Is today’s low commodity price going to consume the industry or is it going to trigger the second unconventionals revolution? The answer lies in the history of North America’s successful track record with Oil & Gas innovation.

The last eight years in North America have proven to be the hub of innovation in unconventionals. The combination of daring investors, visionary operators, and innovative service companies drastically lowered the threshold of commodity prices needed to economically produce from shale/tight formations. While we as an industry congratulate ourselves for this success, it is time for the next wave of innovation to pave the way for the second unconventionals revolution.

Today’s challenging economic environment calls for a second unconventionals revolution to make unconventional assets economical and sustainable at much lower commodity prices. This revolution will be driven by the goal of reducing the breakeven point of the cost per barrel of oil equivalent (BOE) of unconventional assets by:

- Developing a balanced portfolio of new wells, infills and refracs
- Harvesting bypassed reserves with innovative technologies at a lower cost/BOE
- Increasing recovery, while drilling fewer wells

Second Unconventionals Revolution
Harvesting Reserves with a Balanced Portfolio Can Reduce Breakeven Points of Unconventional Assets

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Room for Improvement

Low Recovery Factors
While the oil and gas industry has made immense strides over the past few years in reducing costs to make unconventional recovery economical and profitable, subsurface insight data indicates that fractured horizontal wells still contain a lot of bypassed reserves. Fracturing challenges such as low cluster efficiency, unequal fractures, and loss of fracture conductivity have actually contributed to inefficient completions in shale wells. In fact, nearly two-thirds of the stages in a lateral fail to contribute to production very early during the life of the well.

In spite of tighter frac and well spacing, the industry has not been able to consistently improve recovery factors (RFs) above 5% to 8% in oil-rich reservoirs. Hence, we routinely leave over 92% of reserves in the ground—completely untouched! Efficiently doubling or tripling current recovery factors will be worth billions of dollars to the industry.

Over-drilling
Due to the challenges stated above, in order to increase production from any given field, an operator has to constantly be on the treadmill of drilling and completing new wells to counteract the inefficiently producing wells. This treadmill phenomena has caused the industry to over-drill sections of land, resulting in more wells than required to meet production commitments.

Optimum new wells (black) vs. over-drilled infill wells (red)
The Second Unconventionals Revolution

While the first unconventional revolution has been focused on cost reductions driven by surface efficiency through drilling and completions, and on certain levels of subsurface recovery optimization, the second unconventional revolution will be about harvesting more reserves by drilling fewer wells and building a balanced portfolio to reduce the breakeven point of unconventional assets. The second unconventional revolution will be driven by two more business objectives in addition to the objectives from the first revolution:

**Harvesting Reserves**
Objective: Depleting Reservoirs with Fewer Wells
In the future, we will harvest reserves by:
- Utilizing technological innovations to recover new and bypassed reserves
- Integrating surface logistics with subsurface sequencing
- Developing fields through a lifecycle-driven approach

**Balanced Portfolio**
Objective: Reducing Asset Breakeven Point
We can build a balanced portfolio today by:
- Building the right combination of different cost/BOE wells, such as new wells, infills, and refracs
- Enhancing productivity from new wells based on learnings from refracs
- Reducing the number of infill wells
- Increasing the rate of return, bookable reserves, and balancing the cost and risk of investment across new wells, infills, and refracs

**Well and Frac Placement/Spacing**
Objective: Maximizing EUR
The industry is focused on maximizing estimated ultimate recovery (EUR) by optimizing:
- Well placement
- Well spacing
- Frac spacing
  - Completion and frac design
  - Customized stimulation fluid chemistry and proppant technology

**Surface Operations**
Objective: Achieving Cost Reductions
The industry is focused on reducing costs by:
- Reducing surface footprints
- Optimizing logistics
- Increasing frac fleet reliability
- Increasing surface efficiency as a complete “frac operations system”
Balanced Portfolios Will Drive Down Breakeven Points of Unconventional Assets

The second unconventionals revolution will focus on reducing asset breakeven points, so that unconventional assets can be competitive with conventional assets. Additionally, reservoirs will be harvested in a manner that will allow us to increase reservoir recovery while drilling significantly fewer new wells.

The second unconventionals revolution calls for a new way of thinking about well allocation and full-field development. This new approach takes into account the varying costs per BOE and the different return on investment (ROI) predictabilities of new wells, infills, and refracs. We call this a balanced portfolio. Leveraging the right combinations of recovery methods for these types of wells will drive down the breakeven point of the entire asset.

Building balanced portfolios with the right combinations of refracs, infills, and new wells reduces asset breakeven points.

So How Do You Build a Balanced Portfolio?

Balanced portfolios are designed to achieve the key business objectives within the existing market. For example, some operators could be trying to achieve acceleration of reserve recovery and enterprise value by quantifying bookable reserves. This would allow them to sell the asset(s) and provide a substantial investment multiple to their investors. On the other hand, other operators could be driven by increasing their long-term rates of return and driving efficiency into their operations. All of these factors must be taken into account when creating a balanced portfolio that can be tailored to achieve the desired business objectives.
**Step 1 – Evaluate Production Targets**

Start by evaluating the current production from existing wells, and then determine how much additional production is necessary to achieve objectives (e.g., debt-servicing payments for an asset) or production-growth requirements (e.g., pipeline commitments). This additional production need is what drives production targets.

**Step 2 – Rank Wells**

The question still remains: How do we build the right combination of new wells, infills, and refracs to meet this production target? To accomplish this, collectively rank all the new wells, infills, and refrac candidates of a field, using profit-to-investment ratios. This enables comparison of all of the multiple types of wells ranked across one common dimension, with the top well representing the best rate of return and the bottom well representing the worst rate of return.

*C Field-dependent parameters

Candidate portfolio of new wells, infills, and refracs

Profit-to-investment ratio ranking of new wells, infills, and refrac candidates
Step 3 – Determine Optimum CAPEX Utilization†

The ranked wells are then plotted on a cumulative net present value (NPV) graph vs. a cumulative capital expenditures (CAPEX) graph, with the best-ranked performers on the left and the worst on the right. The wells in the steepest slope from left to right will provide the best expected return. As the slope decreases and becomes negative, so does the corresponding well NPV.

This plot demonstrates the best utilization of CAPEX, where the highest-rate-of-return wells are on the left and the lowest-rate-of-return wells are on the right.

Step 4 – Build a Balanced Portfolio to Lower Asset Breakeven Point†

We then evaluate how many of these wells, from left to right, are needed to produce in order to meet the production target. Answering this question will provide the CAPEX necessary to achieve the production targets using the best-rate-of-return wells, thereby leveraging a balanced portfolio of new wells, infills, and refracs. If you compare this balanced portfolio to a portfolio of solely new drills, as shown on the right side chart in the figure below, the cumulative NPV 10% (y-axis) of both portfolios clearly shows that the balanced portfolio delivers a much higher rate of return. In addition, the cumulative CAPEX (x-axis) of both portfolios reveals that the balanced portfolio needs $50 million less CAPEX to meet the production commitments in this case, which results in delivering a decreased CAPEX/BOE and lower breakeven point for the entire asset.
The balanced portfolio on the left, compared to the new-drill portfolio on the right, has a higher rate of return and requires a lower CAPEX to meet production targets.

**Step 5 – Book Additional Reserves and Achieve Lower Cost of Capital**

Refracs will make it possible for operators to book incremental reserves by harvesting bypassed reserves. By using a structured refrac field development plan via refrac and infill candidates, it will be possible to leverage success of the refracs and increase proven developed producing (PDP) reserves. After achieving a sufficient critical mass of success with PDP reserves, it will be possible to increase the proven developed nonproducing (PDNP) and proven undeveloped (PUD) reserves of an asset.

This improves the enterprise sale value of the asset, and increases the ability to gain more favorable terms for access to capital. This is very valuable for small- to mid-cap operators that are trying a build a mixed portfolio of different debt terms and costs of capital. This allows them to grow an asset for sale with lower average cost of capital, and to provide their investors with investment multiples in a finite time period.
Harvesting Reserves
At lower commodity prices, such as those seen today and in the foreseeable future, the industry will become more conscious of evaluating the reasons behind low productivity and recovery factors. The focus will be on identifying areas in the reservoir where bypassed reserves can be recovered economically, while developing new reserves in parallel.

Harvesting these new and bypassed reserves will be driven by a reservoir-centric lifecycle approach and innovative technologies. The following graphic illustrates the projected evolution in the lifecycle development of unconventional reservoirs.

Combining Infills and Parent Refracs
Infills can often result in higher drilling and completion cost per BOE than parent wells due to asymmetric fractures and well bashing into parent wells. This leads to low recovery from infill wells and loss of production from parent wells. However, in the very near future, harvesting bypassed reserves will include appropriate combinations of horizontal infill and parent refrac wells. This will help maximize pad recovery factors and lower cost/BOE of the entire pad.

Reconnects
We will see periodic mini-stimulation treatments on horizontal wells to reconnect fracs to the wellbore and overcome periodic losses of frac conductivity and fracture connectivity to the wellbore. Reconnects will be performed periodically as a prescheduled well maintenance plan, just like we perform regular oil changes to revitalize our automobiles.

Multilaterals
New wells and infills will no longer be confined to solely vertical and horizontal wells, but will also include multilaterals, where operators will leverage thousands of existing wells to drill sidetracks, reducing their drilling and surface infrastructure costs. These networks of subsurface multilaterals will increase reservoir contact and make it possible to better harvest bypassed reserves left between thousands of existing wells.

Enhanced Oil Recovery (EOR)
We will also see smart-EOR methodologies that will cleverly leverage this complex web of closely spaced vertical and horizontal wells across multiple tight formations in shale reservoirs.
Lifecycle-Driven Harvesting of Reserves
Depending on where unconventional wells lie in the Reservoir Lifecycle (RLC) stage, they will have multiple lives or will be involved in a tailored recovery approach. New wells will be drilled and completed by proactively planning for the future lifecycle stages of the reserves in a particular section of a field. For example, larger refrac designs may be utilized on older wells in order to recover bypassed reserves, while smaller reconnect treatment methods may be used on newer wells to periodically enhance near-wellbore frac conductivity during the life of the well.

In the future, field development will be about smart combinations of reservoir lifecycle (RLC) stages.

Optimizing Combinations of Harvesting Reserves and Surface Logistics
During the first unconventionals revolution, the oil and gas industry rightfully put all eyes on optimizing the movement of surface logistics, such as rigs and frac crews, from one location to another in order to reduce operational costs.

The second unconventionals revolution will aim at maximizing well productivity and recovery factors by harvesting reserves, and this effort will be driven by optimum fracture sequencing tailored for specific reservoir conditions. We will no longer look at wells in isolation, considering them individually as new wells, infills, or refracs. Instead, we will design an optimized combination of wells for reserves harvesting in a specific drilling section, taking into consideration changing reservoir conditions such as pressure and stress regimes during the life of the field.

The industry will focus on building the right balance between lifecycle-driven reserves harvesting and cost-reduction-driven surface logistics optimization.

Combining surface logistics with subsurface frac sequencing
Combining Infills and Parent Refracs to Increase Pad EUR

Infills (child or development wells) often result in asymmetric fractures and well bashing into parent wells, thus leading to low recovery from infill wells and loss of production from parent wells. To address this challenge, stimulations of infills will be combined with parent refracs to help increase pad recovery and mitigate the currently ongoing self-destruction of assets.

By refracturing parent wells before stimulating the infill well, we will be able to pressure up the pressure-depleted areas around the parent well, and mitigate well bashing from the infill wells. This will also allow us to generate relatively symmetric fractures when we stimulate the infill well, which should maximize its recovery potential. The parent wells that were refractured would not only protect the parent well from losing production by mitigating well bashing, but would also increase its incremental EUR by stimulating bypassed reserves. The combination of increase in infill well EUR, protection from parent well production loss, and increase in parent well EUR will increase the EUR of the entire pad.

- **Child Well EUR** (from symmetric fracs)
- **Parent Well EUR Loss** (from well bashing mitigation)
- **Parent Well EUR** (from refracturing bypassed reserves)
- **Pad EUR** (from maximizing stimulated reservoir volume)

Zipper-Fracturing Infills after Parent Refracs to Increase Pad EUR

A possible scenario with staggered laterals is to refracture the parent wells first, and then zipper-frac the infill wells between them. This could allow us to maximize stimulated reservoir areas between the staggered laterals by leveraging the same subsurface advantages mentioned in the concept above.

In cases where previous parent or development wells are closely spaced, a more innovative approach will be needed to mitigate negative well interference. This approach would require us to treat the section of land or pad as one single production unit, and the utilization of far-field diversion could help move stimulation fluid toward higher-pore-pressure areas of unstimulated rock between staggered horizontal wells.

- **Child Well EUR** (from symmetric fracs)
- **Parent Well EUR Loss** (from well bashing mitigation)
- **Parent Well EUR** (from refracturing bypassed reserves)
- **Pad EUR** (from maximizing stimulated reservoir volume)
Combining Infills and Parent Refracs to Reduce Number of Infills
In large-scale field development, depending on the well spacing, extending the half-lengths of induced fractures in parent and infill wells could also help to reduce the number of infill wells between existing parent wells.

We would do so by applying larger stimulation fluid volumes to parent refracs and to the primary stimulation treatment of the infill well. This combination could allow us to reduce the number of infill wells and still achieve a similar stimulated reservoir volume.

- **↑ Child Well EUR** (from extending fracture half-lengths)
- **↓ Parent Well EUR Loss** (from well bashing mitigation)
- **↑ Parent Well EUR** (from extending fracture half-lengths)
- **↓ Pad Cost/BOE** (from reducing number of drilled infills)

Performing Pad Level Refracs and Reconnects to Increase Pad EUR
Multiple refrac wells on the same pad could be combined with reconnects, where one technology will focus on recovering bypassed reserves left behind by unequal fractures between wells, and the other technology will focus on keeping propped fractures connected to the wellbore.

This approach would treat the section of land or pad as one single production unit to help mitigate well bashing between neighboring refrac wells. Smart combinations of refrac and reconnect sequencing, along with utilization of far-field diversion, will help move stimulation fluid toward higher-pore-pressure areas of unstimulated rock between wells.

- **↑ Well EUR** (from refracturing bypassed reserves)
- **↑ Well EUR** (from reconnecting stimulated reservoir to wellbore)
- **↓ Well EUR Loss** (from well bashing mitigation)
- **↑ Pad EUR** (from accessing bypassed reserves)
Timing of Reserves Harvesting

In the future, the right timing for reconnects and refracs will play an important role. As the lifetime of the well and reservoir progresses, it will affect poroelastic stress reorientation in the reservoir, driven by time, depletion, drawdown rate, and pressure decline. In addition, damage mechanisms leading to degradation of fracture conductivity will change with life of the well. This could allow us to leverage optimum timing for re-stimulations to our advantage by enhancing our ability to induce fracture complexity and increase stimulated reservoir volume. Optimum timing could drive us to “protectively schedule” periodic reconnects and refrac stimulations to maximize reservoir recovery.

The Future

As we evolve with the harvesting of reserves, the subsurface learnings across these phases will drive improvements in new drills and primary completion designs. While today there are a lot of bypassed reserves to harvest, the progression in the second unconventional revolution will be to take learnings from recovery methods such as refracs and reconnects, and improve new well placement and well spacing, as well as associated completion and frac designs, so we will have less bypassed reserves to harvest in the future.

Additionally, in the future, field development will no longer focus solely on drilling and completing new wells. As a major paradigm shift, balanced portfolios will include clever synergies of drilling new wells while also timing the rework of an inventory of thousands of existing wells with periodic refractures, repetitive conductivity restoration treatments, multilateral sidetracks, and EOR treatments. This will pave a revolutionary way for designing completions that are targeting new acreage and harvesting reserves.

These innovations will help us to further reduce the breakeven points of unconventional assets, thus bringing unconventional reservoirs closer to the breakeven points of conventional reservoirs.

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† This balanced portfolio case study uses actual data from wells across the Marcellus, Eagle Ford, Haynesville, and Bakken shale plays.