

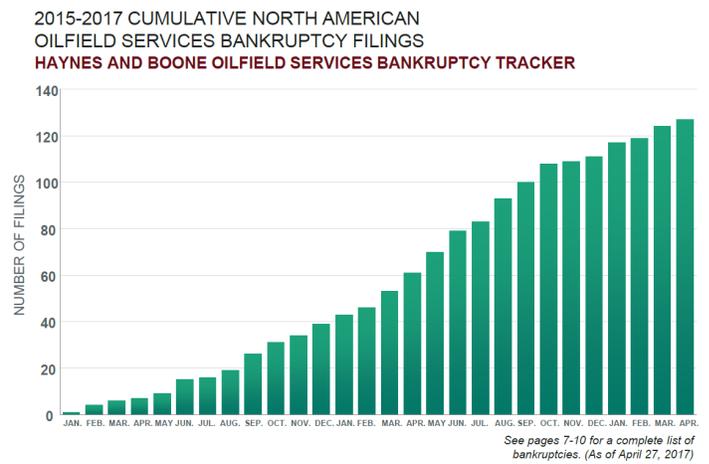
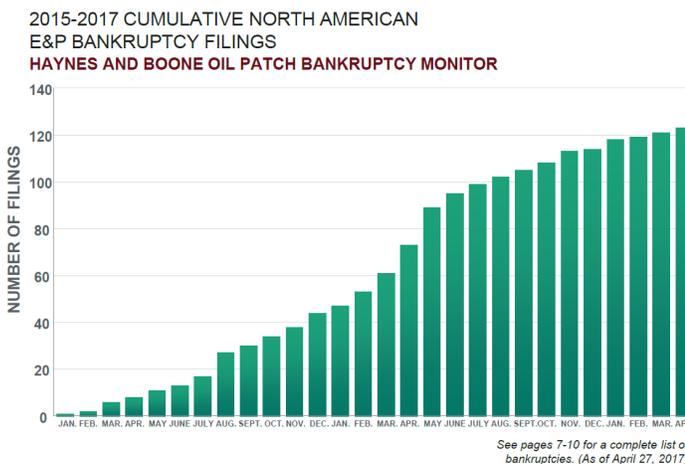
The Impact of the Oil Price Decline on Innovation and Efficiency in the Oil Patch

May 2017

It's hard, but possible, to teach an old dog new tricks

115 years since Spindletop¹, innovation continues to play a vital role in the oil and gas extraction industry. It appears though, that few industries if any have seen such dramatic improvements in how they operate than the oil and gas industry has seen during the current oil price downturn that began almost 3 years ago.

Since the \$100/bbl peak in oil prices in July of 2014 and to an even greater degree, since the precipitous price decline that followed that year's November OPEC policy change, oil producers have been operating with their back against the wall. The pressures on profits, cash flow, and balance sheets from oil price levels that were previously viewed as impossibly low, put almost all oil companies in a "do or die" position. Some have relied on stronger than average balance sheets and best in class resource quality to be in the "do" camp while many others have followed the alternative. According to the law firm Haynes & Boone LLP (H&B), 250 exploration and oil services companies have filed for bankruptcy since January 2015 in North America alone. These bankruptcies represent over \$100B in total debt, according to H&B. At the same time, drilling activity as measured by the Baker Hughes active rig count, declined by 80% from the October 2014 peak to the May 2016 trough (rig activity has since rebounded but it is still down over 50% from the prior peak).



Source: Haynes & Boone LLP

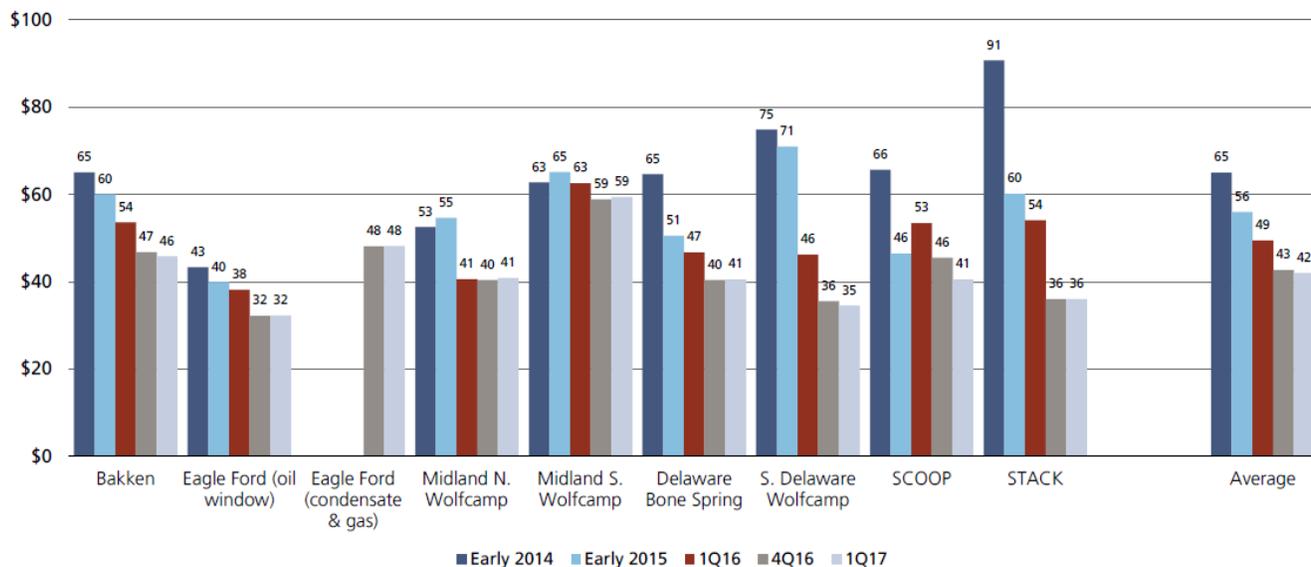
Necessity is the mother of invention

Plato wrote that the creator of the perfect Republic "will be our needs" and clearly the need to be creative in the oil industry has been present in full force during this downturn. In this vein, some oil producers have found a way to take their highest quality oil resources and marry them with sweat, smarter workflows, leaner supply chains, and rapidly evolving unconventional drilling and completion technologies to swiftly lower the breakeven costs of many

¹ <https://en.wikipedia.org/wiki/Spindletop>

of their drilling campaigns. Amongst these, some have been successful in reaching a point where they can be economically viable at oil prices near \$45/bbl and can even drive toward profitable production growth at prices over \$50/bbl. This compares to early 2014 activity that may have required \$80+ to breakeven in some shale plays and \$100+ to breakeven in new deep water drilling projects.

Oil Price Needed for Breakeven Returns in Major Oil Shale Plays Stays Flat QoQ on Average



Source: UBS

In this paper, we will discuss some of the innovations oil companies have been employing to get to this new performance level and what we might expect to see going forward. It is important to keep in mind though that much of the cost savings oil companies are delivering during the current period are driven not only by technology but also by smarter work flows and the benefits of operating in a deflationary supply chain environment where pricing for oilfield services has come down significantly from prior levels. The sub \$50/bbl oil world has shown that despite the advanced age of this industry, some oil companies can rise to be the most nimble, creative, and dynamic companies in existence in any industry. First, let’s begin by taking a look at the results of these recent efforts.

Results Speak for Themselves

There may be many ways to consider the impact of efficiency and technology in the oil patch but the simplest, in our view, is in the result. While technology and efficiency gains are not limited to US shale drilling, it is in this area that they are probably most noticeable at this point, as they have been quicker to produce real impact. US shale drilling tends to be shorter cycle (4-5 months from drilling commencement to production) compared to large offshore projects or the likes of Canadian oil sands which may take 5 years or more from commencement to first production. It stands to reason therefore, that the adoption of better practices and technologies appears here more rapidly and prominently than in the longer cycle projects.

One measure of the changes that oil shale producers are delivering is captured in the Drilling Productivity Report (DPR) published by the US Department of Energy (DOE). The DPR looks at 7 shale regions in the US, including 4 which are primarily oil focused (Permian, Bakken, Niobrara, and Eagle Ford), and 3 gas focused (Haynesville, Marcellus, and Utica). In these reports, the DOE attempts to segregate the impact of oil production from legacy wells and that from new wells recently drilled. This leads to an approximation of the impact and productivity that an average active drilling rig is having in the oil patch today. While big swings in the rig count may be distorting the

exact figures, the direction is clear and in our view is a reliable indicator of changes in productivity and efficiency in oil and gas drilling.

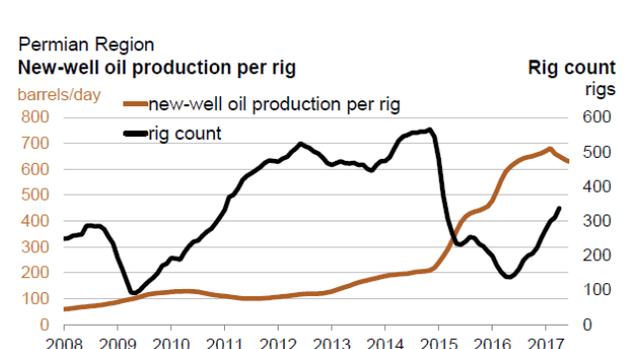
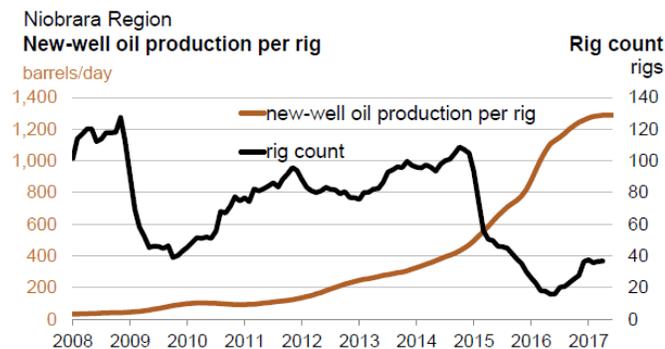
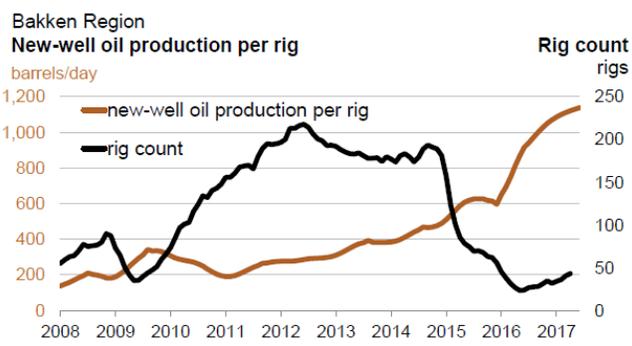
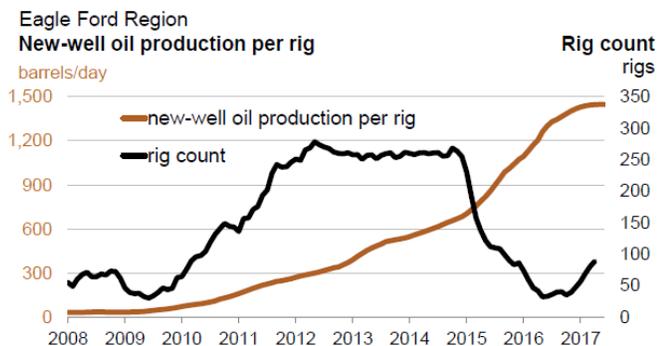
The results are quite amazing. According to the DPR methodology, the average rig drilling in the 4 leading oil shale plays has seen a 2.7x increase in the amount of oil production it is delivering in 2017 compared to 2014.

Comparing the average new oil production estimated per active rig for 2014 with the same average for 2017 YTD implies that Bakken and Eagle Ford have seen production per rig increase by ~2.5x and the Niobrara and the Permian basins have seen 3x+ rates of improvement.

This result is even more amazing when we consider that many of the latest innovations in drilling and fracking techniques and technologies are still evolving and are only being deployed on a subset of the wells being drilled. Therefore it is highly likely that we continue to see more oil per rig at a lower overall cost per barrel. While much of these gains are likely to be offset by a recovery in oilfield cost inflation, it does appear likely that for the strongest producers in US shale, the average costs per barrel will be kept in check for the time being despite rising prices by drilling contractors, fracking companies, and various other parts of the supply chain.

Average "new oil" per rig			
Region	2014FY	2017 YTD	Change
Bakken	439	1,114	2.5x
Eagle Ford	612	1,443	2.4x
Permian	200	655	3.3x
Niobrara	390	1,283	3.3x
Average	411	1,124	2.7x

Source: DOE, 1919ic



Source: DOE

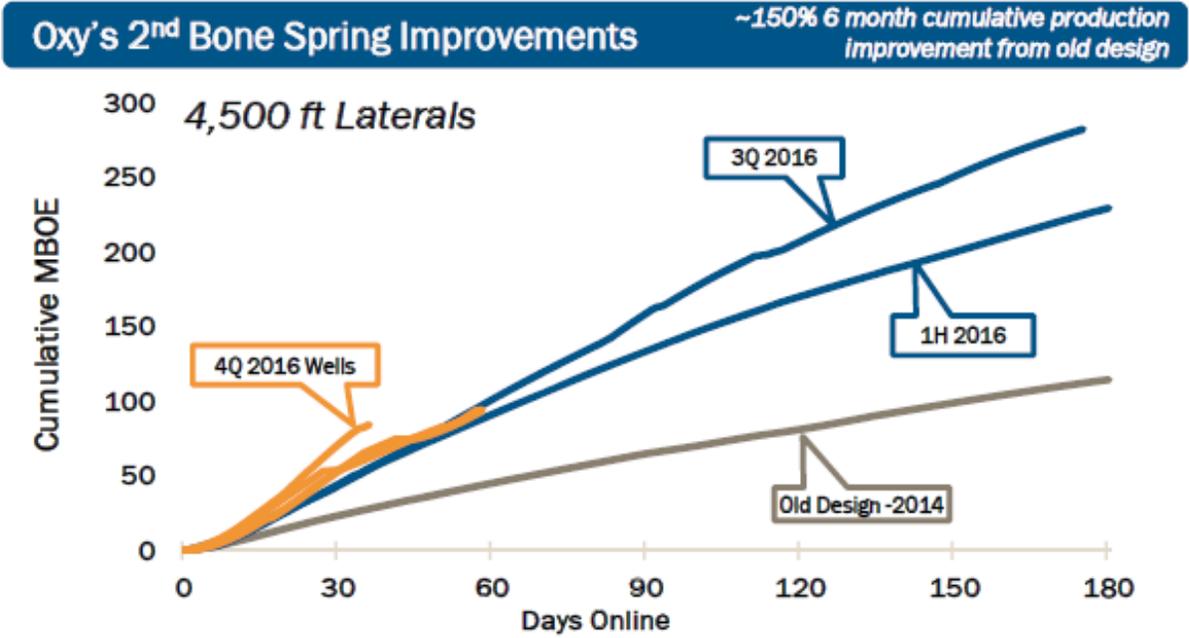
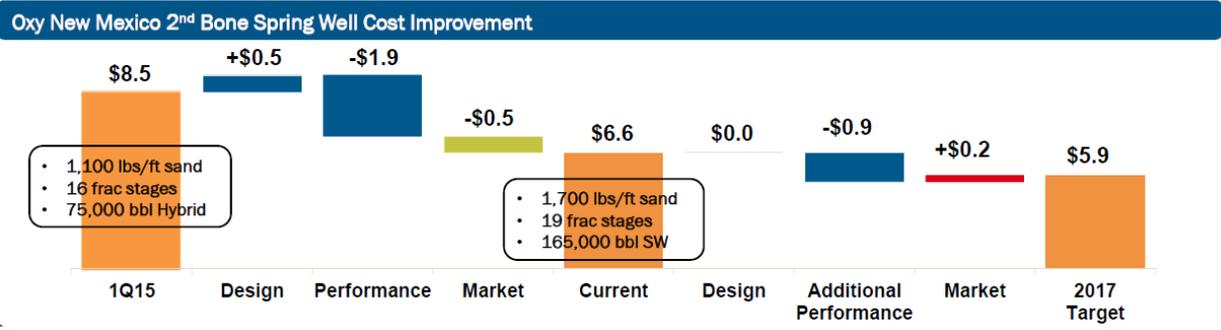
How did we get here?

The results above are impressive and in our view beg two key questions: 1) How did they do it? and 2) Can they sustain, or even improve upon, these results? To tackle the first question we will attempt to decompose the factors that have driven the lower cost per barrel so far. In our view these fall into two primary buckets: Decreases in supply chain pricing and efficiency gains including technology. We will discuss these factors further below. The answer to the second question, in our view, is simply: yes, at least for a few years.

From the conversations we have had with some of these successful exploration & production (E&P) companies and with their oilfield services (OFS) suppliers we have heard some repeated themes. These include faster drilling from using rapidly evolving drill bit technology through lean practices that involve breaking down every step of the drilling process and working closely with contractors to improve each and every step so that they can perform it faster and more competently. Another significant source of efficiency often mentioned by these companies is the use of advanced seismic, geological, and geochemical analysis to achieve more advanced geo mapping to pinpoint the optimal placement of the horizontal well, often defining the “zone” or “sweet spot” to within 10-15 feet for optimal drainage. This concept is then combined with advanced (and improving) geo steering tools and know how, to carefully, yet rapidly place the oil well carefully within this narrow zone through 7,500+ feet of lateral well placement. The lateral sections as well have been increasing in length and in many cases this is helping to drive lower unit costs. On the fracking and completion side, companies mention using geophysical and geochemical data to pinpoint the best locations to target their fractures and the proper balance of force and sand to employ. While these concepts have always been key to successful shale drilling, the current downturn has pushed companies to take a leap forward in the implementation and perfection of these technologies. To illustrate this we can look at an example from Occidental Petroleum (OXY) and how they recently explained their success in the Permian basin.

OXY lowers cost per barrel in the Permian by 54%

In their results presentation for the 4th quarter of 2016, OXY described the improvements they are seeing in drilling the 2nd Bone Spring formation in the Permian basin. Through better design, reductions in nonproductive time, technology, and technique, OXY has managed to lower the drilling and completion cost per well by 22% from Q1 2015 to Q4 2016 and has line of sight to another 10% reduction in 2017. At the same time it is seeing 150% improvement in oil production from the newer wells compared to the older ones. Putting these two factors together takes that total 30% savings in cost per well and drives a 54% reduction in cost per barrel. Breaking down the components underlying the cost savings implies that about 1/2 of the total savings per barrel came from getting more oil out of the same kind of well, about 1/3 came from drilling faster and more efficiently and the balance of 10-15% savings came from the impact of lower oil service pricing.



Source: OXY

What's next?

The period of 2015 and early 2016 saw a step change reduction in costs per barrel amongst leading shale players but the rate of improvement in reducing costs per well appears to have slowed. Companies we speak to describe this as having gone from cutting days off of well drill times to cutting hours. Just about all of these companies though are still working to optimize the best approach to well design, execution, and fracking and have yet to unleash the full power of these improved efficiencies. As these cutting edge improvements are deployed along all of their active drilling campaigns, and as more rigs go to work, it is fair to assume that the US shale leaders continue to deliver more barrels at lower unit costs. In order to continue delivering incremental efficiencies though they are relying more and more on new technologies to drive these incremental efficiencies. Some technological solutions that E&P companies are employing involve the development of in house mobile apps to manage efficiency on the field, using internet of things, big data platforms, and machine learning techniques to improve the efficiency of drilling and fracking operations as well as for stronger maintenance practices for mature wells and equipment. Oil service companies like National Oilwell Varco² and Schlumberger³ have developed new drilling rigs that automate many of these processes that traditionally were controlled manually. The early data appears promising of future improvements and production enhancements that these could drive once deployed in the field. Adoption of these

² More information about the NOVOS system can be found at <http://www.nov.com/NOVOS.aspx#content>

³ More information about Rig of the Future can be found here http://www.slb.com/resources/publications/industry_articles/drilling/201701_dc_drilling_completions.aspx

technologies is still in the very early phases of development so the impact is not yet fully reflected in the already significant improvements discussed above.

Conclusions and Implications

The current oil price downturn which began in 2014 has put the oil industry, including US shale oil operators, to the test. Many have not made it and some more may eventually yield to these market pressures. Some though have survived despite the pressure from very low oil prices and in many cases we find similar themes amongst these survivors. These characteristics include low debt levels and top decile resource quality coming into this downturn and a culture of innovation and execution to match. This subset of oil and gas companies have used efficiency gains and lower supplier pricing to dramatically reduce the breakeven oil price they need to be profitable, in some case by 50% or more. While these benefits have been most evident amongst the top tier of US shale oil operators, improvements are underway in other segments of the oil patch as well both domestically and internationally. Employing advanced technologies both industry specific and some that are more ubiquitous amongst multiple industries has contributed as well. Perfection and full deployment of these improvements has still not peaked, in our view, and in all likelihood best in class operators will be able to offset renewed oilfield service price inflation through ongoing improvements that are still evolving. These gains in efficiency and the rapid renewal of robust drilling rig activity is likely to lead to higher than expected oil production growth from US shale producers.

Putting this in perspective- The other 94%

US shale oil from the leading 4 regions covered in the aforementioned DPR report represent about 5 million barrels per day (5mmb/d) of production. With the above mentioned improvements, this subset may very well be set to grow at staggering rates of 15% or more per year with little, if any, cost escalation. On the margin, this is a bearish outcome for the price of oil, as it increases the risk of supply growing faster than demand. Looking at this factor in isolation would in fact be bearish, but investors are often wiser when trying to look at the broader picture. We would caution investors to consider the context in this case. 5mmb/d is significant indeed but it is only about 6% of total crude oil supply capacity globally. Much of the other 94% has not seen, and is unlikely to see, anything like the improvements mentioned in this report and has been virtually uninvestable for much of the past 3 years. Countries like Mexico and China are already facing significant declines in production and even in the few places where production capacity is increasing (Brazil, Russia, etc.) it is mostly from the completion of projects that were launched 5 or more years ago with few if any new ones coming up behind them. So while the impressive gains in oil shale production are likely to continue, the bigger picture is far more complex and will rely largely on the rate of declines set to take place outside North America.



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