISUT® moves the upgrading step into the reservoir itself—directly where viscosity, mobility, and quality constraints originate. Catalytic reactions transform heavy molecules as they flow through the catalytic zone, reducing viscosity and density, generating more mobile fractions, and improving flow before the oil ever reaches surface facilities.

Regulatory expectations, investor scrutiny, and downstream market demands continue to rise. Producers are expected to deliver lighter, lower-carbon barrels while sustaining margins and extending the life of existing assets. Incremental gains are no longer sufficient to bridge the gap between market requirements and operational reality. ISUT® provides a practical, scalable, and capital-efficient pathway to improve quality, reduce operating intensity, and unlock more value from heavy-oil resources—using the infrastructure already in place.

A More Efficient Pathway to Higher Recovery and Value

ISUT® moves upgrading into the reservoir, where viscosity and mobility challenges originate. A catalytic zone forms along the flow path, improving mobility and producing a lighter crude stream. In many fields, stepping from primary to traditional thermal methods is costly; ISUT® offers a more efficient option, accessing heavier portions of the reservoir, lowering steam and diluent use, and delivering higher-value barrels within existing infrastructure.

ISUT® integrates seamlessly into existing development configurations—vertical or horizontal wells, single-lateral or multi-lateral architecture, cyclic or continuous operation, thermal or primary production. It strengthens mobility and enhances recovery. It also delivers upgrading inside the reservoir without altering surface facilities or operating practices.

Environmental and Economic Impact

In-Reservoir Catalytic Upgrading

Compatible With Existing Recovery Methods

Higher-Value Crude & Less Diluent

THE NANOCATALYST

A Nano-Engineered Catalyst Specifically Designed to Operate Inside the Reservoir

ISUT® uses a proprietary nano-engineered catalyst that operates directly inside the reservoir—where mobility, viscosity, and quality constraints originate. Rather than relying on a traditional supported catalyst, the nanoparticles are injected, self-dispersing and anchoring to rock and sand surfaces to form a persistent catalytic zone along the injection path.

The catalyst remains active under the heat of the injected stream and in the presence of hydrogen, upgrading fluids as they move through the zone. This creates an in-reservoir fixed-bed environment that continually upgrades the injected oil stream.

Why This Catalyst Is Transformational for Heavy Oil

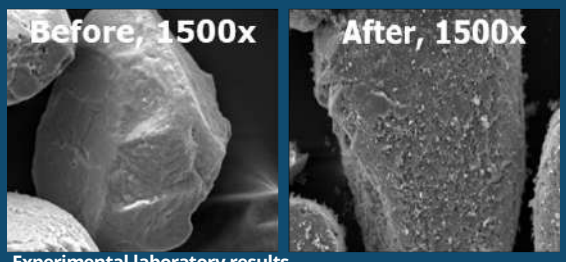
1. Designed for Reservoir Conditions

The catalyst operates at moderate reservoir temperatures (270–350 °C), where reactions proceed in the presence of hydrogen without reaching the severe conditions that cause coking or deactivation. At the nano-scale, the particles anchor onto sand and rock grains without restricting flow, so the reservoir itself becomes the support. The result is a stable catalytic zone that upgrades oil where it matters most..

2. High Activity at Nano-Scale

At ~70–100 nm, the catalyst exposes a large surface area of active phase per unit mass, enabling effective upgrading at ISUT® operating temperatures.

Its nano-scale size allows it to penetrate ~50 cm into the formation and attach throughout the rock, creating a large reaction volume around the injection zone while preserving porosity and flow through the reservoir.



Experimental laboratory results

Nanocatalyst deposition observed to be localized on surface of sand face where the dispersed nanoparticles are observed to be much smaller than pore throats.
Catalyst: 70-100 nm
Pore Throat: 1000+ nm

3. Enables In-Situ Upgrading & Quality Improvement

As oil passes through the catalytic zone, heavier fractions are upgraded into lighter ones, improving crude quality:

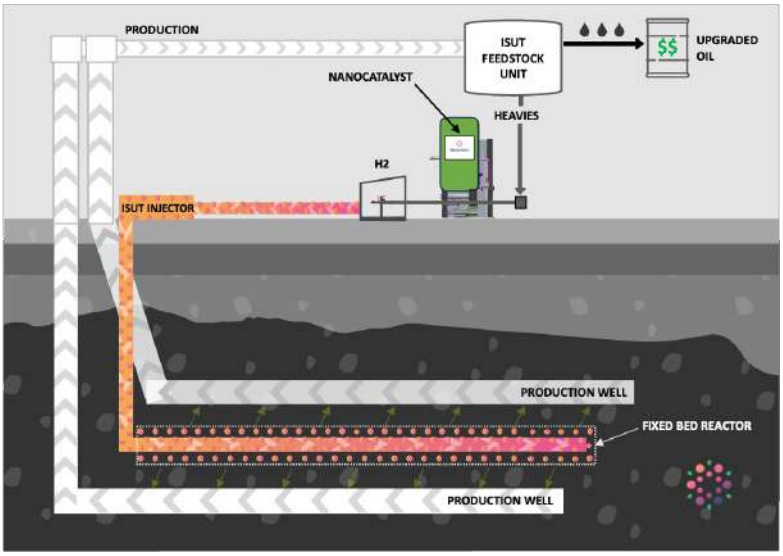
- **Higher API gravity**
- **Lower viscosity**
- **Reduced heteroatoms (TAN, sulfur, nitrogen, metals)**
- **Lower microcarbon residue (MCR)**
- **More pipeline-friendly crude with less diluent**

Nano-engineered • Anchors to rock • Long-life catalytic zone • Active in reservoir

THE ISUT® PROCESS

A Single, Integrated Thermal + Catalytic System Operating Directly Inside the Reservoir

ISUT® (In-Situ Upgrading Technology) integrates catalytic upgrading into existing thermal recovery operations, transforming the well pair or lateral into a long-life catalytic reactor. The process strengthens both recovery and product quality without altering surface facilities or requiring new plant infrastructure.



Two stage process: one-time preparation phase establishes the nanocatalyst bed, and a cyclical upgrading and recovery phase.

1. Catalyst Injection Phase (One-Time)
2. Sustained Upgrading and Recovery

1 Catalyst Injection Phase (One-Time)

A. Creation and dispersion of the nanocatalyst in a heavy stream within the Nanocatalyst Unit.

B. Delivery of the ultra-dispersed nanocatalyst—along with hydrogen or hydrogen-lean gas—to the reservoir through the ISUT® injector well.

C. Nanocatalyst permanently anchors to rock and sand surfaces, establishing a long-life fixed-bed catalytic zone inside the reservoir.

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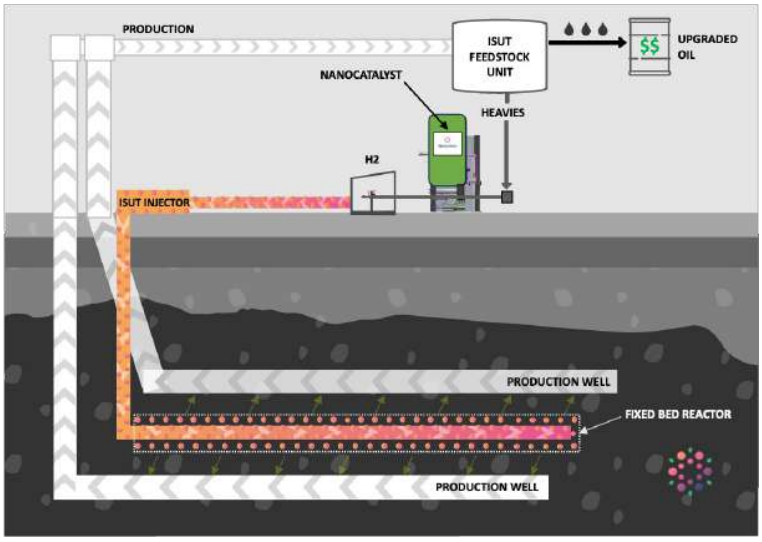
Sustained Upgrading and Recovery



1. Heavy stream and hydrogen source are continuously injected into the ISUT® injector well, initiating the in-reservoir upgrading process.

2. Hydrogen dissociates on the nanocatalyst surface, generating reactive hydrogen species that crack heavy molecules (VR cracking).

3. Cracking reactions increase temperature locally, expanding the steam chamber and improving sweep and recovery.

4. Gases and light liquids formed during cracking disperse into the reservoir, acting as solvents and enhancing mobility.

5. Upgraded bitumen and cracked VR are produced back to surface through the production well.

6. The surface feedstock unit separates heavy stream for reinjection and sends upgraded oil onward for sales.

7. Heavy stream is recirculated to the ISUT® injector, sustaining the sustained upgrading and recoveryprocess.

DEPLOYMENT CONFIGURATIONS

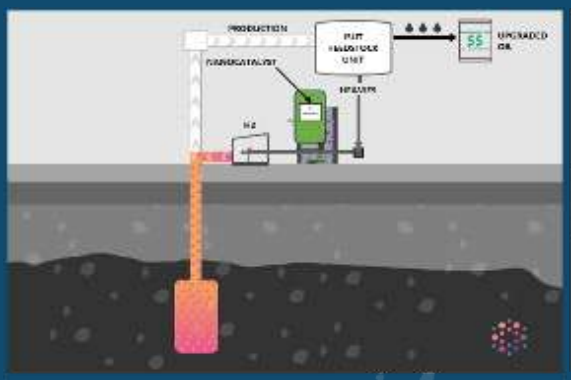
A Flexible System That Integrates Into Existing Thermal Recovery Designs

ISUT® is engineered for seamless deployment across both new and operating heavy-oil assets. The technology integrates into existing well architectures with minimal modifications, transforming standard thermal processes into catalytic upgrading systems without requiring new surface facilities or major infrastructure changes.

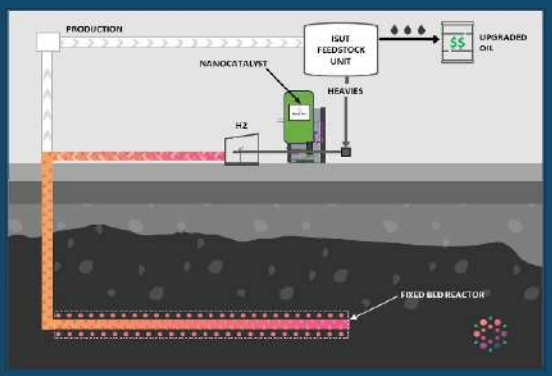
The nanocatalyst injection is performed once during a designated preparation step. After anchoring to the rock surface, ISUT® functions as a long-life catalytic enhancement to CSS, SAGD, hybrid solvent/thermal systems, pressure-drive, or multi-lateral wells—continuously upgrading crude in situ and improving mobility throughout production.

This allows operators to enhance performance without interrupting operations, without new capital infrastructure, and without changing established thermal workflows.

Vertical Cyclic (Huff-and-Puff)



Single-Lateral (Huff-and-Puff)



CSS (Cyclic Steam Stimulation)

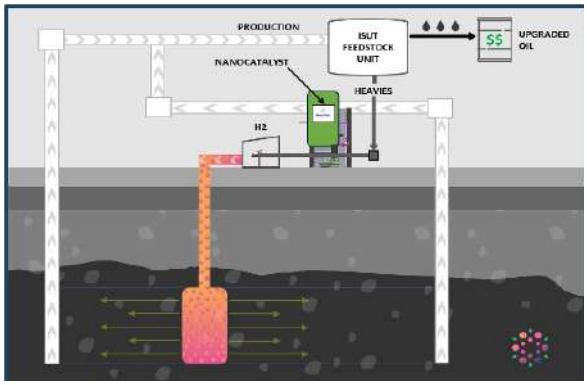
How ISUT® Integrates:

- Catalyst is injected during a pre-steam or early steam cycle.
- Anchors to steam-influenced rock surfaces around the wellbore.
- Subsequent cycles operate normally, but with continuous in-reservoir catalytic upgrading.

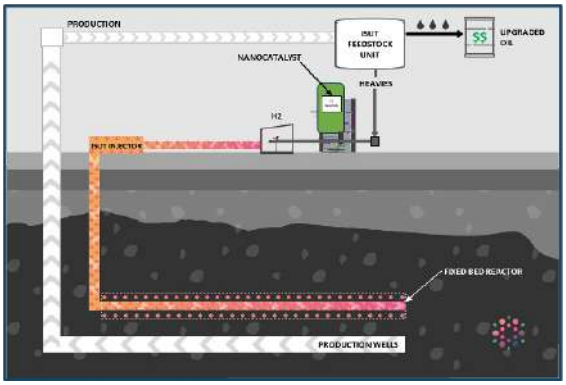
Key Benefits:

- Higher recovery per cycle
- Lower viscosity and reduced steam requirement
- Improved lifting efficiency
- Enhanced access to tight or lower-perm zones

Vertical (Pressure Drive)



Single-Lateral (Pressure drive)



Hybrid Thermal / Solvent or Pressure-Drive Systems

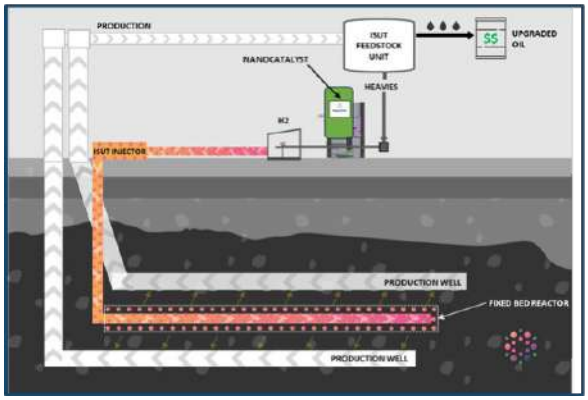
How ISUT® Integrates:

- Catalyst is placed with a hydrogen source or hydrogen-lean gas.
- Works synergistically with solvents and low-pressure drives.

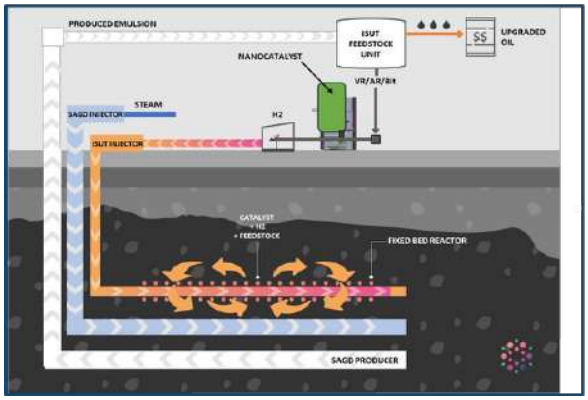
Key Benefits:

- Additional light-end generation improves mobilization
- Solvents become more efficient due to catalytic cracking
- Enables upgrading even in lower-temperature operations
- Extends applicability of marginal or end-of-life assets

Multi-Lateral & Extended-Reach Wells



SAGD (Steam-Assisted Gravity Drainage)



Hybrid Thermal / Solvent or Pressure-Drive Systems

How ISUT® Integrates:

- Catalyst anchors along lateral branches, creating distributed catalytic zones.
- Ideal for accelerating recovery in low-pressure or heterogeneous areas.

Key Benefits:

- Improved sweep efficiency across extended footprints
- Better conformance in variable geology
- Higher recovery from lower-quality rock
- Continuous in-situ upgrading along multiple drainage points

SAGD (Steam-Assisted Gravity Drainage)

How ISUT® Integrates:

- Catalyst is placed along the horizontal injector well.
- Forms a catalytic zone along the rising steam chamber interface.
- Upgrading occurs continuously as mobilized bitumen drains to the producer.

Key Benefits:

- Lower SOR and reduced energy intensity
- Faster chamber development
- Higher API gravity and reduced diluent blending
- More stable long-term production

TECHNICAL MECHANISMS & FIELD PERFORMANCE

How ISUT® Improves Mobility, Recovery, and Oil Quality Directly Inside the Reservoir

Mechanism Overview

As heavy molecules contact the catalytic zone, they partially crack into lighter components and blend with upgraded fractions. This reduces viscosity and density, enhances mobility, and improves sweep efficiency—particularly in heterogeneous or lower-permeability zones.

Result:
Higher injectivity, stronger conformance, and more efficient hydrocarbon mobilization across the reservoir.

ISUT® drives performance through three interconnected catalytic and thermal mechanisms:

Mobility improvement

Catalytic cracking reduces viscosity and lightens heavy components near the wellbore.
Result: Better injectivity, broader reservoir contact, and improved access to tighter intervals.

Reservoir upgrading

Catalytic reactions convert part of the heavy stream into lighter fractions, increasing API and lowering diluent demand.
Result: Higher-value barrels and more stable long-term quality.

Steam chamber enhancement / thermal efficiency

Localized heat and reaction gases improve heat retention and steam-chamber growth.
Result: Lower SOR and improved mobilization in deeper/colder zones.

Up to 40% viscosity reduction

10% incremental recovery

Lower steam per barrel produced

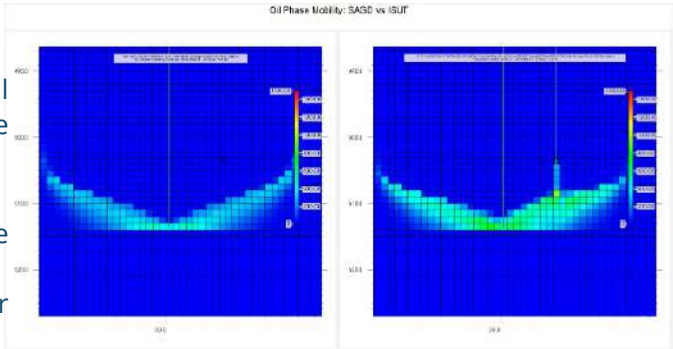
Higher lifting efficiency and chamber stability

Improved API and reduced TAN/metals

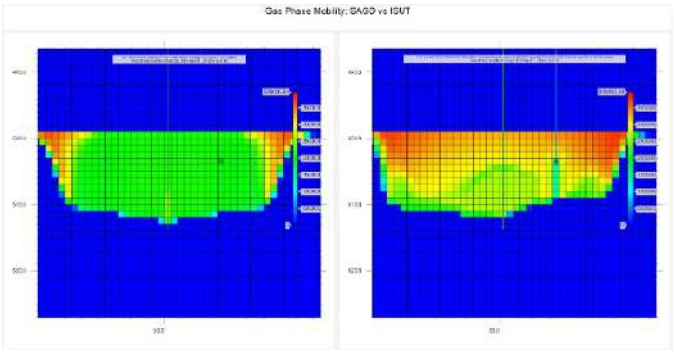
Together, these mechanisms strengthen asset performance, improve margins, and extend the life of maturing reservoirs.

Mobility improvement

Oil-Phase Mobility (SAGD vs ISUT®)



The ISUT® case demonstrates visibly higher oil mobility around the injector and across the chamber interface. This reflects:
Local viscosity reduction from catalytic cracking
A lighter fluid mixture that responds more efficiently to steam
Improved mobility near the wellbore and deeper into the reservoir

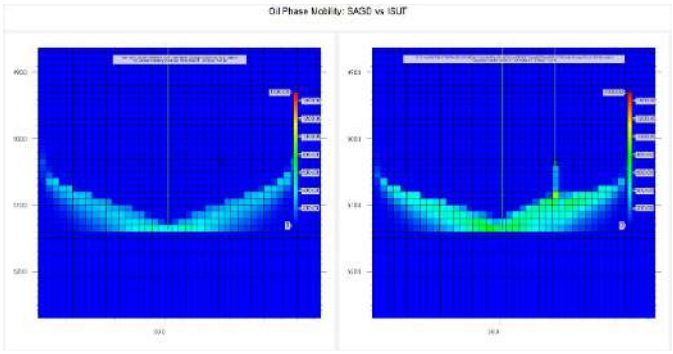


Gas-Phase Mobility (SAGD vs ISUT®)

ISUT® produces additional light-ends and reaction gases that behave like a distributed solvent system. These gases disperse through the chamber, improving:

- Sweep efficiency
- Lateral chamber development
- Access into previously bypassed zones

Total Mobility (SAGD vs ISUT®)



The combined mobility response—oil + gas—shows the most important operational impact:

- Wider, more uniform mobility across the steam chamber
- Better conformance, especially laterally
- Enhanced thermal coverage, reducing cold pockets left behind by conventional SAGD

Why This Matters for Field Performance

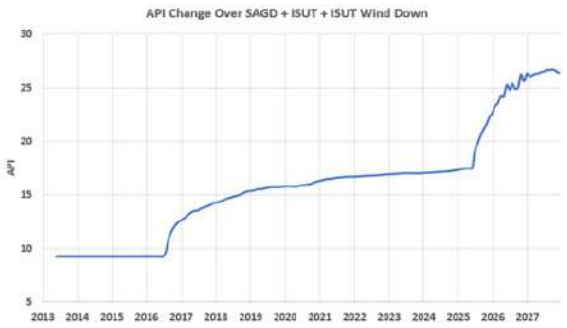
Improved mobility is one of the earliest and most reliable field indicators of catalytic impact. With ISUT®, operators can expect:

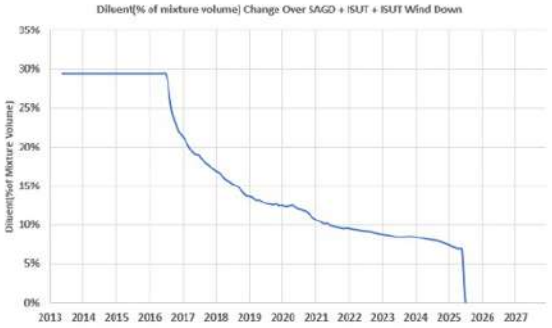
- Faster chamber expansion
- Higher early-life production rates
- Lower steam demand per barrel mobilized
- Reduced pressure requirements to move oil
- More stable production over time

ISUT®'s ability to shift mobility—without additional surface infrastructure—translates directly into higher recovery efficiency, lower OpEx, and enhanced field economics, particularly in maturing or geologically complex reservoirs.

Reservoir upgrading

ISUT® establishes a catalytic upgrading zone inside the reservoir, where heavy molecules partially crack into lighter components before reaching surface facilities. This improves both mobility and product quality in a single step.





API Gravity Increase Over Time

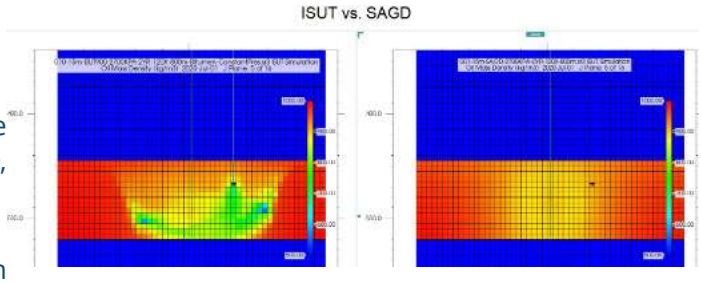
The API curve shows a steady rise once ISUT® begins operating—unlike SAGD, which remains flat.

Meaning: The catalyst cracks vacuum residue into lighter hydrocarbons in situ, lowering density and improving flow.

Oil Density Maps: ISUT® vs SAGD

Density maps show a lighter, more uniform oil zone around the wellbore with ISUT®, compared to the heavier distribution under SAGD.

Meaning: Catalytic upgrading expands the volume of lighter hydrocarbons in the chamber, improving conformance and enhancing drainage.



Diluent Requirement Reduction

The diluent-use curve drops sharply after ISUT® activation and continues declining.

Meaning: Higher-quality, lighter oil requires significantly less condensate to meet pipeline specs, increasing net bitumen sellable per barrel.

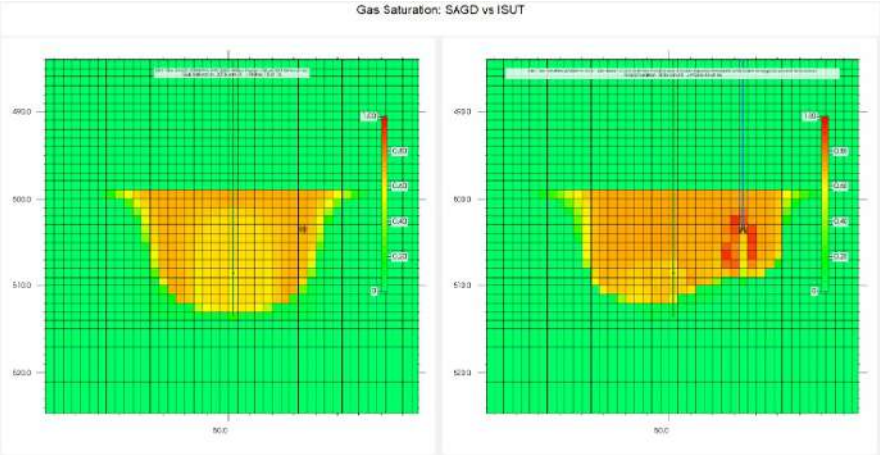
Production Quality Stability

As ISUT® output remains lighter for longer, the reservoir maintains more consistent quality across production stages, reducing variability in pipeline specifications and surface handling.

Steam chamber enhancement / thermal efficiency

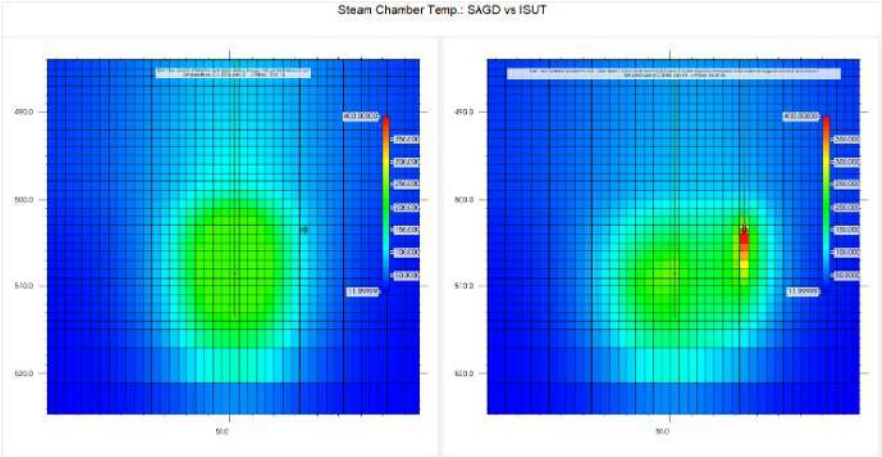
ISUT® increases thermal efficiency inside the reservoir by altering how heat is generated, transported, and retained within the steam chamber.

The presence of unreacted hydrogen and catalytic reaction gases produces a localized “thermal blanket,” while catalytic cracking reactions release additional heat along the wellbore and chamber boundaries. These combined effects improve chamber growth, stability, and steam utilization efficiency.



Gas Saturation Maps

ISUT® shows higher local gas saturation, forming a thermal blanket that reduces heat loss and supports wider, more uniform lateral chamber growth compared to SAGD.



Steam Chamber Temperature Maps

Under ISUT®, the chamber maintains a larger high-temperature core and retains heat more effectively, demonstrating improved thermal efficiency and reduced energy loss to surrounding rock.

Result:

A hotter, wider, more stable chamber that requires less injected steam to mobilize the same or greater volumes of bitumen.

Field Impacts & Commercial Value

ISUT® reshapes thermal project performance by improving the fundamental physics of mobility, upgrading, and heat efficiency inside the reservoir. As viscosity drops, density lightens, and the steam chamber becomes more effective, operators see measurable gains in recovery, quality, and cost per barrel—without altering existing facilities.

Stronger Recovery Performance

By reducing viscosity and improving sweep efficiency, ISUT® supports more uniform chamber growth and better access to lower-permeability rock. This delivers higher effective recovery and more stable production over the pad life.

Higher-Value Barrel Through In-Reservoir Upgrading
Catalytic reactions lighten the produced fluids before they reach surface equipment, steadily increasing API gravity and reducing heavy-end content. The result is a more pipeline-friendly crude and improved realized pricing.

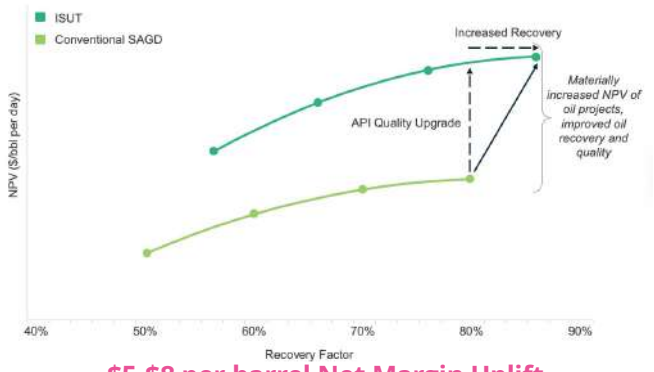
Material Reduction in Diluent Demand
Improved mobility and lower density mean operators require significantly less condensate or synbit to meet pipeline specifications. This reduces one of the largest operating costs in thermal operations and increases netbacks.

Steam Efficiency Gains
ISUT®'s combination of improved chamber conformance, localized catalytic heat release, and a thermal "insulation" effect from reaction gases reduces the steam required per barrel of oil gained. Lower SOR strengthens both operating cost and environmental performance.

Commercial Value Summary
Across field trials and simulation-based forecasts, ISUT® demonstrates the ability to:

- Recover more barrels per well pair
- Produce a lighter, more pipeline-friendly crude
- Reduce diluent purchases and exposure to condensate prices
- Lower steam intensity and associated fuel costs
- Extend the economic life of mature or marginal assets

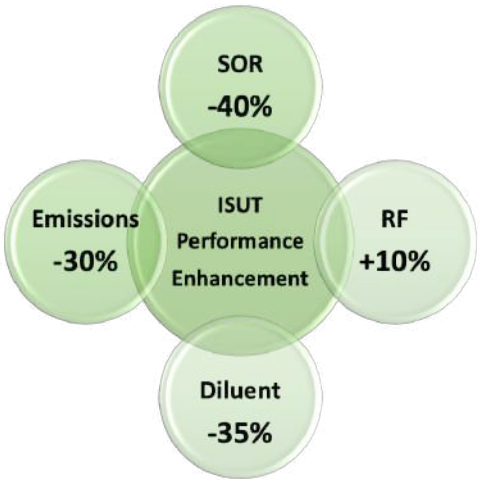
Together, these impacts create a clear financial advantage—lower cost per barrel, improved margins, and a more competitive heavy-oil product.



$5-$8 per barrel Net Margin Uplift

Sensitivity Analysis & Expected Field Impacts

Across low-, mid-, and high-intensity operating scenarios, ISUT® consistently improves key performance indicators. Sensitivity analysis shows that catalytic upgrading delivers value regardless of well length, injection rates, steam quality, or reservoir pressure—demonstrating strong robustness for commercial deployment.



Lower Steam-to-Oil Ratio (SOR): up to –40%

Improved viscosity reduction, stronger conformance, and localized catalytic heat release reduce the steam required per barrel of oil.

Reduced Diluent Requirement: –30% to –35%

Higher API gravity and lower density lessen the need for condensate or synbit blending to meet pipeline specs.

Increased Recovery Factor: +5% to +10%

Enhanced sweep efficiency and chamber enlargement increase the volume of recoverable bitumen per well pair.

Key Parameters	Low	Mid	High
H2/AR volume ratio at SC	110	120	130
Reservoir	Low Case 15m thin Pay		Base case 30m rich pay
ISUT Injection Rate, bpd	300 (pilot)	600	900
Well Length, m	400	800	1200
Target Pressure, KPa	2700	3000	3300
Start up timing (inc. circ);	18month	2 year	3 year

Sensitivity Ranges Considered

- H_2/AR Ratio: 110–130
- Injection Rate: 300 / 600 / 900 bpd
- Reservoir Pressure: 2700–3300 kPa
- Well Lengths: 400–1200 m
- Start-Up Timing: 18 months – 3 years

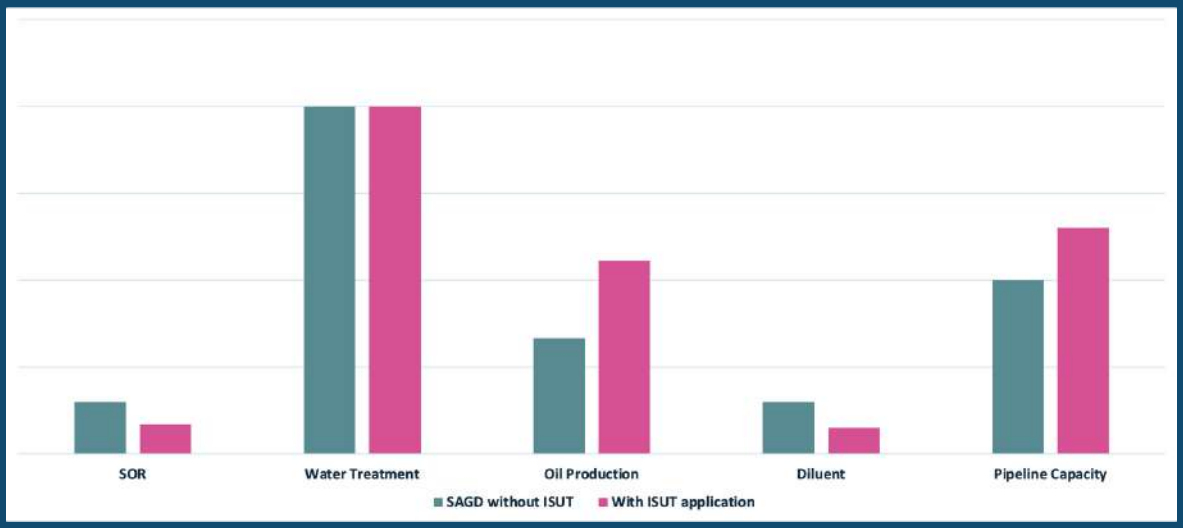
ISUT® performs consistently across a wide range of realistic field conditions—from pilot-scale injection programs to aggressive commercial operations.

Together, these improvements materially enhance project economics, lower operating intensity, and extend the commercial life of heavy-oil assets.

Full-Field Debottlenecking & Throughput Gains

ISUT® increases field throughput by unlocking the major constraints that limit SAGD operations—steam, water treatment, diluent supply, and pipeline capacity.

By improving mobility, lowering density, and reducing diluent demand, operators can move more saleable barrels through the same surface facilities, without new CAPEX.



What the graph shows

Across key bottleneck categories, ISUT® consistently delivers:

- **Lower SOR:** Less steam required per barrel → frees up boiler capacity and lowers operating cost.
- **Higher Oil Production:** Improved conformance and upgrading increase produced-oil volumes.
- **Lower Diluent Use:** Higher API and lighter viscosity reduce condensate/synbit requirements.
- **More Pipeline Capacity**: A lighter barrel + lower diluent ratio allows more sellable crude to move through existing pipelines.
- **No Change in Water-Treatment Limits:** Even with unchanged water-handling capacity, ISUT® increases total throughput by improving efficiency inside the reservoir.

Result

More oil, same infrastructure.
ISUT® enables operators to debottleneck the full field—boosting pad-level and asset-level productivity, while reducing cost per barrel and strengthening overall project margins.

Conclusion: Making Heavy Oil Competitive

ISUT® represents a new class of reservoir technology—one that transcends traditional categories. It is enhanced recovery, in-reservoir upgrading, thermal efficiency, mobility improvement, diluent reduction, and oil-quality uplift delivered simultaneously in a single subsurface step.

By uniting catalytic upgrading, hydrogen-driven reactions, localized heat release, and gas-phase insulation effects, ISUT® reshapes how heavy oil is produced. These interconnected mechanisms work together inside the reservoir to deliver:

- ✓ **Higher recovery through improved mobility and conformance**
- ✓ **A lighter, more pipeline-friendly crude through in-reservoir upgrading**
- ✓ **Lower steam and energy demand, driving meaningful cost savings**
- ✓ **Reduced diluent dependence, unlocking pipeline and export benefits**
- ✓ **Greater stability and longer field life through improved chamber efficiency**

This is why ISUT® stands apart. It is not an incremental improvement—it is an industry-shifting platform that enables heavy oil to remain competitive in a market that demands lower emissions, higher efficiency, and better margins.

While many of the examples in this brief reference SAGD—the most energy-intensive thermal process—they illustrate the broader potential across all thermal configurations. The same catalytic mechanisms that elevate SAGD performance also strengthen CSS, hybrids, multi-laterals, and even marginal or late-life assets.

ISUT® is field-ready

As operators look for solutions that reduce steam intensity, improve margins, expand pipeline options, and deliver a higher-value barrel, ISUT® offers a practical and commercially de-risked pathway forward.

To explore how ISUT® can unlock value in your field, contact us.

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