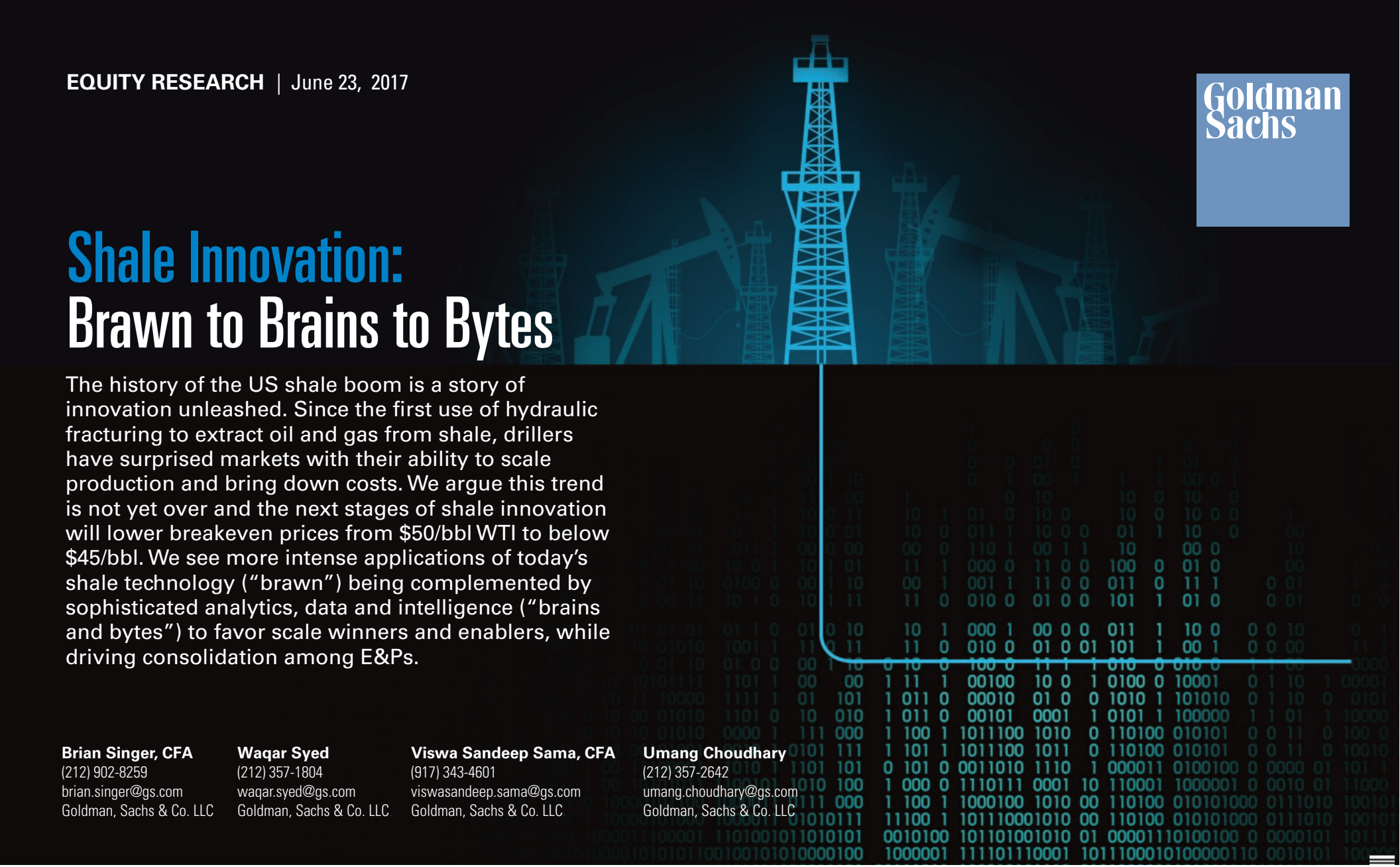
Goldman Sachs

Shale Innovation:
Brawn to Brains to Bytes



The history of the US shale boom is a story of innovation unleashed. Since the first use of hydraulic fracturing to extract oil and gas from shale, drillers have surprised markets with their ability to scale production and bring down costs. We argue this trend is not yet over and the next stages of shale innovation will lower breakeven prices from $50/bbl WTI to below $45/bbl. We see more intense applications of today's shale technology ("brawn") being complemented by sophisticated analytics, data and intelligence ("brains and bytes") to favor scale winners and enablers, while driving consolidation among E&Ps.

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PM Summary: Shale innovation from Brawn to Brains and Bytes should concentrate winners

We believe technological innovation in shale will continue, though beneficiaries are likely to become more concentrated. If the industry is able to more widely apply leading edge technology – likely requiring some consolidation among producers given the need for contiguous acreage to drill longer laterals – the breakeven oil price needed in shale (to earn an 11% after-tax return before considering land acquisition costs) could fall by $5/bbl. The next leg of innovation is likely to warrant: (1) increased focus on multi-disciplined pre-planning for how wells are drilled/fracked, and (2) ability to use large proprietary datasets to help improve well performance and/or lower capital/operating costs. While we believe this could further reduce breakevens, the magnitude is hard to quantify given early stages of implementation. We believe the companies best positioned are those that have contiguous acreage, size/scale to develop and use proprietary datasets, and team-oriented corporate cultures. We highlight Buy-rated EOG (on CL)/PXD/RRC and Neutral-rated OXY/CXO among E&Ps and Buy-rated SLB (on CL), HAL, NBR, SLCA, SOI, Neutral-rated NOV, BHI (Not Rated), and GE Oil & Gas (part of GE, Neutral covered by GS Equity analyst Joe Ritchie) among oil service companies that are at the forefront of ongoing innovation.

We still see US shale breakevens moving lower with current and future technologies

Throughout the shale revolution, the Street has largely marked to market shale productivity gains and has not been forward looking regarding ongoing productivity. We see productivity gains continuing and the potential for US shale breakeven to fall by another $5/bbl with the application of today's leading edge well design and technologies. This could further improve the competitive position of US shales relative to other sources of global supply. We do not believe that the improvement in breakeven prices will stop, as the next leg of improvement will likely be driven by new technologies. We see three stages of shale productivity in the industry– Brawn, Brains, and Bytes. The **Brawn stage** was characterized by E&Ps changing four key variables of well design – (a) making horizontal wells longer (longer laterals); (b) increasing the amount of fracking per well (frac stage count); (c) fracking more closely together (cluster spacing); and (d) using more sand per well (sand intensity). The **Brains stage** is being driven more by a multi-disciplined, analytical and team-oriented approach to drilling/fracking. We expect the **Bytes stage**, currently very early stage, will be driven by the application of big data analytics and Artificial Intelligence/Machine Learning techniques to improve decision-making, equipment reliability and productivity.

Don't discount the engineers

E&Ps have been able to bring down the US shale breakevens from nearly $70/bbl to around $50/bbl, with unique deliverability on the global stage. The extent of the fall in breakevens and scale of deliverability have consistently beat Street expectations. As we look forward, we do not believe we are fully done with US shale productivity improvements. We see a path to another $5/bbl reduction from the application of today's leading edge well designs and technologies, likely achievable by 2020. We note that in order to implement the leading edge well designs, one of the primary constraints would be lack of contiguous acreage. However, we see consolidation among US producers as a way to solve this issue, and allow for E&Ps to increase the length of their horizontal laterals and to benefit from shared facilities and data analytics.

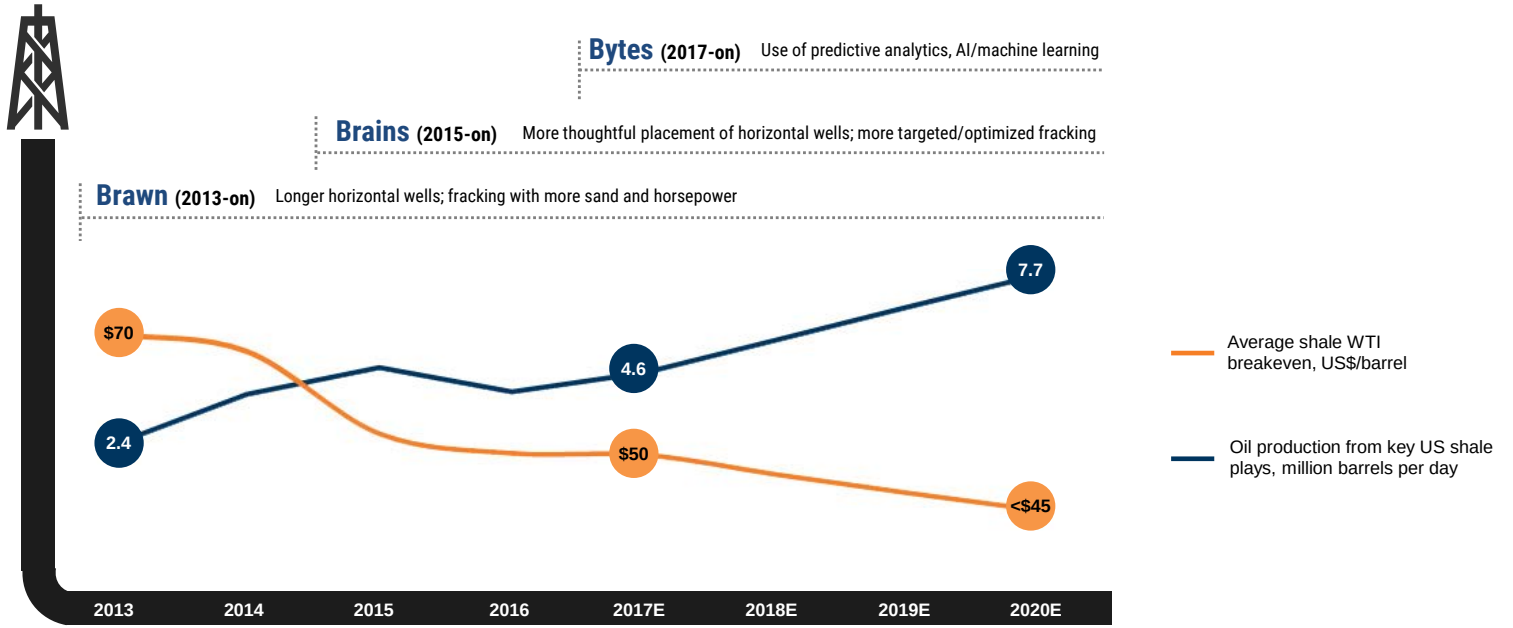
Don't discount the data scientists

While it is hard to quantify the exact impact, we see the potential for US shale breakevens to improve further with help from "Brains" and "Bytes." We consider other technologies available for well productivity improvement – like super-spec rigs, high-spec rotary steerable tools, advanced geosteering, engineered completions, diverter technology etc., albeit at early stages of adoption and implementation – to form part of the "Brain" stage. In the "Bytes" stage, new technologies like Artificial Intelligence and Machine Learning can improve the quality of decision-making for E&Ps, improve service equipment reliability, further reduce cycle times, improve productivity, and reduce overall costs for the customers due to less human intervention.

Need to think differently about winners going forward – concentration over democratization

The evolution of technology into the oil and gas industry will concentrate more winners over the next few years on our view that the drivers of productivity gains during the Brawn phase require less scale/planning while the Brains and Bytes phases need scale/size. We see companies with shale scale, access to proprietary datasets for machine learning/data analytics, and those that are enablers of this technology penetration as winners. Among E&Ps, we prefer EOG, PXD, CLR, RRC and COG, which have "shale scale" and/or which are leaders in technology improvement. In the oil services sector, we highlight SLB, HAL, BHI/GE Oil & Gas, NOV, NBR, SLCA and SOI as companies that are developing new technologies or solutions to improve efficiency and reliability in the oilfield, in turn contributing to the reduction in breakeven prices for US shales. In Exhibit 3, we highlight positioning of various E&P and oil service companies based on their contribution to capital cost reduction, operating cost reduction and well productivity improvement.

Exhibit 1: Future shale innovation can still lower supply cost but will likely should concentrate winners and drive consolidation
Evolution of shale technology innovation drivers, US shale production and breakeven WTI oil prices



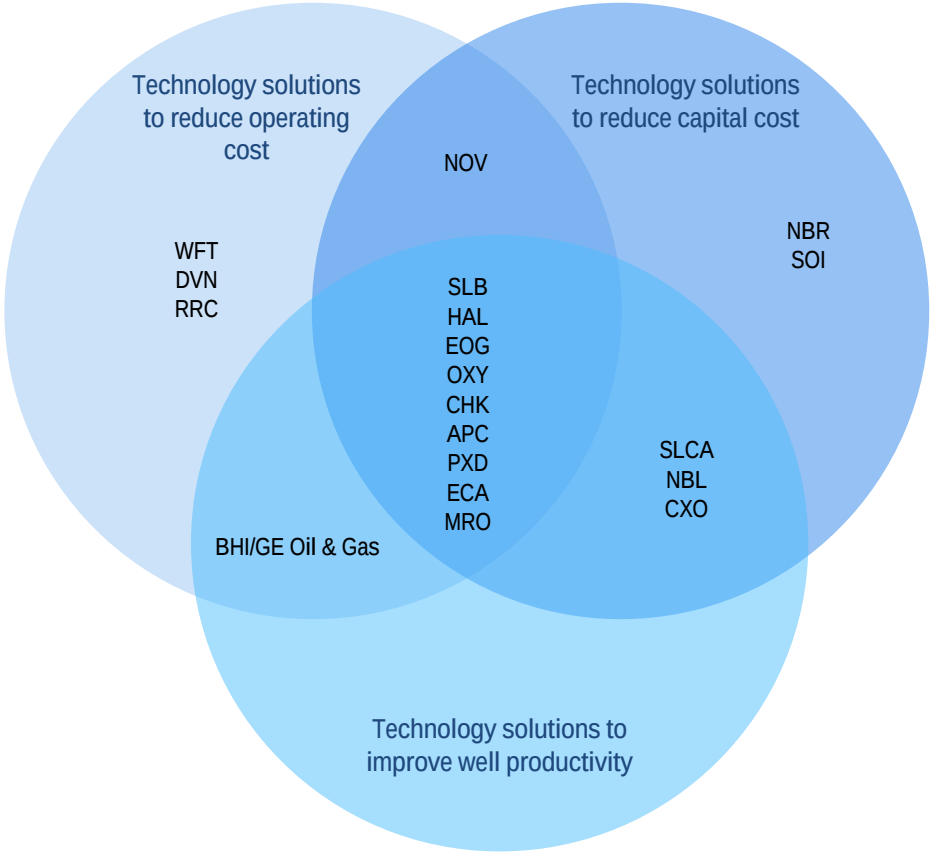
Source: Goldman Sachs Global Investment Research.

Exhibit 2: How Big Data/Machine Learning technologies can be applied to Oil/Gas drilling
Key areas technology can influence operating costs, capital costs, productivity and reliability

Where can technology be used?	What technologies can be used?	To what end?
Future development planning	• Big Data analytics • Artificial Intelligence • Machine Learning	To automate and optimize the development plan for a company
Well design	• Big Data analytics • Artificial Intelligence • Machine Learning	To help E&Ps make better decisions about their wells in real-time
Drilling activity	• Machine Learning	To automate the drilling process, reduce human intervention and improve efficiency
Well completions	• Engineered completions • Microbes • Microseismic	To improve well productivity
Production monitoring	• Fiber optics • Sensors • Welldog's Watchdog system	To make necessary changes to the well in order to maintain or improve rate of production
Preventive maintenance	• Sensors • Big Data analytics • Artificial Intelligence	To gather data via sensors to prevent equipment downtime and minimize associated costs

Source: Goldman Sachs Global Investment Research.

Exhibit 3: We believe these companies either have or are working on solutions that can drive greater operating/capital cost reduction or/and improving well productivity
Highlighted producers have indicated the use of predictive analytics/machine learning/artificial intelligence



Private Ecosystem: Some names to know

Solutions aimed at improving well productivity:
- Biota
- Tachyrus
- Welldog

Solutions aimed at improving processes or use data analytics:
- Mineralsoft
- Seeq
- Ambyint
- Element Analytics
- Neos
- TIBCO Spotfire

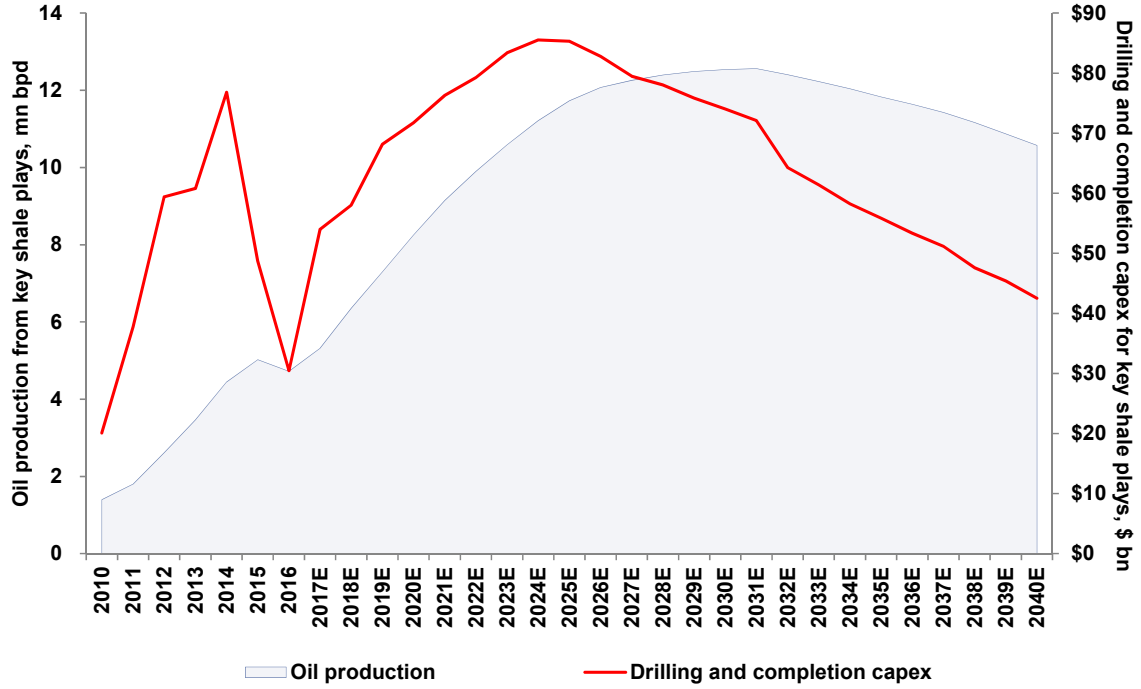
Solutions involving AI/ML:
- Simularity
- Nervana
- Contextere
- Element Analytics

Note: The proposed transaction between BHI and GE Oil & Gas is pending closure; See Exhibits 30 and 31 for a description of the solutions provided by the public companies under GS coverage; See Exhibit 14 for a description of the private companies mentioned above.

Source: Company data, Goldman Sachs Global Investment Research.

What does this mean for shale production/capex trends? We see production growing over the next 10 years, beginning to plateau in the second half of the next decade. We believe we will see continued growth in US production led by shale through the middle of the next decade. We see productivity gains as key to commercializing additional oil/gas and lowering supply cost. We have seen oil production from key US shale plays grow at a 21% CAGR in 2012-2016; we see 14% in 2017-21. Global supply-demand imbalances could shift this more positively or negatively as we see US shale as the key producing area beyond OPEC where production can respond relatively quickly to price signals.

Exhibit 4: We see further technology innovation helping to drive higher shale production and capex until the mid-2020s
US oil production from key US shale plays (Permian Basin, Eagle Ford, Bakken, Anadarko Basin, DJ Basin) in thousands of barrels per day; capex to drill and frack shale wells in billions of US dollars



Source: IHS, EIA, Goldman Sachs Global Investment Research

Cyclical cost positioning driven by pace of drilling/fracking activity increases/decreases. This report focuses on the secular trends in shale innovation and the impact through the cycle on supply costs (net of estimated cyclical inflation/deflation). Individual years can see breakeven prices below or above the secular trend depending on the pace of activity that year relative to available capacity of rigs and fracking equipment. As examples, the sharp decrease in US rig activity in 2015-16 led to lower costs relative to our assumptions on a longer-term basis, and the sharp rise in activity in 2017 is driving a cyclical increase in costs back to the secular trend. Our base case assumes that well costs in 2016 were down 40% from peak (due to cyclical and secular drivers) and that over 2017 costs will rise about 20%-30% for cyclical reasons. On a global basis, we note the 2017 rise in cyclical costs is unique to shale, with the rest of world still seeing downward cost pressures. Our outlook for $5/bbl decline in breakeven oil prices from further application of today's shale technology nets out both the cyclical deflation in 2016 and the cyclical inflation in 2017.

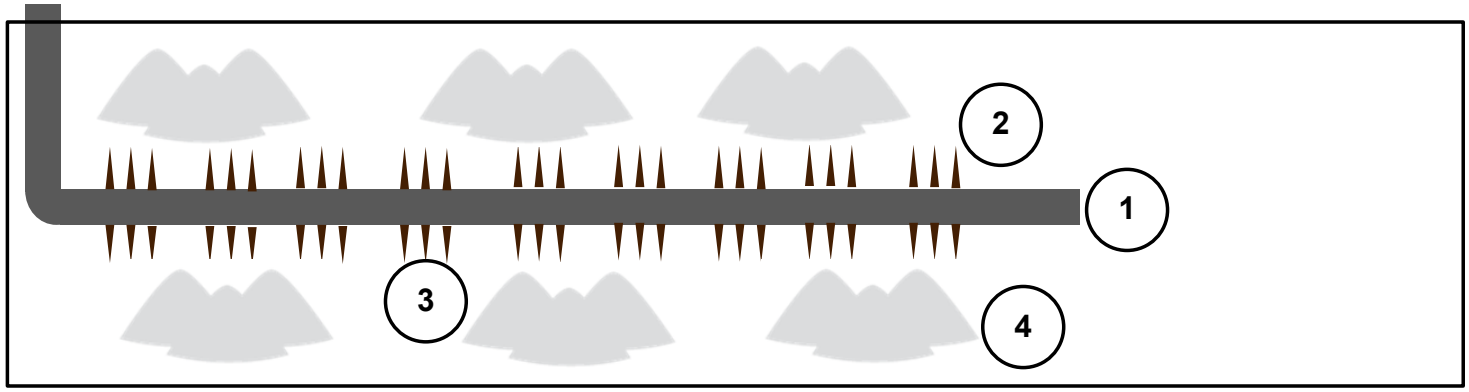
Don't discount the Engineers: We see $5/bbl lower US shale breakevens from further application of today's technology

We believe US shale breakevens can fall by another $5/bbl with the industry's move towards today's leading edge well design from the current average. In this section, we discuss the current average and leading edge well designs, key variables that E&Ps can flex to improve well productivity, and the impact of some of those changes on well productivity.

Four key variables have driven innovation in the Brawn phase

1. **Longer Laterals**: After drilling vertically until a certain depth, the well turns horizontal in order to tap into the relatively thin shale formation. The longer the horizontal lateral, the greater the contact with the reservoir.
2. **Higher # of fracture stages**: After drilling the well, the completion crew fractures the wells in stages. The total number of stages has increased with longer laterals but has also increased as the stages are more tightly packed.
3. **Tighter cluster spacing**: Each stage is further divided into clusters. Typically each stage has 3-8 clusters of perforations.
4. **Greater sand intensity**: Sand is mixed with water and chemicals and pumped into the well at high rate and pressure. The fluid mixture breaks up the oil/gas bearing reservoir allowing for oil/gas molecules to flow into the well. The sand helps keep the fissures open while oil/gas flow out of the reservoir through the well to the surface.

Exhibit 5: Four forces in pictures – longer laterals, more fracture stages, tighter cluster spacing and higher sand intensity
Horizontal well: Longer laterals, more fracture stages, tighter cluster spacing, higher sand intensity

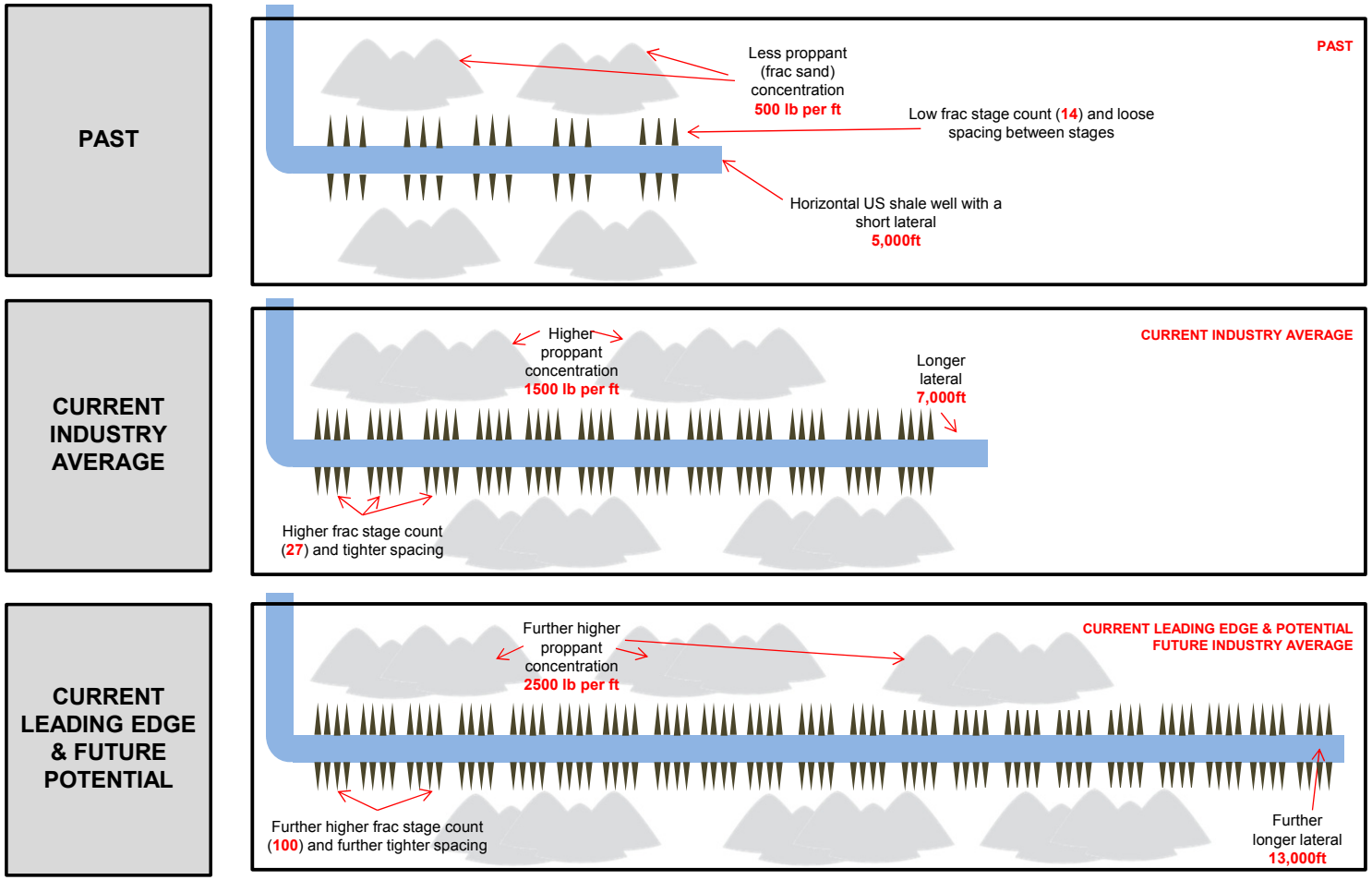


Source: Goldman Sachs Global Investment Research.

We still see room for a further increase in longer laterals and completion intensity. Based on the leading edge well development/completion in every area, we see potential for companies to move to longer laterals and even higher completion intensity. In Exhibit 6, we present our view on where the industry was in the past, where the average is today, and where the leading edge is today based on the four key forces of well productivity. Within the realms of technology that exist as of today, we see the potential for the industry average to catch up to the current leading edge. However, we believe that simultaneously, companies that are already at the leading edge will continue to innovate and maintain or expand the gap relative to others in the industry. We believe on average the industry lateral length can increase to up to 13K ft from 7K ft currently by applying leading edge technology. Similarly, we believe the industry can drill higher proppant intensive wells on average across key shale plays around 2,500 lb/ft.

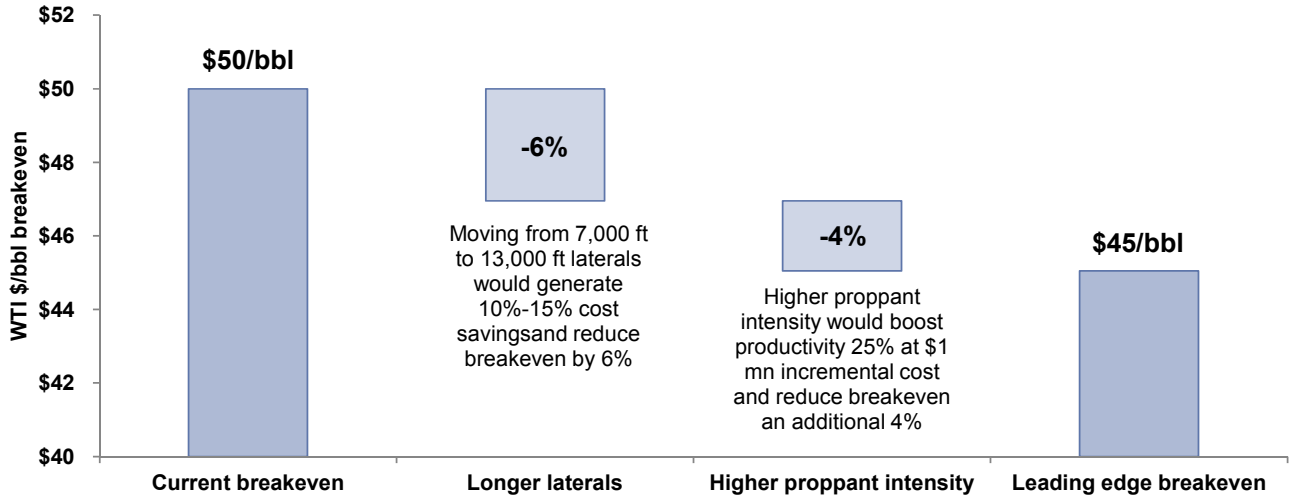
We see $5/bbl impact on breakevens from a further move to longer laterals and completion intensity. As highlighted in Exhibit 7, we believe the move to longer-laterals and greater completion intensity can drive 10% lower per-unit development costs. This can drive breakevens lower from $50/bbl currently closer to $45/bbl. Our breakeven analysis assumes that cyclically, well cost rises 20%-30% off of the 2016 bottom which gives oil services companies normal operating margins which vary by business line and are based on the need to justify either new building economics or reactivation economics for that business line. Beyond cyclical cost pressures, we believe that the move to leading-edge design requires further consolidation of leasehold acreage among E&P producers and additional oil service equipment like high spec rigs, higher sand volumes/deliverability, more pressure pumping horsepower, among others which raises absolute well costs. However, the lower breakeven oil prices result from greater well productivity that more than offsets the increase in well cost.

Exhibit 6: Changes in drilling and completion designs have resulted in higher well productivity thus far
Industry continues to push the limits on the FOUR key forces; we see potential for the industry average to approach current leading edge



Source: EIA, IHS, Goldman Sachs Global Investment Research.

Exhibit 7: We see $5/bbl lower breakeven and expect half of it can be driven by longer laterals and half from higher proppant intensity (we assume 25% higher productivity from 10% higher costs)
Impact on breakevens from longer-laterals and higher completion intensity; net of assumed cyclical cost inflation of 25% off bottom



Source: Goldman Sachs Global Investment Research

Differentiation among producers is likely to pick up as we shift more towards "Brains" and "Bytes" from "Brawn." As producers continue to push beyond past drivers of productivity improvement and more towards the "Brains" stage, we expect greater company-specific differentiation. We believe optimizing where horizontal wells are landed, how they are steered and fracked requires greater pre-planning/engineering and increasingly more data that analyzes past wells and maps out future wells. At present, we see EOG at the leading edge based on their applications of landing zone optimization/higher-density completions and use of proprietary data towards decision-making on future drilling/fracking decisions. We see room for others to catch up, but we do not see the rest of industry equally positioned. Some companies will likely end up utilizing data/technologies provided by oil services companies, which could come at a higher cost.

Case study: Evolution of Pioneer's methods of completions (fracking)

In Exhibit 8, we present a case study from PXD which has experimented with the above mentioned variables in order to improve well productivity. In PXD's version 1.0 completion design which it employed in 2013-14, stage spacing 240 ft (implies a stage count of 42 for 10K ft lateral), cluster spacing was 60 ft, and proppant concentration was 1,000 lb/ft. Later in 2015, PXD shifted to version 2.0 designs which involved stage spacing of 150 ft (implies a stage count of 67 for 10K ft lateral), cluster spacing of 30 ft, and proppant concentration of 1,400 lb/ft. While this design change resulted in absolute well cost increase of around $0.5 mn, PXD was able to get higher production from its wells (35% higher), which effectively lowered per-barrel production costs. PXD further changed these variables in its version 3.0 completions in 2016, which resulted in a total increase of $0.75 mn in well costs from v2.0 but also resulted in production rates that were 50%+ higher than the version 1.0 wells.

Exhibit 8: PXD has increased proppant concentration, fluid concentration, cluster spacing, stage spacing and lateral length, resulting in a 50% increase in resource per well and a 20% reduction in unit capital cost
Evolution of horizontal Permian Basin well by PXD

		Completion vintage		
		v1.0 2013-14	v2.0 2015	v3.0 2016
Proppant concentration	lb/foot	1,000	1,400	1,700
Fluid concentration	bbl/foot	30	36	50
Cluster spacing	feet	60	30	15
Stage spacing	feet	240	150	100
Incremental cost	$ mn	NA	$0.50	$0.75
Resource per well	mn BOE	1.0	1.4	1.5
Capital cost per BOE	$/BOE	$6.48	$5.19	$5.15

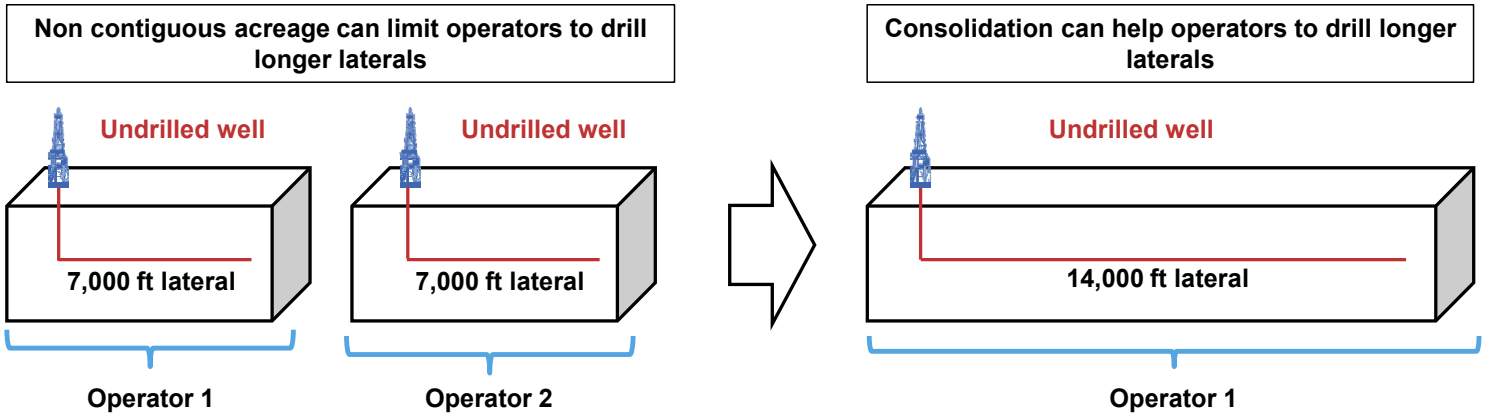
Source: Company data, Goldman Sachs Global Investment Research.

Acreage limitation constraints to drive greater consolidation

The primary constraint to fully applying leading edge technology, in our view, is limited availability of contiguous acreage. Other constraints would be related to limited availability of equipment necessary to be able to drill leading edge wells (super-spec AC drive land rigs and rotary steerable tools and high-spec completion equipment). We believe a move towards greater adoption would require capital investment and newbuilds from oil services companies.

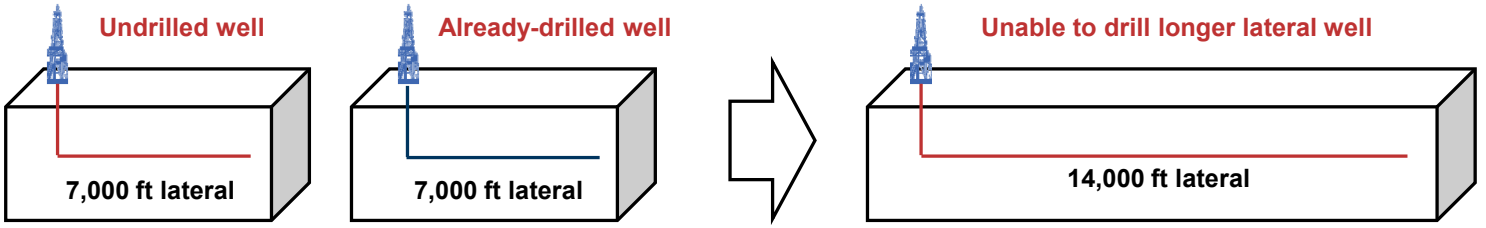
Acreage limitations constrain drilling longer laterals; consolidation likely in less mature plays: One of the primary challenges for E&Ps in drilling super laterals in our view is non availability of contiguous acreage. As illustrated in Exhibit 9, leasehold acreage could put a lid on lateral length for some E&Ps. Assuming the neighboring acreage is undrilled/undeveloped, this could potentially be solved through consolidation or asset purchase. In areas that have been aggressively drilled already (like the Bakken in North Dakota and Eagle Ford Shale in South Texas), the benefits of consolidation may be less robust.

Exhibit 9: Non-contiguous leases limit operators' ability to drill longer laterals; we believe consolidation via asset transactions and corporate acquisitions/mergers would allow for longer lateral development which can drive further cost reductions



Source: Goldman Sachs Global Investment Research.

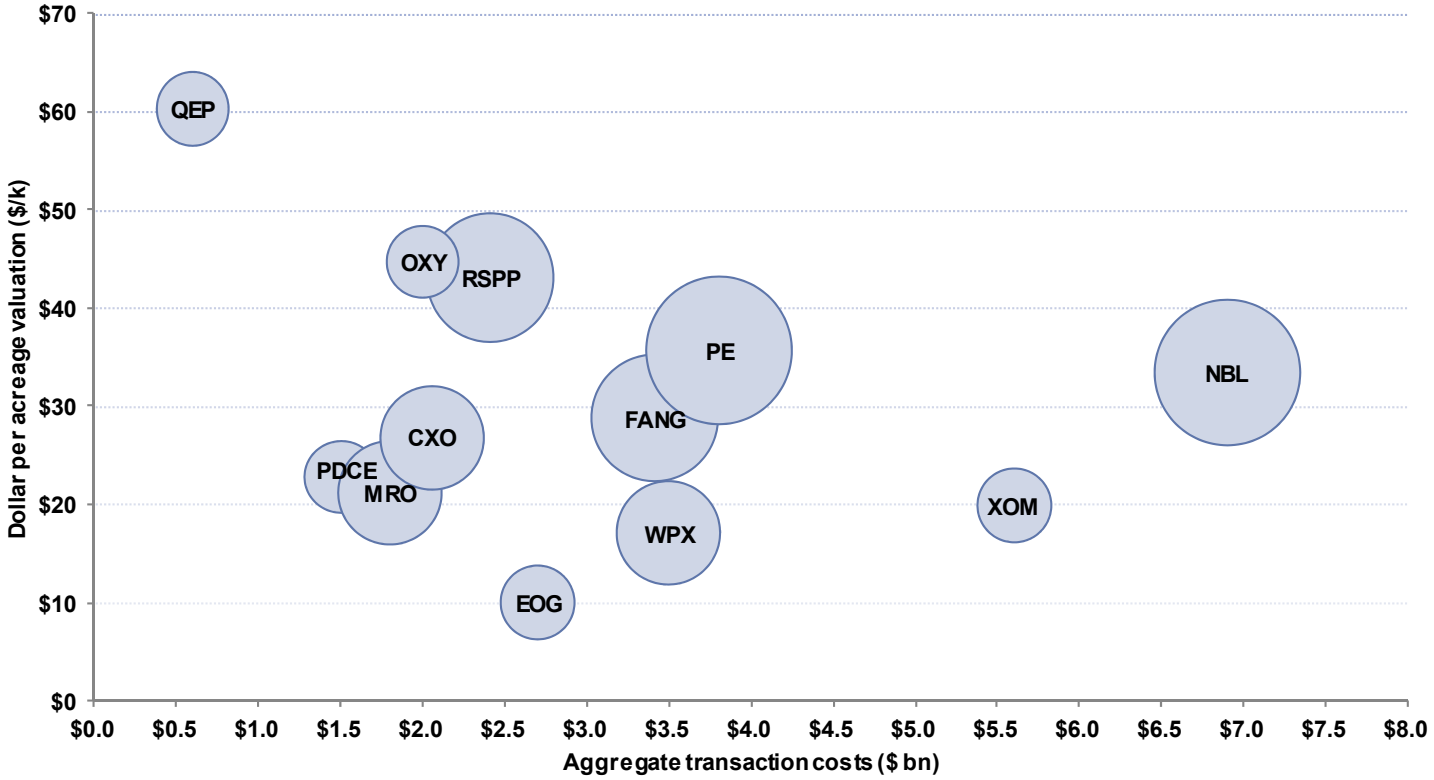
Exhibit 10: Mature plays are more extensively drilled which could limit opportunity to drill longer lateral; we believe consolidation is more likely in less mature plays



Source: Goldman Sachs Global Investment Research.

More consolidation is coming over time, though we have already seen $50 bn of M&A in past two years from mostly private companies/assets. From January 2015 to March 2017, we saw almost $50 bn of M&A (from 36 deals with a minimum $0.2 bn). Of these deals, however, we have seen very little corporate M&A (only three transactions of publicly traded companies). Instead, we have seen a substantial amount of asset or private company acquisitions, largely focused on cores of major plays as companies attempt to build more contiguous acreage positions or expand in a given play. Consolidation has been most prevalent in the Permian Basin (West TX and southeast NM), where we have seen and expect leading productivity gains. We see potential for greater E&P consolidation among publicly traded companies over time as companies try to build contiguous acreage positions, particularly if oil prices/futures remain lower for longer as we expect. For more details on company positioning, please see our May 29, 2017 report, "The Shale Productivity Paradox, v2."

Exhibit 11: We have seen more than $50 bn in M&A since 2015 in shale, but we believe technology innovation trends will drive more consolidation over the next decade so producers can build more contiguous acreage positions
Total acquisition capital outlay ($ bn) in the Permian Basin since 2015 vs. adjusted dollar per acre ($/k); bubble size reflects number of total transactions per company (1-4 range)



Source: IHS, Company data, Goldman Sachs Global Investment Research.

Limited current supply of high-spec rigs and tools will likely require capital investment for newbuilding

The other constraints involved in moving from the current industry average to the leading edge are associated with availability of high-spec equipment/consumables, ranging from super-spec drilling rigs, pressure pumping fleets, high-spec rotary steerable tools and drill bits, and frac sand.

- **Industry only has about 500 super-spec land rigs currently –** a move to the leading edge would imply the need for greater newbuilds.
- **Major players that supply high-spec rotary steerable tools are fully sold out.** This benefits SLB and BHI, in our view, as they offer the leading rotary steerable tools that are required to effectively drill long horizontal laterals.
- **Active pressure pumping horsepower is sold out temporarily, but more reactivations are coming:** We see the pressure pumping industry to be fully utilized by 2H17 and expect new supply to be added in 2018. If the E&P industry moves from the average to leading edge, more capacity may be needed and higher pricing would be required to justify that investment, in our view. Similarly for frac sand, if all E&Ps shift to leading edge proppant intensity, the frac sand industry will need to build more processing capacity. Typical lead times for greenfield developments are around 12-18 months, with the biggest hurdle being permitting.
- **Higher pressure from longer laterals:** Longer laterals make it difficult to manage pressure at the toe of the lateral, requiring a high degree of equipment reliability for successful execution. This is more of a technological constraint as opposed to an equipment availability constraint.
- **Diminishing returns from greater frac stages, for now:** If fracture stage count were to go beyond 50-60 per well, the generally preferred "plug and perf" method may be ineffective as it would slow down the completion process. E&Ps may instead need to use the "sliding sleeve" method which is less effective. As such, the costs of incremental stages relative to incremental productivity gains will remain important.
- **Water availability and disposal:** Rising service intensity could present difficulty in sourcing fresh water at the well site and also in disposing produced water. Saltwater disposal wells were attributed by the state of Oklahoma to an increase in seismic activity (not in a key area that is driving US production growth).

Don't discount the data scientists: Big data analytics and AI/ML at the forefront of future technology

After initially relying on 'brawn' and 'brains' to improve well productivity, the oilfield is now shifting its focus to 'bytes'. Big data analytics, Artificial Intelligence and Machine Learning are at the forefront of several E&Ps' and service providers' minds as they look to not only improve well productivity, but also lower capital and operating costs through better and faster decision-making, more reliable equipment, less human intervention etc. While we acknowledge it is difficult to quantify the exact impact these technologies may have on shale breakevens, we discuss potential future technologies, where they can be applied and to what end, and who some of the key players are – both public and private.

Exhibit 12: How Big Data/Machine Learning technologies can be applied to Oil/Gas drilling
Key areas technology can influence operating costs, capital costs, productivity and reliability

Where can technology be used?	What technologies can be used?	To what end?
Future development planning	• Big Data analytics • Artificial Intelligence • Machine Learning	To automate and optimize the development plan for a company
Well design	• Big Data analytics • Artificial Intelligence • Machine Learning	To help E&Ps make better decisions about their wells in real-time
Drilling activity	• Machine Learning	To automate the drilling process, reduce human intervention and improve efficiency
Well completions	• Engineered completions • Microbes • Microseismic	To improve well productivity
Production monitoring	• Fiber optics • Sensors • Welldog's Watchdog system	To make necessary changes to the well in order to maintain or improve rate of production
Preventive maintenance	• Sensors • Big Data analytics • Artificial Intelligence	To gather data via sensors to prevent equipment downtime and minimize associated costs

Source: Goldman Sachs Global Investment Research.

Where does industry source data from?

Public data: The E&P/Oil services industry has for years had access to state data due to mandatory filing regulations. Most producers agree that there are significant limitations on public data as the accuracy of well performance is lagged and the drivers of well performance are not clear.

Proprietary data: Advancements in information technology have allowed the E&P industry to capture and maintain data sets more real time. Proprietary data sets which measure multiple parameters by well at much narrower intervals of time are critical for best using machine learning/data analytics to not just predict well performance but try to improve it. Based on company commentary in recent months, there is a more intense focus on building these databases. Beyond the producers, oilfield service companies are using similar technologies in order to improve the uptime and reliability of their equipment in order to minimize costs for their customers. Equipment manufacturers like GE and NOV are already using sensors to gather data from their installed base of equipment and analyze it to identify potential failures in the future. However, this application is confined to the offshore rigs currently and has the potential to be applied more broadly. SLB has made a big push and has invested in opening several facilities with a focus on big data analytics and AI/ML.

How is data technology helping the oil & gas industry?

Future development planning. E&Ps approve business plans based on a certain set of macro assumptions regarding oil/gas prices, financial capability based on balance sheet/cash flow, existing infrastructure availability (existing pads/takeaway capacity), leasehold requirements, availability of oil service equipment, among others. To the extent that AI/ML applications can better inform managements about optimum development plans, companies can make better decisions. In addition, AI/ML application can help in (1) more accurate determination of costs and well productivity, by incorporating the industry's/company's past experiences in such projects, and (2) better execution of the company's projects by keeping costs in line with plans.

- **Range Resources (RRC)** noted potential for machine learning to reduce the time it takes the company to plan future development and better predict production performance.
- **EOG Resources (EOG)** is applying integrated solution which captures multiple real-time data (geological, petrophysical, mapping, others) to optimally develop shale plays which reduces time from development planning to first production.

Well design: The design of where wells are landed, how they are steered around potential hazards (faulting) and how wells are fracked (horsepower, fluid/sand concentration) are critical to well performance. Companies are in various stages of using data analytics to support landing, steering and fracking. Over time we expect wider use of predictive analytics to improve performance.

- **EOG:** EOG has developed in-house proprietary databases and applications that capture real-time information of every rig/completion fleet/well. Using this data, management believes it can more efficiently drill (by knowing the various rock intervals and the depth of the target zone) and to complete (optimum pressure rate, fluid/proppant concentration by stage) a well. Management believes application of the technology is in its early innings.
- **Pioneer Natural Resources**: PXD is using supercomputers and GEOS software at Lawrence Livermore National Laboratory to model and visualize the propagation of fractures in three dimensions and with time. Management indicated that this would enable the company to better optimize completion activity by various zones and by geographical area within the Permian Basin.

- **Encana:** Management is using its dataset to see how much fluid/proppant each cluster is using during its completion and how much each cluster contributes during production. This was initially tested on a 10K foot lateral well with eight different versions of completion designs across 30 stages and 150 clusters with goal of evaluating the effectiveness of each design.
- **Chesapeake Energy:** CHK believes its data and core lab are a competitive advantage. Management believes this allows for faster decisions on expected performance and asset value relative to the rest of industry
- **Laredo Petroleum:** LPI noted it is using data to assess the individual impact of geologic completion and well design variables on horizontal well production. This process has enabled Laredo to fully leverage its contiguous acreage base to support drilling extended lateral lengths from 10K feet to more than 15K feet today.
- Oil Service providers like **MicroSeismic Inc.**'s hydraulic fracture mapping and monitoring service enables E&Ps to study previously completed wells and modify their completion designs in order to improve productivity.
- Biotechnology start-up **Biota** uses DNA sequencing to help E&Ps identify sweet spots, flag connectivity within different zones of a reservoir etc. Biota's technique relies on Microbes that reside in the earth's sub-surface.

Technologically advanced drilling rigs: SLB and NBR are in the process of developing and piloting next generation drilling rigs which will feature closed loop automation and will come ready with the ability to offer integrated services in addition to just the primary offering of drilling. These can include casing and tubing running services, directional drilling etc. The rigs will feature a new operating system that allows for seamless communication between the surface and downhole equipment. Over time, the rigs will be able to perform several tasks automatically, enabled by Machine Learning. Advancement of this technology not only enhances the drilling performance as rigs can deliver repeatable results, but also lower costs due to reduced human intervention.

Improving equipment reliability. Unplanned equipment downtime and non-productive lost time are some of the biggest drivers of project cost escalation. The industry is highly focused on improving equipment reliability, and AI/ML can help in this regard. The industry is especially targeting preventive replacement of drilling/completing equipment and operational equipment (like artificial lifts).

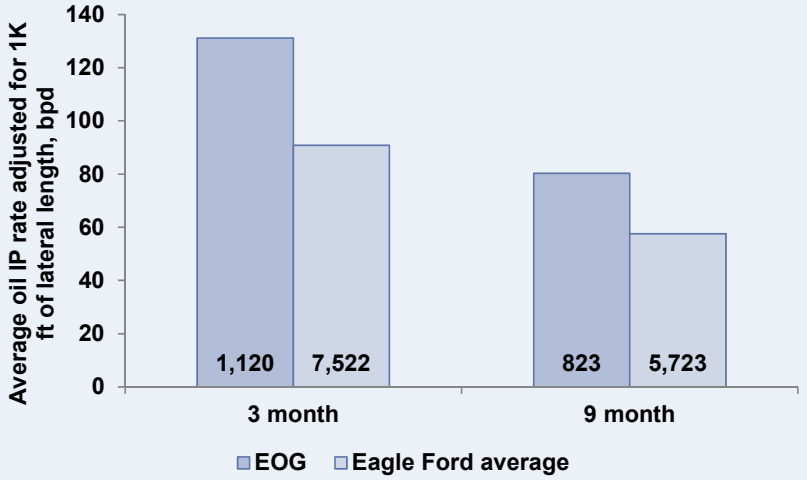
- Large cap oil services companies like **Schlumberger (SLB), Baker Hughes (BHI)/General Electric (GE)** collect large quantities of data during the well construction and completion process which they can internally analyze to offer customized recommendations for their customers. SLB recently set up offices in the UK and in Silicon Valley with a focus on advancing these capabilities.
- Equipment manufacturing companies like **National Oilwell Varco (NOV)** have been using sensors to gather data from their installed base of equipment and run analytics on these to determine when the next equipment failure is likely to happen and thereby warn their customers ahead of time. Technologies like this can help customers avoid costly downtimes by being better prepared for a failure or by fixing the issue ahead of time.
- Vertically integrated E&Ps like **Pioneer Natural Resources (PXD)** noted that typical pressure pumping equipment would only last around 300 hours before failing due to metal fatigue. The company is working with Oak Ridge National Labs and has produced a proprietary fluid which, the management believes, can improve the metallurgy at the time of forging and increase the service life of the pressure pumper by tenfold. Management indicated that the first pressure pumping equipment built by using the new technology has passed 750 hours so far.

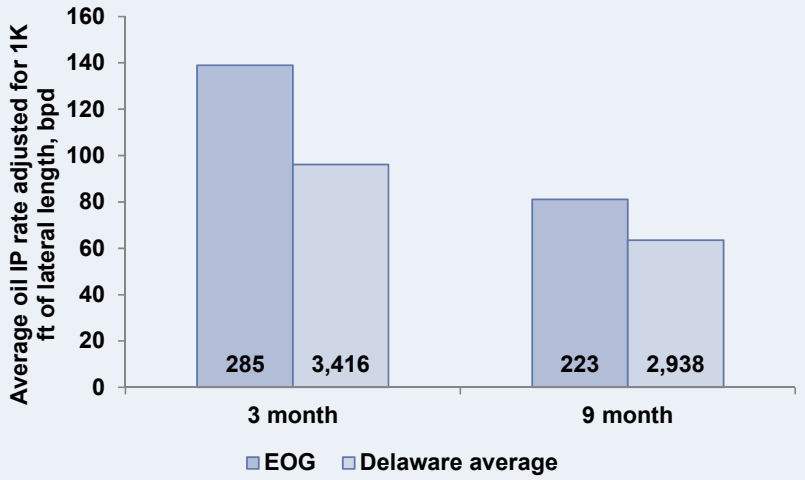
Application of data analytics to help drive superior well productivity: EOG case study

By combining higher intensity completions (Brawn), better geosteering to target landing zones/recover more oil/gas closer to the well (Brains) and using data science/analytics (Bytes) to accelerate learnings, EOG has demonstrated the achievement of superior well productivity as compared to peers in key shale plays. EOG has spent 6-7 years to create proprietary database which captures real-time information on every rig/fleet/well and various in-house apps that allow decentralized access to this data. EOG believes it still remains in the early innings of using technology to advance productivity and is now focused on shifting from data on demand to learning on demand as it looks at advancing big data/predictive analytics in order to drive future efficiencies. The ultimate goal is to use its dataset to provide: (1) its geosteering staff/completions engineers with better guidance for what to expect real time from the well; (2) optimal well spacing patterns; and (3) better fracture stimulation recipes (fluid/sand concentration). Management noted it is in the early stages of integrating into drilling new wells with a goal of substantially increasing well performance. Overall, we believe EOG is ahead of the curve, which further cements its technological leadership, advances the benefits of scale and can help continue leading well performance.

The exhibit below shows that EOG Resources 9 month production rates are 28%-40% above peers in Delaware Basin and Eagle Ford (key drivers of production growth for the company). It is difficult to determine how much of the stronger well performance should be attributed to superior geology (better acreage) vs. the individual components of innovation (i.e., "Brawn" vs. "Brains" vs. "Bytes" leadership). However, EOG's better well productivity drives $5-$15/bbl lower per-well breakeven as compared to its peers and helps translate into superior per-share growth and corporate returns which suggests superior capital efficiency, in our view.

Exhibit 13: EOG's 9-month IP rates adjusted for lateral are 40%/28% above peers in the Eagle Ford/Delaware Basin respectively
9 month peak oil IP rates adjusted for lateral length in the Eagle Ford/Permian Delaware Basin





Source: IHS. Goldman Sachs Global Investment Research.

Exhibit 14: A sampling of private companies working on technologies applicable to oil/gas drilling
We do not take a view on the efficacy/application of each company's technology

- **Biota:** "Founded in 2013, Biota applies DNA sequencing and data science to explore the earth's subsurface. We provide actionable insights to the oil industry for maximizing reservoir production and reducing environmental impact. Biota enhances multimillion-dollar decisions with DNA data services for production profiling, sweet spot identification, and reservoir connectivity."
- **Ambyint:** "With the launch of ambyint in 2015, the immense power of the Industrial Internet of Things (IIoT) was introduced to Western Canada's oil patch. As a result, every well in operation was given the power to be made "smart" — able to be remotely operated, to produce more with less, and to do it better every single day."
- **Seeq:** "Seeq is founded on the premise that process manufacturing companies need better solutions for deriving business insight from Industrial Process Data. You can think of Seeq as the "Google" of your Industrial Process Data: fast, interactive, and intuitive. Customers using Seeq experience faster insights on production data, a higher return-on-investment from existing data sources, and increased collaboration among employees to drive better operations decisions."
- **Nervana:** "Using deep learning as a computational paradigm, Nervana is building a full-stack solution that is optimized from algorithms down to silicon to solve machine learning problems at scale. Deep learning accurately predicts subsurface faults without the need of manual intervention. This improves exploration effectiveness and increases ROI. Deploying deep learning solutions to analyze real-time data from sensors at drilling sites, pipelines and refineries improves equipment availability, minimizes risk and lowers cost of production."
- **Simularity:** "Simularity uses machine learning and statistical probabilities in a patent-pending process to learn what "normal" looks like in any time series data set. We can tell when things aren't acting normally, and we can also identify event signatures for specific events that can provide context and prescriptive maintenance instructions."
- **Contextere:** "contextere enterprise software curates personal, situational and enterprise data to deliver consumable, contextually relevant content that answers the simple question "What should I do next?". Using human-centric machine learning and intelligent context generation we are creating the first mobile personal assistant for the industrial worker."
- **Element Analytics:** "The Element Platform helps industrial organizations rapidly turn time-series data into actionable insight. The platform automates the heavy lifting of making data ready for analytics, and enables machine-learning modeling to surface reliability, productivity, and sustainability insights for operations."
- **Neos:** - aircraft based remote sensing platforms for exploration – "Combining advanced sensor, computing and data analysis techniques with the experience of our team of world-class geoscientists, mathematicians and engineers, we analyze and interpret geological, geophysical and geochemical data to build an accurate view of the Earth. We constantly innovate, using cutting-edge technology to acquire and interpret data. We use our skill and experience to transform that data into knowledge, so our clients can quickly make informed decisions about where to explore, lease, and drill."
- **Tachyrus:** "Operators leverage our platform across 10,000+ wells to cut costs and increase production in steamfloods, CO2 floods, chemical floods and waterfloods. Thermion: Cyclic Steam Optimization; Atmion: Steamflood Optimization; Aqueon: Waterflood Optimization; Dioxeon: CO2 Flood Optimization; Pythia: Artificial Lift Optimization; Pythia: Workover Optimization"
- **Mineralsoft:** "MineralSoft is an integrated data platform for oil and gas. Our inputs: complex, disorganized, and fragmented data about oil and gas production. Our product: revenue optimization and automated intelligence for mineral owners, investors, and stakeholders."

Source: Company data.

Exhibit 14 cont'd: A sampling of private companies working on technologies applicable to oil/gas drilling
We do not take a view on the efficacy/application of each company's technology

- **Welldog:** "Welldog's WatchDog is an electronic or fiber optic downhole monitoring system. WatchDog downhole gauge monitoring systems are engineered to overcome two historical client challenges, cost and reliability. Systems are cost effectively engineered and used to, characterize and optimize production, or to conduct long term surveillance of reservoir performance. Access to actionable production and/or reservoir performance data delivers the ability to make informed and confident decisions."
- **MicroSeismic, Inc.:** "MicroSeismic, Inc. is an oilfield services company providing completions evaluation services and real-time monitoring and mapping of hydraulic fracture operations in unconventional oil and gas plays. Founded in 2003, MicroSeismic invented the use of surface microseismic monitoring to listen to the naturally occurring, low-energy seismic noise emitted from a reservoir during hydraulic fracturing stimulation. Utilizing surface, near-surface, and downhole arrays, MicroSeismic helps oil and gas companies understand how the reservoir responds to stimulation and its impact on customer economics."
- **TIBCO Spotfire:** "TIBCO Spotfire helps well engineers the world over analyze data faster. Spotfire's intuitive, interactive, analytic platform enables users to make better decisions across diverse and challenging environments. Oil field services companies benefit from using Spotfire analytics across their organizations—from technical use cases to cross functional areas such as HR, finance and health safety and the environment. Spotfire helps to drive down costs through rigorous analysis at every stage of a delivered service."

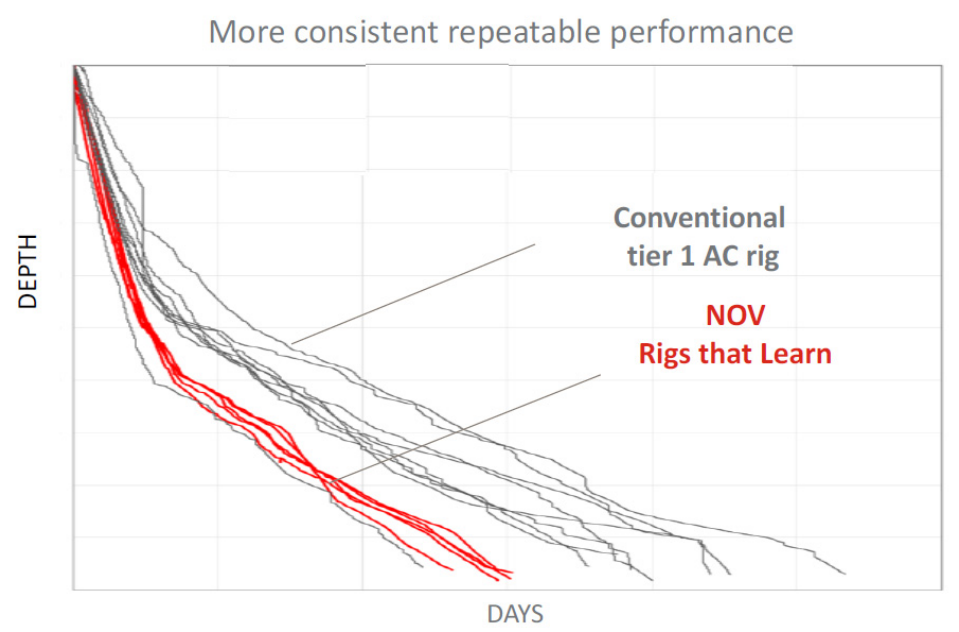
Source: Company data.

Application of AI/ML in improving drilling performance: NOV case study

By combining machine learning capabilities with closed loop drilling automation, NOV has demonstrated the achievement of efficient, repeatable and reliable performance from drilling rigs. Through this technology combination, rigs were able to drill faster, timing and quality of decision making was improved, human error potential was reduced, and the amount of stress on crews and assets was mitigated.

The exhibit below shows that National Oilwell Varco's Automation system can reduce drilling time at a well's bottom by 30% on average. More important, NOV's Automation system brought the drilling time within a narrow 2.5 to 3.0 day window versus 2.5 to 5.5 days for conventional drilling methods.

Exhibit 15: Illustration of the impact of closed loop drilling automation on drilling rig performance

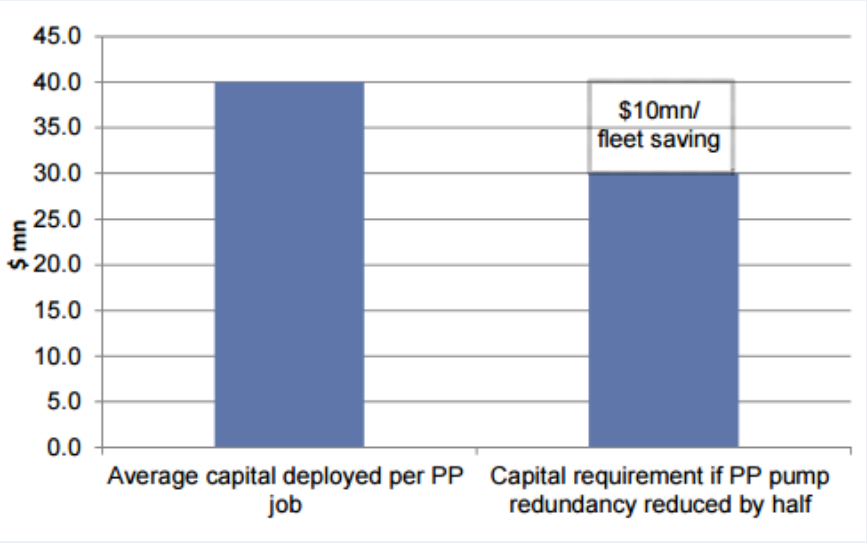


Source: NOV

Application of AI/ML in reducing capital intensity in pressure pumping

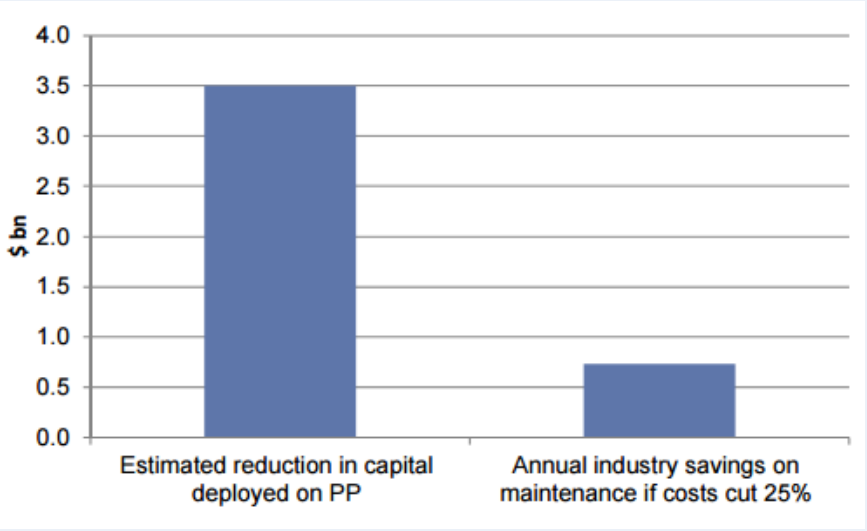
An average pressure pumping job in the US requires about 20,000 HHP. However, the industry typically takes about 40,000 HHP to the wellsite, in order to maintain redundancy and lower non-productive job time in case of equipment failure. This level of redundancy is inefficient for the oil and gas industry. Should equipment reliability be enhanced, through initiatives like Schlumberger's (predictive maintenance through data analytics), the level of equipment redundancy needed at the wellsite will be reduced. We estimate that if the level of redundancy required in the field is reduced in half, the capital deployed on a pressure pumping job could be reduced by 25% from about $40mn to $30mn. Similarly, predictive analytics can reduce equipment maintenance, and we estimate that a 25% reduction in maintenance costs could lead to the industry saving about $0.7bn annually (or $7bn in 10-years) on the industry's fleet of 14mn HHP at 85% equipment utilization.

Exhibit 16: Average capital deployed per pressure pumping fleet could be reduced by 25%
Assuming 40,000HHP average US pressure pumping fleet



Source: Goldman Sachs Global Investment Research.

Exhibit 17: The industry could cut total deployed capital in PP fleets by $3.5bn
25% lower maintenance costs is a $0.7bn annual opportunity



Source: Goldman Sachs Global Investment Research.

What are the potential challenges involved in digitizing the oilfield?

While the digitization of the oilfield will have positive implications for US shales and their positioning on the global cost curve, we see some "teething" issues or implementation challenges. Some of these concerns were also highlighted by companies recently at the Offshore Technology Conference in Houston.

Lack of adequate amounts of data to run meaningful analyses: Big Data analytics requires large amounts of data in order to produce meaningful results. Some of the larger industry players – both in the E&P space and in oil services space – have access to large historical data sets which sets them apart from the rest of the industry. We highlight companies like EOG, OXY, PXD, CXO, SLB, HAL, and GE Oil & Gas as advantaged relative to other smaller companies on this aspect.

Cultural challenges due to friction between data scientists and geological engineers: Owing to risks associated with implementing recommendations from AI/ML techniques, we believe geological engineers working at the field level might be hesitant about following recommendations made by data scientists that run the Big Data analytics. We believe that senior management involvement would be required in order to emphasize the need for a move in this direction.

To share or to not share the data? Some industry participants like HAL have been advocating democratization of Big Data in order to improve the accuracy of results, while several others have maintained the proprietary status of their data. While the argument about greater collaboration driving better conclusions is true, we believe that companies would be less willing to collaborate given the difficulty in maintaining their differentiated advantage and making sure that they are not at an economic disadvantage.

How to invest in this theme? Democratization to concentration

We believe the drivers of future shale productivity will be concentrated among fewer companies or require consolidation. This is because the "Brains" and "Bytes" stages warrant larger sets of data and more team-oriented collaborative cultures. As such, we believe stock picking will be critically important going forward, especially if our lower for longer oil price outlook plays out. Among E&Ps, we believe companies with "shale scale" contiguous acreage position in the core of the shale plays will be able to drive greater efficiency with longer laterals. We also see potential for companies which are early adopters of new technology (like predictive analytics/machine learning) to benefit from greater productivity improvement and better efficiencies. We prefer EOG (on CL) and PXD among companies that have scale and are early adopters of new technology like machine learning and artificial intelligence.

Exhibit 18: We see EOG, PXD, SLB, HAL as continuing their technological advantage going forward
Key technology themes and stock leaders; Buy-rated stocks noted in bold; SLB and EOG on Conviction List

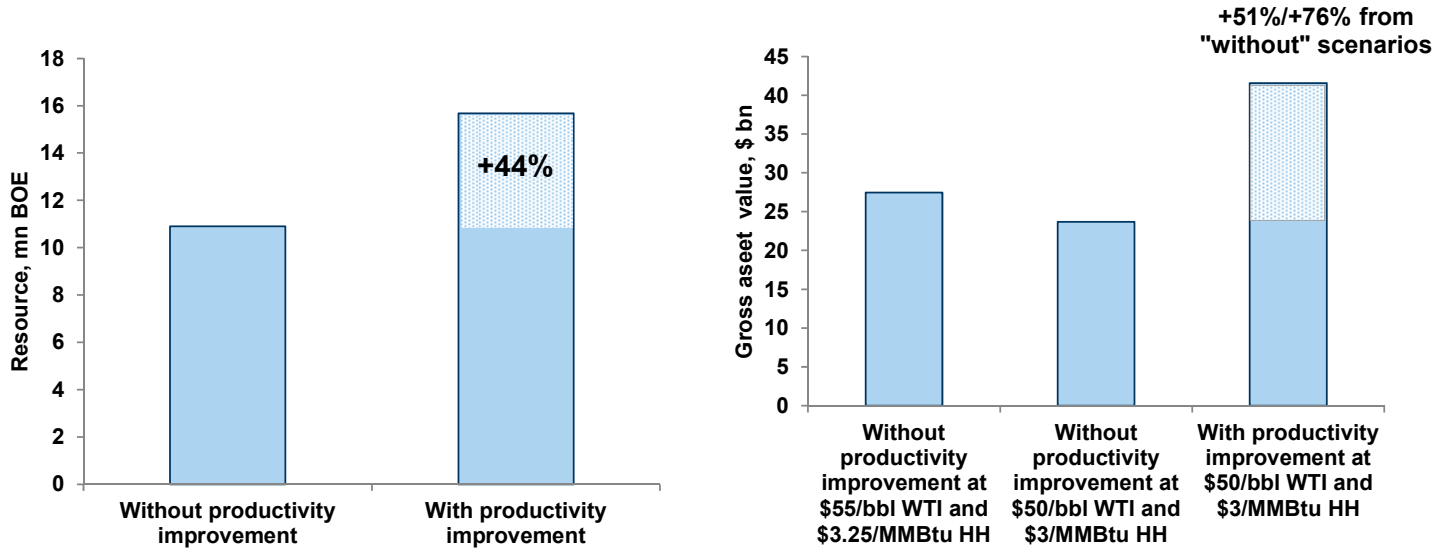
Theme	Stocks to own for the theme
Technology leaders	**EOG,** OXY, **PXD, APC,** CHK, **ECA,** MRO, **SLB, HAL**
Shale scale winners	**EOG, PXD, COG, RRC,** AR, CXO, **CLR**
Productivity enablers	**SLB, HAL, NBR, SLCA**

Source: Goldman Sachs Global Investment Research.

Shale scale winners: We believe companies with contiguous acreage position in the core of the shale plays will benefit from (1) lower operating: more contiguous acreage position should allow greater utilization of midstream/other facilities and scale in operations; and (2) lower capital costs: ability to drill more longer lateral wells will allow the companies to realize better well costs as compared to peers. Companies with shale scale acreage positon have generally lower operating cost structure and capital costs as compared to peers, in our view. We believe companies with less scale will look to acquire and build shale scale to drive efficiencies.

Productivity can drive higher equity value even with lower prices: PXD case study. We believe productivity improvement can be an important driver of equity valuations even if shale productivity gains results in lower commodity prices. For PXD, we see potential for a 44% increase in recoverable resources after assuming 3%-10% annual shale productivity improvement through 2020 (10%/6% productivity improvement in Permian/Eagle Ford). At $55/bbl WTI oil and $3.25/MMBtu Henry Hub gas, the gross asset valuation for PXD is $27 bn. At $50/bbl WTI and $3.00/MMBtu gas the asset value would fall 14%. However, in our view a 10%/6% annual productivity improvement through the end of the decade can more than reverse the upside to such a degree that asset value would be 51% higher at the lower oil/gas price with productivity gains than at $55/bbl WTI and $3.25/MMBtu gas without productivity gains.

Exhibit 19: For PXD, productivity improvement can drive improvement in asset valuation even at $5/bbl lower oil prices
PXD gross asset value before/after assuming 3%-10% annual productivity improvement for shale plays through end of 2020



Source: Company data, Goldman Sachs Global Investment Research.

Exhibit 20: We highlight key technologies used by E&Ps, what phase they are in, and which companies are involved
Select commentary by E&Ps in key areas technology can influence operating costs, capital costs, productivity and reliability

Drilling/completion activity optimization

Proprietary database

Stage: Implementation

Database which captures the well information drilled by the company and industry.

Most of the industry captures well information for reservoir models and runs multi-variate analysis on the wells. Larger-scale companies (like **EOG, OXY**) have indicated that their database is more proprietary and captures more real-time in-depth well information.

Drilling/completion efficiency

Stage: Pilot/Implementation

Applying analytics to select optimum equipment and new technologies to increase equipment life.

OXY: Reduce drilling days, fewer tool failures and precision landing

PXD: Partnered with Oak Ridge National Labs, to increase the service life of pressure pumping equipment

ECA: Using "Cube development" to drive greater surface efficiency

Improving well productivity

Stage: Pilot/Implementation

Applying techniques which improves targeting and completion technique.

EOG: Goal is to provide geosteering staff/completions engineers with (1) better guidance on where wells should be drilled/steered; (2) optimal well spacing patterns; and (3) better fracture stimulation recipes.

OXY, PXD, CHK, MRO, APC, CXO, ECA, NBL among others applying the technology

Operating cost reduction/base production optimization

Predictive maintenance/Active well management

Stage: Implementation

Ability to repair/replace equipment to reduce/prevent production downtime.

EOG: Monitoring systems at well site to optimally ensure active well management and minimum downtime of existing producing wells.

OXY: Lift System diagnostic/optimization via artificial intelligence. Potential for further efficiencies with chemical treatments, safety, failure detection, etc

DVN/CHK: Predictive analytics to reduce downtime in production and improve base production

MRO: Data analytics to correlate well/meter/facility performance which leads to interventions and increases production by reducing downtime. Surveillance dashboards prioritize work based on automation alerts, operational trends, and planned maintenance reducing frequency of well visits and operational staffing requirements

APC, RRC, PXD, ECA among others applying above technology

Optimizing future development plan

Future development planning

Stage: Conceptual

To automate and optimize the development plan

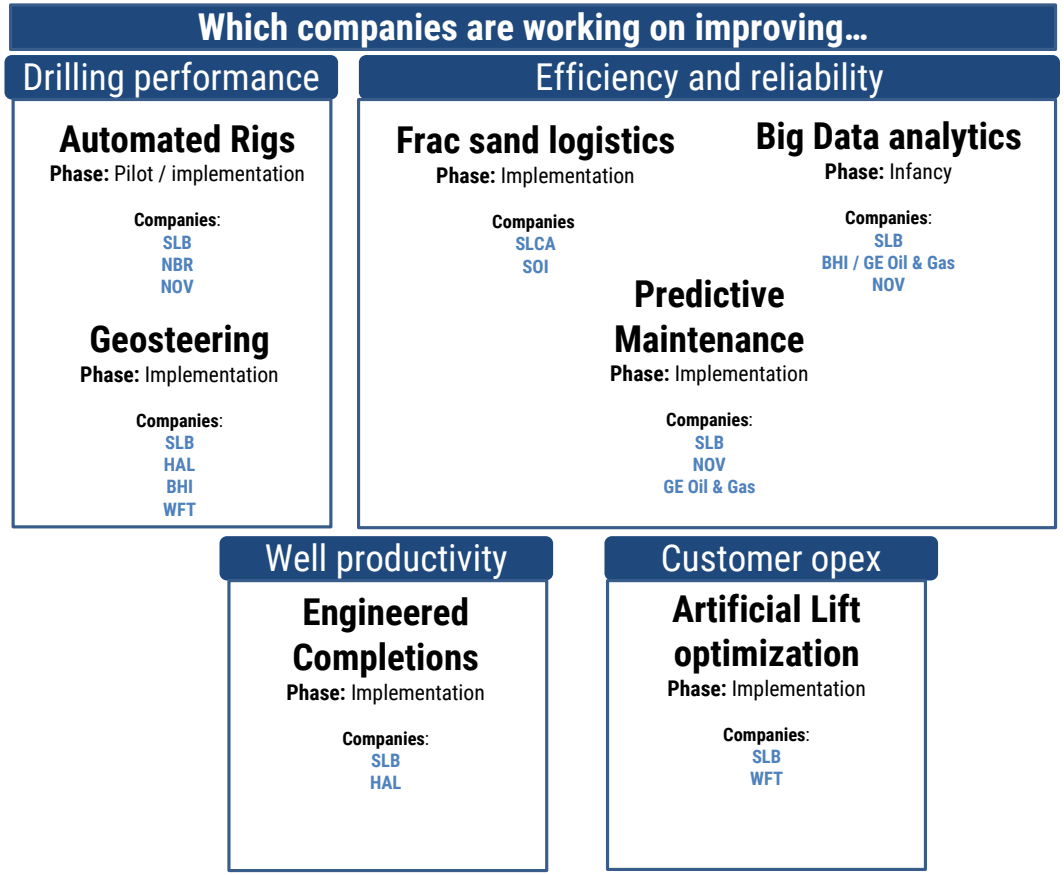
RRC: Tools which will help manage pad constraints, gathering/processing/takeaway limitations/opportunities, permitting and regulatory requirements, lease configurations among others.

OXY: Predictive, interactive multivariate statistical model that predicts geologic sweet spot areas and compares completion practices and cost factors

EOG, CXO, EQT among others applying above technology

Source: Goldman Sachs Global Investment Research.

Exhibit 21: We highlight key technologies in use in the oilfield, what phase they are in, and which companies are involved

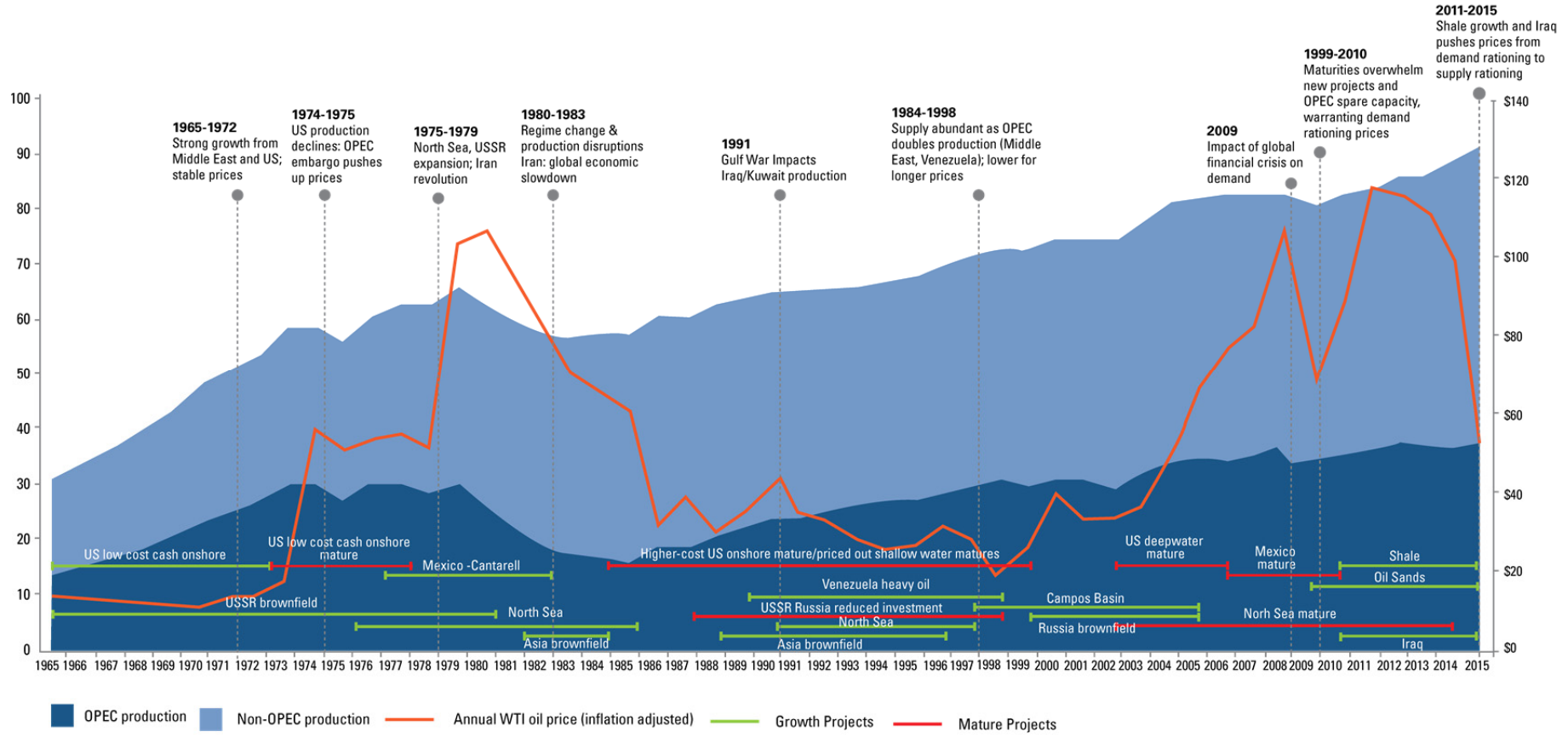


Source: Company data, Goldman Sachs Global Investment Research.

Historical context: Shale is the latest in more than 50 years of global oil/gas innovation

Look back suggests shale still has room to run, as many oil technology/resource "win zones" last 7-15 years. Shale is the latest in a series of innovations in the oil/gas industry that has allowed for development of shallow water offshore, Arctic, deepwater offshore and oil trapped below layers of salt. A look back at the past 50 years of oil's history shows that resource areas tend to expand over 7-15 years. We are in year six of the shale expansion, and we believe shale growth is on track to continue growing meaningfully for another 7-10 years. In periods in which supply growth is robust, we have seen oil prices fall or remain low until technology matures. This was the case both in 1965-72 after which US growth slowed and prices rose (partly on the OPEC embargo) and in 1984-98 after which the Gulf of Mexico/North Sea matured and prices rose sharply. We believe we are in a lower for longer environment until there is greater evidence shale deliverability is surprising to the downside or OPEC runs out of spare capacity.

Exhibit 22: History shows material new sources of supply lasts 7-15 years; assuming shale/OPEC can meet demand, oil prices likely need to stay lower for longer



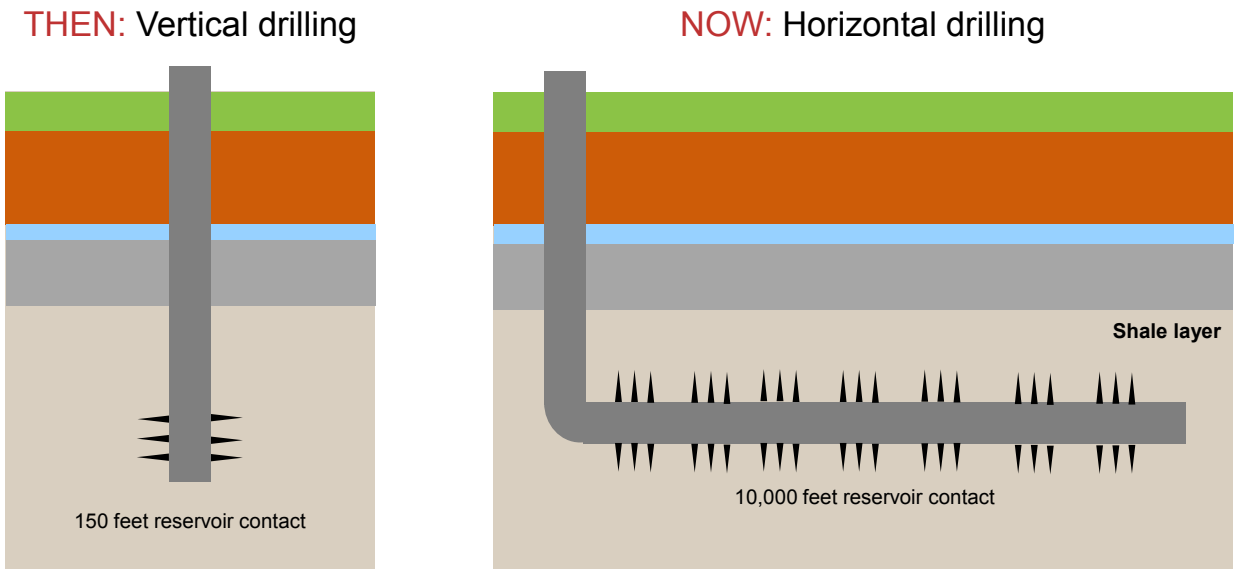
Source: BP Statistical Review of World Energy, Goldman Sachs Global Investment Research

How did we get here? Horizontal drilling & fracturing have revolutionized shale recovery

As discussed earlier, innovation in oil gas production has been a constant seemingly since the mid-1800s when oil rigs were first developed. Since then we have seen the drilling rig evolve, production move offshore, and natural gas frozen/shipped/regasified. Seismic technology has allowed for greater imaging to both increase probability of success on exploratory drilling and to explore in areas of greater geologic complexity. Recently, water/carbon dioxide injection was perfected to develop fields that were perceived to be more mature. Geologists/geophysicists studying long-producing areas like onshore Texas and Pennsylvania have long identified substantial hydrocarbons "in place" (in the ground). But historically, technology has only accommodated a small amount of the oil/gas in place to be recovered commercially.

Vertical wells have lower reservoir contact and were unsuitable for shale development. Before the onset of shale development, the oil and gas industry has been using vertical drilling to tap into the conventional reservoirs. This technique was suitable for conventional reservoirs given larger contact area achieved through vertical drilling. While shale formations and reserves within were always in place, this technique was less effective for the development of shales which are thinner and far more spread out, rendering them uneconomical.

Exhibit 23: Industry increased contact area with the reservoir materially by shifting from vertical to horizontal wells
Simplified graphic of a horizontal and vertical well

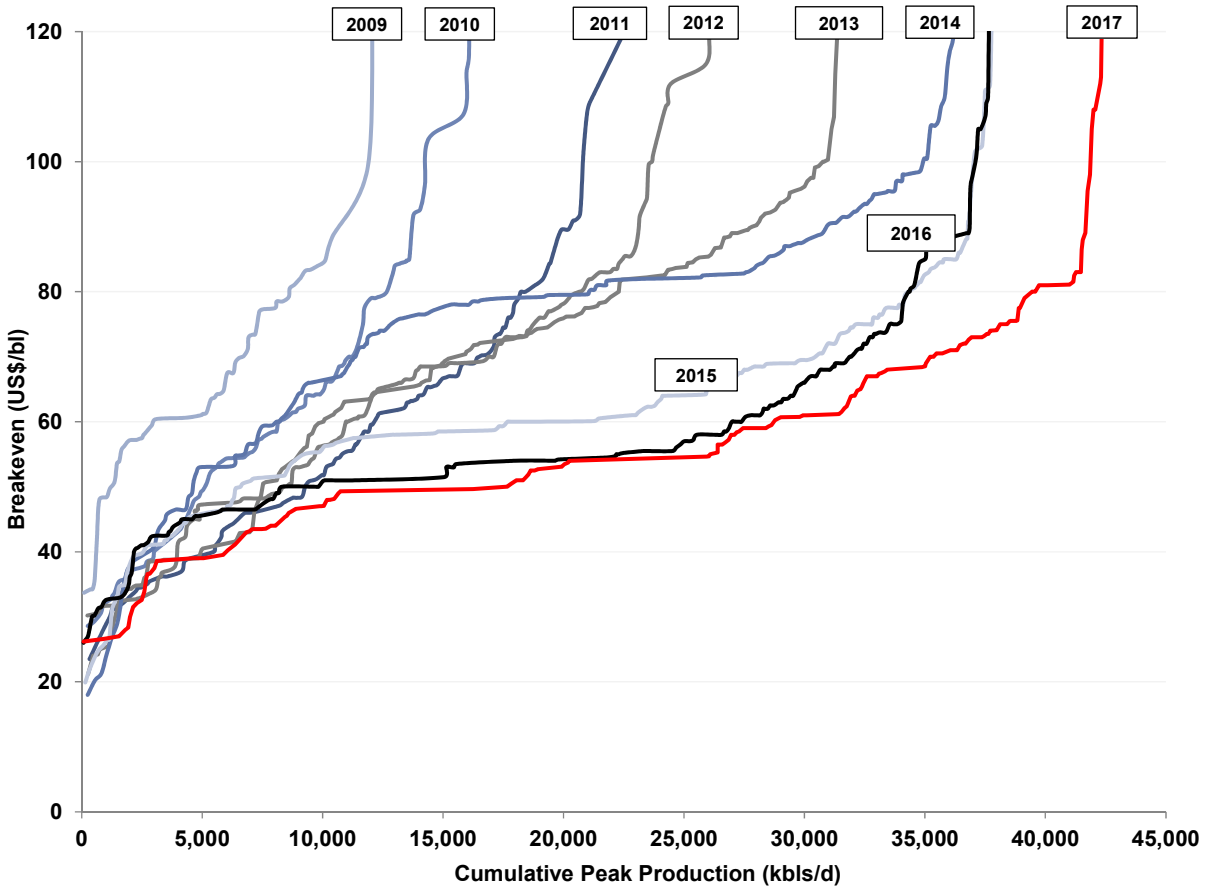


Source: Goldman Sachs Global Investment Research

Horizontal drilling can improve reservoir contact by nearly 200 times relative to vertical drilling

Ability to drill wells horizontally has unlocked potential to recover oil/gas from shale reservoirs. Over time, the oil and gas industry migrated towards horizontal drilling, a technique in which the drill bit is gradually turned 90 degrees after initially drilling vertically to a certain depth to establish extended direct contact with the shale formation. This technique allowed substantially higher area of contact with the shale formation relative to the vertical drilling technique, thereby improving production and recovery rates. By our estimates, contact with the reservoir can be improved as much as 200 times through horizontal drilling (using a typical 10,000 ft lateral with 8 ¾ inch diameter wellbore) relative to vertical drilling. In addition to drilling horizontally, the oil and gas industry also used hydraulic fracturing to stimulate the shale rock and improve rates of production.

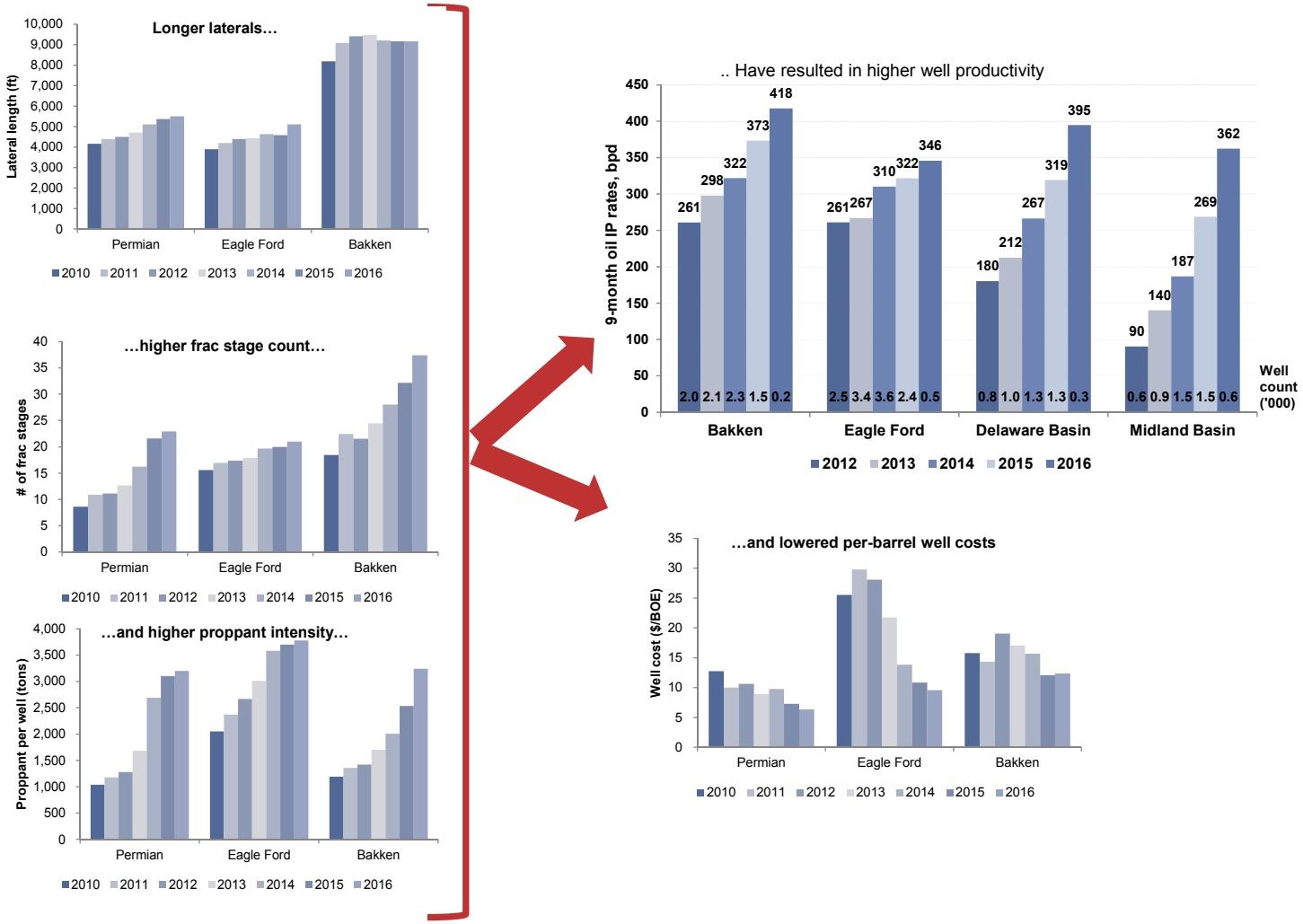
Exhibit 24: As US shale drilling became more productive and more commercial, shale flattened the global oil cost curve since 2013
Evolution of the global oil cost curve over the years; Breakeven prices are for Brent oil, which was about $10/bbl above WTI oil in 2014 and is assumed at $3 per bbl above WTI oil in our 2016-17 cost curve



Source: Goldman Sachs Global Investment Research.

US shale breakevens have come down from $70/bbl WTI in 2013 to $50/bbl today. We believe producers' drive to reduce per-unit development cost of a typical shale well via drilling longer laterals and higher completions (higher proppant intensity, shorter frac stages and cluster spacing) has led to a material decline in per-barrel breakevens from $70 WTI in 2013 to $50 today, adjusted for cyclical cost inflation. Cyclically, costs fell significantly in 2016 as a result of the sharp reduction in shale drilling, and costs are now on the rise in order to bring oil service companies margins back to normal. Our estimates broadly improve 25%-30% increase in well costs off bottom.

Exhibit 25: First leg of well productivity increases have been driven by increasing contact with the reservoir via longer laterals, more horsepower, greater frac stages and greater use of sand



Source: IHS, Goldman Sachs Global Investment Research.

Why is shale innovation solely a "US phenomenon," and could it spread internationally? Shale innovation has largely taken place as a result of oil price, culture, capital and data. It has been independent exploration and production companies (E&Ps), not the Majors, that have been the key innovators. A study commissioned by the EIA in 2013 and partially updated in 2015 found substantial shale oil resource available for production at technology of the time in countries beyond the US, most notably Russia, China, Libya, Argentina and the UAE (technically recoverable shale gas resource is even more plentiful across a wider number of countries). While shale is being pursued in Argentina, Russia and China, we expect very little meaningful impact to global supply compared to what we have seen in the US. We attribute the unique shale phenomenon in the US to four key factors:

- **Infrastructure:** There has been greater network of pipelines and available drilling rigs/fracking crews in the US. There has been greater availability of water as well in key areas of shale development in the US.
- **Regulatory:** The US has clear fiscal regime for commodity pricing and taxation (though some tax rules particularly at the state level have changed). Additionally, the US has clear land/mineral ownership regulations.

US shale growth was among the major beneficiaries of low interest rates over the past decade+

- **Availability and aggressive use of capital:** We believe history will show that the development of US oil/gas shale was one of the primary results of the low interest rate environment we have seen in the US for more than a decade. The principal developers of shale – US E&P companies – outspent cash flow by 10%-50% over the past five years, with funding coming from equity/credit markets and asset sales. National oil companies (NOCs) and Majors typically spend much closer to cash flow or below cash flow.
- **Data from vertical wells drilled for more than 50 years:** The availability of public data on vertical wells that were not drilling for shale but drilled through shale over the last 50+ years have helped companies better target where shale wells are drilled. The industry refers to this as "well control," past well tests that boost confidence in future results, and allocating capital to expand drilling.

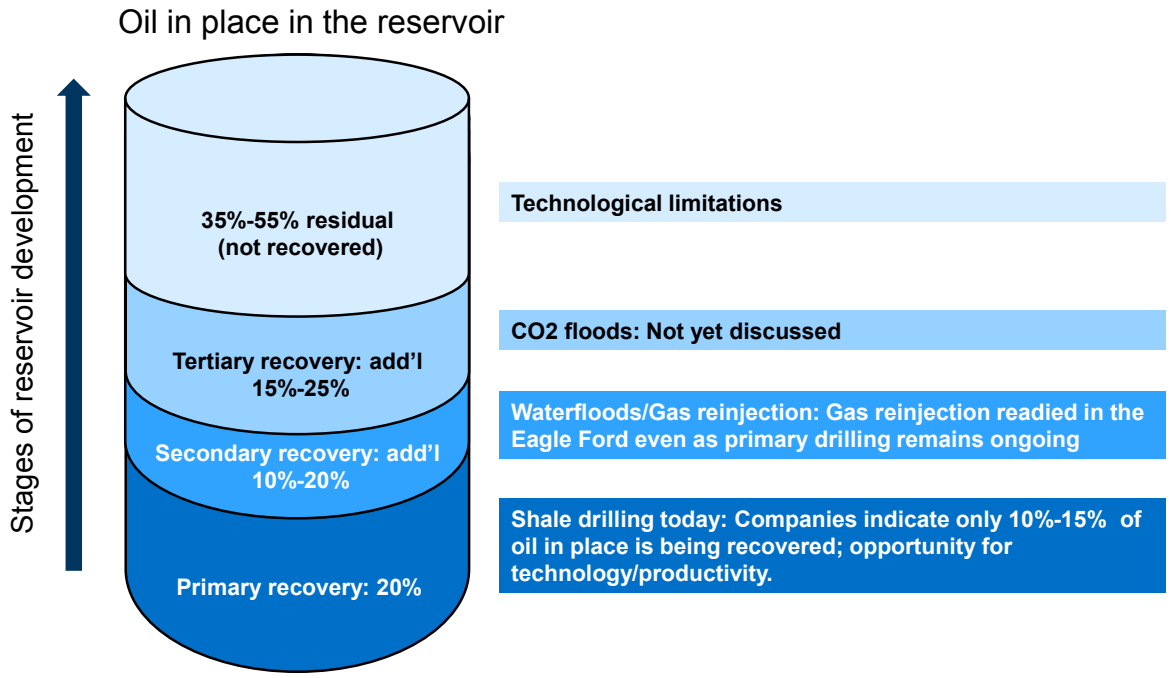
Over time, we believe we will see greater shale development in other countries. For now, we believe the impact remains a largely US phenomenon. Of the US E&Ps that have been the key drivers of shale production growth in the US, none in our view appear to be spending meaningful capital abroad.

Why do we still see productivity gains continuing? Recovery rates remain low

We continue to receive pushback from investors on producers' ability to keep driving more productive wells over the next four years. We highlight that recovery rates of oil/gas in place from shale wells remain in the high single digits to low teens at 10% to 15%, and see recovery rates increasing to around a 20% threshold over the next four years aided by "brawn, brain and bytes" which we highlighted previously.

Recovery rate from primary drilling is generally around 20%, but today's recovery factor is generally in the low teens. Typically for oil wells, the maximum recovery factor of oil in place from primary drilling (drilling that does not involve water/carbon dioxide injection) based on reservoir pressure is typically around 20%. The recovery factor from shale as discussed by producers is currently in the low teens. We believe our 3%-10% productivity improvement can push up the recovery factors from low-teens to 20%, giving us confidence in producers' ability to realize the productivity gains we highlight. Industry is in early stages of looking at secondary recovery mechanisms, though implementation is likely to take place in the next decade.

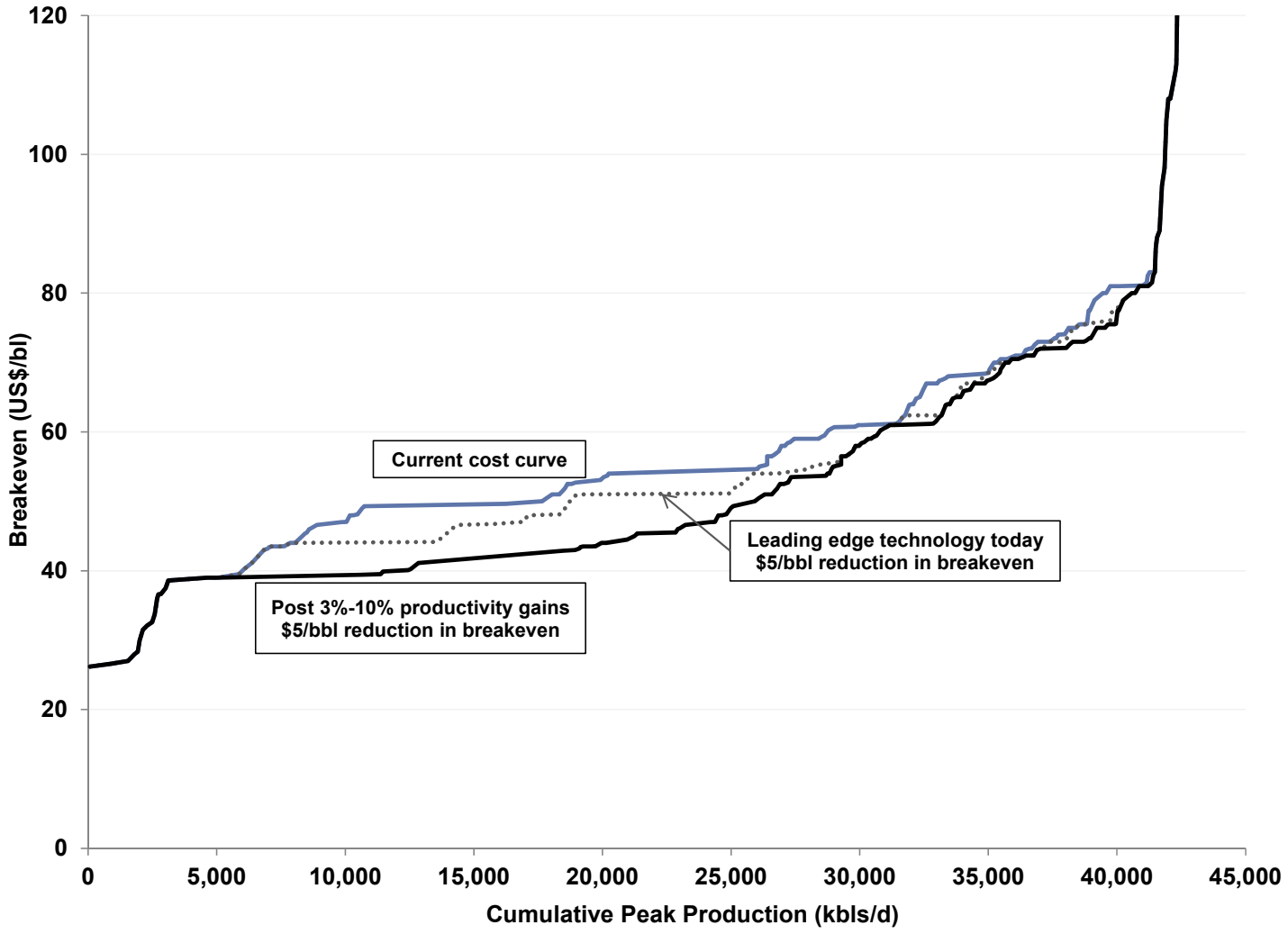
Exhibit 26: Current oil recovery rates are low, which highlights potential for further productivity improvement
Estimate of oil recovered from a typical reservoir by primary, secondary and tertiary drilling



Source: Society of Petroleum Engineers, company reports, Goldman Sachs Global Investment Research.

Exhibit 27: We see potential for shale breakeven oil prices to fall by $5/bbl if industry moves to leading edge technology which likely requires consolidation; impact of bytes stage is unclear but if overall net productivity rises 3%-10% through 2020, breakevens could fall another $5/bbl

Oil cost curve based on our 3%-10% productivity improvement scenario and leading edge lateral per-well development; Breakeven prices are for Brent oil, $3 per bbl above WTI oil

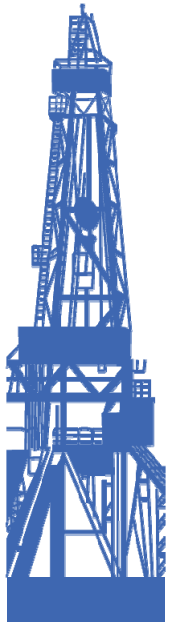


Source: Goldman Sachs Global Investment Research.

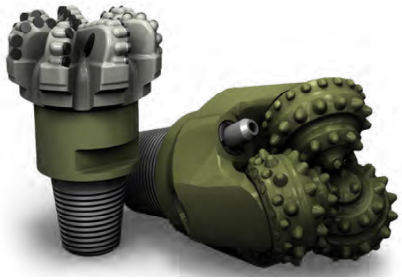
What are some of the technologies that exist today?

Exhibit 28: Some of the technologies available today in the oil service industry

Super-spec rigs allow drilling of extended-reach laterals: AC drive power; 1,500HP, 7,500 psi circulation systems, 750,000lb hook load, pad capability

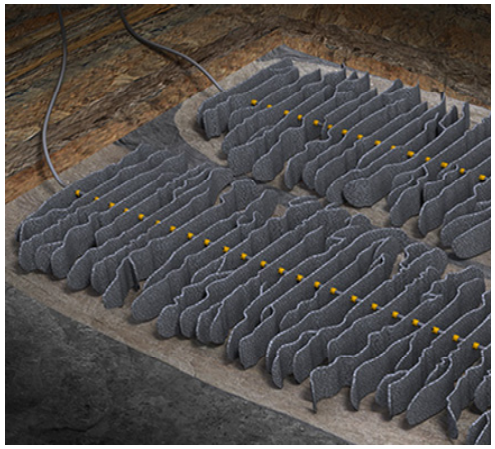


Polycrystalline diamond compact **drill bits improve drilling efficiencies due to less breakdown**



Rotary Steerable System aid in accurate horizontal well placement and improve the quality of well's contact with the reservoir

Engineered completion ensures every fracture is stimulated and propped open from the tip of the fracture to the wellbore, gives control of fracture placement, sizing and conductivity



Source: SLB, Goldman Sachs Global Investment Research.

Super-spec drilling rigs: E&Ps today are mostly using multi-well pads to carry out their horizontal development drilling programs. As such, rigs that can easily move around the pad with minimal disruption or downtime are needed. Several AC rigs that are currently available have this capability. In addition, to be able to support the drilling of long laterals without giving up on efficiency, rigs need to have at least a 1,500 HP rating. In addition, a 7,500 psi circulation systems allows the rig to better handle pressures encountered at the toe end of the lateral and keep the wellbore clean from cuttings during the drilling process, while a 750,000 lb hook load capacity allows for racking of enough drill pipe and casing pipe on the rig so as to minimize interruptions during the

drilling process. There are about 300 super-spec rigs in the industry currently, with the potential for another 200 of them to be upgraded to this status. Currently available super-spec rigs are almost fully utilized**. HP, NBR and PTEN are key providers of these super-spec rigs currently.**

High-spec rotary steerable systems: Good quality Rotary Steerable Systems allow for efficient geosteering of wells and thereby allow accurate placement of the wellbore in order to increase its contact with the reservoir. RST tools also ensure that the wellbore is smooth which can reduce well construction costs. As we have noted previously, **SLB and BHI are the leading providers** of high-spec Rotary Steerable Systems and are currently fully sold-out on available capacity.

Engineered completions: Conventional geometric completion techniques assume that all parts of a well's horizontal lateral can produce equal amounts of hydrocarbons and hence fracture them with equal levels of intensity. However, this is not necessarily true, and according to SLB, nearly 40% of a well's perforation clusters don not contribute to production. A better approach in order to solve this issue is engineered completions. Engineered completion accounts for variations in stress and quality along the lateral, and thereby adjusts the completion intensity and improves the percentage of perforation clusters that contribute to production. **SLB and HAL are key providers.**

Diverters: A diverter is either a chemical or a mechanical device used to ensure uniform distribution of the frac fluid inside the wellbore. Typically, the frac fluid follows the path of least resistance and therefore may not necessarily target the most productive parts of the lateral. With the use of diverter technology, pressure pumpers can direct the frac fluid mixture to specific areas of the lateral that are likely to be more productive, thereby improving the overall productivity of wells. **SLB and HAL are key providers of this technology.** Among E&Ps, PDCE, RSPP, PE and others use the technology.

High-spec drill bits: A good quality drill bit is necessary to achieve efficient drilling performance since any failure with the drill bit can result in downtime which not only increases drilling times but also increases cost for the customer. **Companies like SLB and BHI have developed latest generation drill bits** that can last the entire run of drilling from spud to the toe of the lateral, thereby helping achieve shorter drilling times for customers.

Efficient last mile proppant handling solutions: Sand has become a critical component of the well completion process as E&Ps continue to push the limits on its usage and intensity. Current industry average is around 2,000lbs per foot of lateral, while leading edge is around 3,000lbs per foot of lateral. Assuming an average lateral length of 8,000ft, this translates to sand usage of 7,200 tons on average for the industry and >12,000 tons for leading edge wells. **SLCA's Sandbox and Solaris's silo-based systems are an efficient solution to handle these large quantities of sand at the wellsite** and also between the in-basin transload facility and the well site. Sandbox and Solaris reduce truck demurrage costs which HAL estimated to be nearly $500mn across the industry in 2014. Both Sandbox and Solaris are still in the early stages of adoption in the E&P community.

Multi-well pad development driving efficiencies with today's technology: ECA case study

We highlight ECA's work on development optimization via its multi-pad approach as an example of producers using today's existing technology in a way that can enhance well productivity and drive cost efficiencies. At its 6/20 Permian field tour, ECA highlighted ongoing efforts to transition to increased implementation of cube development. "The cube" targets drilling an even greater number of wells to develop multiple oil-bearing reservoirs stacked on top of each other from a single surface location, allowing ECA to achieve efficiencies via shared infrastructure and drive productivity via minimized well interference.

Enhanced well productivity: ECA's multi-well pad development uses a combination of tighter spacing between wells (385-450 feet), precision targeting, advanced completion techniques and longer laterals in order to drive stronger well performance and improved resource recovery. In particular, ECA highlighted two pads, which have demonstrated industry-leading results, resulting in an average 20% improvement in 3-month rates and contributing to an increase in ECA's estimates for recoverable resource per well. The multi-well pad approach also helps to reduce risk of lower production that could occur via downtime or communication associated with previously-drilled wells.

Cost efficiencies above ground: ECA also highlighted the significant capital and operational efficiencies associated with multi-well pad development. ECA noted that it is seeing D&C savings of 19% per well compared to traditional single well development.

Exhibit 29: Encana is optimizing its development to put more wells on a pad to make shale development more efficient
Encana's Davidson pad in West Texas with four rigs, where it recently brought 19 wells online (now 33-wells in total)

Source: Company presentation

Appendix: More detail on "Bytes" stage progress among select E&Ps/Services companies

Exhibit 30: APC, CHK, ECA, EOG, OXY, PXD and NBL are moving towards machine learning/artificial intelligence with the aim to drive well productivity improvement

Commentary by companies on the application of Big Data/predictive analytics/machine learning/artificial intelligence/new technologies

1. Well productivity improvement		
Stage	**Company name**	**Comment**
Initial application/using data analytics	DVN	**Optimizing drilling/completions activity** using proprietary database.
	LPI	3-D Reservoir modeling by using **proprietary database and data-driven models.**
	CLR	**Proprietary database** with over 600 wells (100 modern shale logs) with analytics to drive better results.
	PE	Applying **multivariate analytics** on database, which includes third party-operated wells acquired through data trades, to drive faster learnings on impact of variables (geology, proppant/fluid loading, lateral length, etc) on well performance.
	FANG	Applying **multivariate analytics** on reservoir database to drive faster learnings to improve well performance.
	WPX	**Proprietary data** to understand initial rates, EURs and, ultimately, create the most NPV from the drilling spacing unit.
	APA	Use Schlumberger Petrel 2011 software to aggregate oil reservoir data that supports **"seismic-to-simulation"** workflow**.**
	QEP	**Enhancing completion design and development sequencing** using proprietary database.
	WLL	**Core lab** that provide insights that help in **customizing frac jobs for the particular reservoir rock conditions at each location.**
	EQT	Optimizing drilling completion activities and reducing operating costs using **advanced analytics.**
	COG	Optimizing drilling completion activities and well performance using **proprietary database.**
	RRC	Proprietary databases/analytics in SW Marcellus which provides expected production rates based on various completion recipes.
	GPOR	Using **analytical processes** in petro-physics, geo-modeling and hydraulic fracture stimulation.
	CNX	**Proprietary Database and predictive tool** to refine earth model and improve decision making.
Moving towards artificial intelligence and machine learning	CHK	**Redesigning drilling and well completion programs** using its proprietary databases and on-site core labs that provide quick, high-end analysis on a real-time basis.
	EOG	**Shifting from data on demand to learning on demand** as it looks at advancing big data/predictive analytics in order to drive future efficiencies. EOG's goal is to provide geosteering staff/completions engineers with (1) better guidance on where wells should be drilled/steered; (2) optimal well spacing patterns; and (3) better fracture stimulation recipes.
	ECA	Leveraging proprietary real-time drilling/pump data/analytics to drive **precision targeting and advanced completions**
	APC	**Advanced Analytics & Emerging Technology** group to test **completion designs** with the goal of maximizing the net present value per section in the DJ Basin with plans to move to machine learning/artificial intelligence.
	CXO	Applying analytics and leveraging real-time information to optimally **geosteer** and **complete** wells.
	MRO	**Optimizing completion activity** using real-time multi-variant analysis and 3D hydraulic fracture modeling.
	NBL	Application of **advanced analytics** to drive faster learnings with plans to move towards real time design modification.
	PXD	**Planning for predictive analytics to** drill wells and narrow outcomes on these wells. Plan to use **supercomputers** and GEOS software to model and visualize in 4-D the propagation of fractures. Using **machine learning algorithms** to better quantify key performance drivers and apply new learnings at a faster rate for future completions.
	OXY	**Plan to move to real-time predictive analytics** combining both geologic and completion data to speed up the process of optimum targeting and frac designs.

Source: Company data

Exhibit 30 cont'd: Mainly larger scale companies have indicated focus on improving capex/opex efficiencies and optimizing future development plan using AI/ML/new technologies

Commentary by companies on the application of Big Data/predictive analytics/machine learning/artificial intelligence/new technologies

2. Drilling/completion efficiency		
Stage	**Company name**	**Comment**
Pilot/Implementation	OXY	Using **Oxy Drilling Dynamics/data analytics** to improve efficiency, reduce drilling days, reduce tool failures, among others.
	ECA	Using **"Cube development"** greater surface efficiency and reduces risk of lower production associated with infill drilling and offset hydraulic fracturing interference.
	MRO	Using **real-time data feeds** from drilling operations in conjunction with geophysical models to maximize efficency and control targeting; conduct **statistical analysis** on D&C dataset to minimize capital inefficiency, operational time and optimize process sequencing.
	EOG	Using real-time data which feeds into dashboard of drilling/completion staff which helps reduce costs by improving efficiency and equipment reliability.
	RRC	Applying **analytics** to estimate the performance of drilling/completion equipment.
	CXO	Using real-time data feeds from drilling and completion operations to maximize efficiency.
	PXD	Partnered with Oak Ridge National Labs, to improve metallurgy during forging to **increase pressure pumping service life ten-fold.**

3. Operating cost reduction/base production optimization		
Stage	**Company name**	**Comment**
Implementation	EOG	Monitoring systems to optimally deploy maintenance staff efficiently and ensure **active well management (management by exception)** and minimum downtime of existing producing wells.
	DVN	**Predictive analytics** to reduce downtime in production by 2% (drives $100 mn of value annually).
	APC	**Integrated Operations Center** which utilizes algorithms for monitoring and managing operations/facilities like water management, tank batteries, facilities and pipeline infrastructure.
	MRO	**Data analytics** to correlate well/meter/facility performance which leads to interventions and increases production by reducing downtime. **Surveillance dashboards** prioritize work based on automation alerts, operational trends, and planned maintenance reducing frequency of well visits and operational staffing requirements.
	CHK	Potential for 10% reduction in downtime and 10% improvement in base production in 2017 by **optimizing/installing/proactively managing artificial lifts.**
	RRC	**Monitoring system** which applies real-time data feeds to actively manage compressors, pressure systems, well chokes among others.
	ECA	**Artificial lift** that applies machine learning to moderate chokes on wells in order to maximize productivity in real-time.
	OXY	Using **proprietary artificial lift platforms** to detect failures earlier. Potential to use data analytics to drive further efficiencies with chemical treatments, safety, failure detection, etc.
	PXD	Application of **sensors** in the wells/facilities by 2018 which can be monitored from a centralized center for active well management.

4. Optimizing future development plan		
Stage	**Company name**	**Comment**
Conceptual	RRC	Tools which will help manage pad constraints, gathering/processing/ takeaway limitations/opportunities, permitting and regulatory requirements, lease configurations among others.
	EOG	Applying integrated solution which captures multiple real-time data (geological, petrophysical, mapping, others) to optimally develop shale plays which reduces time from development planning to first production.
	CXO	Potential to create an optimum development plan spanning geosciences, well drilling and completion operations/logistics and midstream marketing.
	EQT	Scheduling tool which incorporates drilling/crew logistics, downtime associated with the production, pipeline capacities, water infrastructure and other variables.
	OXY	Predictive, interactive multivariate statistical model that predicts geologic sweet spot areas and compares completion practices/cost factors.

Source: Company data

Exhibit 31: Key technologies being used or likely to be used by Oil Services companies or related vendors

Purpose of Technology	Company involved	Status	Description of the solution
Improved drilling performance	SLB	Pilot	SLB is piloting two rigs termed 'Rig of the Future'. The new drilling system will be braded OneDrill and commercially introduced in 2H17. It will feature integrated surface and downhole capabilities, connected hardware, software and data expertise, and be enabled by automation and machine learning.
	NBR	Implementation	Nabors' PACE M800 SMARTRig features pad optimal capability, integrated operating system, smart applications (Rigwatch, ROCKit, REVit, Drillsmart, Recipe to Drill), 25,000ft drill pipe racking capacity and is NDS-Ready.
	NBR	Conceptual	iRig design which features closed loop drilling and full automation, including predictive alerts and maintenance. The rig will be capable of performing casing & tubular running, directional drilling, mud logging, and managed pressure drilling in addition to the primary drilling function.
	NOV	Implementation	NOV's fully automated closed-loop drilling systems feed high-speed drilling data into its autonomous control system which optimizes the well construction process by adjusting drilling parameters.
Improved quality of well's contact with the reservoir	SLB	Implementation	SLB's geosteering service uses real-time measurements (from its LWD and MWD tools) necessary to identify structural characteristics of the reservoir and adjusts the drillbit in order to keep the wellbore within the productive region.
	HAL	Implementation	HAL has several technologies that assist in geosteering wells, including Gamma sensors, Resistivity sensors, Downhole drilling motors etc.
	BHI	Implementation	BHI offers 'Reservoir Navigation Services' to help drill and geosteer complex high-angle horizontal wells.
	WFT	Implementation	Uses LWD data to identify sweet spot for wellbore placement.
Improved well productivity	SLB	Implementation	SLB's BroadBand sequence fracturing maximizes wellbore coverage. Every fracture is stimulated and propped open from tip to wellbore to shift 40% of uneconomical wells towards 100% economic wells.
	HAL	Implementation	HAL's Pinnacle division is a leading provider of reservoir monitoring and fracture mapping services using fiber optics and sensors.
Frac sand and last mile logistics	SLCA	Implementation	SLCA is one of the leading suppliers of frac sand, which E&Ps have been using as a way of improving well productivity. Also, SLCA's Sandbox business provides an efficient way to manage the last mile transportation of this frac sand.
	SOI	Implementation	SOI's silo based systems allow for efficient management of the large quantities of frac sand at the well site and also offer remote monitoring capability.

Source: Company data, Goldman Sachs Global Investment Research.

Exhibit 31 cont'd: Key technologies being used in the oilfield by Oil Services companies or related vendors

Purpose of Technology	Company involved	Status	Description of the solution
Improved equipment reliability through Big Data analytics	SLB	Conceptual	SLB is working with companies like Google and Microsoft to improve data analytics capabilities in the oil field.
	GE/BHI	Conceptual	With comprehensive data analytics, operators will be able to make the best decisions in real time, allowing them to drill a well faster, find better producing zones, and improve ultimate recovery. In addition, the data would provide much better intelligence on asset performance and, through automation technology, could flag risks and even mitigate them, without need for human intervention.
	NOV	Implementation	NOV has an industrial data platform called 'Max' which handles data from all of NOV's offshore rigs, land rigs, service equipment and manufacturing facilities. Max handles all of this data derived from sensors and allows for predictive maintenance. NOV's RigSentry BOP and Rig Monitoring systems both use Max.
Monitoring of installed equipment	SLB	Implementation	BOP monitoring and predictive maintenance partnership with RIG.
	GE	Implementation	BOP monitoring and predictive maintenance partnership with DO.
Operating cost reduction for the E&Ps	WFT	Implementation	WFT collaborates with operators to develop customized artificial lift systems. WFT provides electronics that enable intelligent wellsite optimization, sensors that monitor the artificial lift systems, software that delivers the real-time monitoring, analysis and control.
	SLB	Implementation	SLB's Artificial Lift monitoring and optimization systems help E&Ps prolong equipment life, improve lift system performance, minimize operator errors at the well site, maximize field crew efficiciency and optimize underperforming wells.
Improved overall value-add of the oil service industry through the use of Artificial Intelligence & Machine Learning	SLB	Conceptual	Recently established a new technology center in Silicon Valley to help the company move up the learning curve on big data technologies. Separately, SLB's OneDrill Integrated Drilling System features machine learning capabilities.
	NOV	Implementation	RigSentry BOP monitoring system features machine learning capabilities.
	GE/BHI	Conceptual	Following the pending transction with BHI, GE plans to bring its Predix industrial operating system to the oilfield.

Source: Company data, Goldman Sachs Global Investment Research.

Summary of ratings, price targets and risks

Exhibit 32: Summary of ratings, price targets, methodology and key risks for covered E&Ps; Stock prices are as of 6/22/2017

	Ticker	Rating	Stock price	12-month Target price	Target return	Valuation Methodology	Key Risks
Anadarko Petroleum	APC	Buy	$45.09	$66.50	48%	DCF/M&A based	Commodity price volatility, government pronouncements, production/cost execution
Antero Resources	AR	Neutral	$20.16	$29.50	46%	DCF/M&A based	Ability to access capital markets, government pronouncements, production/cost execution and commodity price volatility
Apache Corp.	APA	Neutral	$45.63	$55	23%	DCF	Commodity price volatility, drilling results, production, costs and government pronouncements
Cabot Oil & Gas Corporation	COG	Buy	$22.86	$34	49%	DCF/M&A based	Constitution timing, NE Appalachia gas prices, government pronouncements and production/cost execution
California Resources	CRC	Sell	$8.42	$4.50	(47%)	DCF	Ability to grow production/FCF/returns, leverage to oil prices
Carrizo Oil & Gas	CRZO	Neutral	$16.03	$24	50%	DCF/M&A based	Commodity price volatility, disappointing drilling results, costs and government pronouncements
Chesapeake Energy	CHK	Neutral	$4.50	$5.75	28%	DCF/M&A based	Ongoing midstream commitments, commodity price volatility, ability to limit its funding gap, production
CONSOL Energy	CNX	Neutral	$13.62	$21	54%	DCF	Commodity price volatility, disappointing drilling results, costs and government pronouncements
Cimarex Energy	XEC	Neutral	$91.33	$133	46%	DCF/M&A based	Commodity price volatility, higher production costs, strong drilling results and execution
Concho Resources	CXO	Neutral	$113.88	$157	38%	DCF/M&A based	Production mix/growth, ability to grow returns/FCF, disappointing drilling results, government pronouncements
Continental Resources	CLR	Buy	$30.41	$58	91%	DCF/M&A based	Production, costs, well results, government pronouncements
Denbury Resources	DNR	Sell	$1.35	$1.25	(7%)	DCF	Commodity price volatility, better than expected operational execution and lower costs
Devon Energy	DVN	Neutral	$30.01	$40.50	36%	DCF	Production growth, leverage to volatile oil prices, well results and government pronouncements
Diamondback Energy*	FANG	Buy	$85.98	$130	51%	DCF/M&A based	Commodity price volatility, drilling results, costs and operational execution
Eclipse Resources	ECR	Neutral	$2.33	$2.50	7%	DCF/M&A based	Inability to market production at expected netback, drilling results, costs and operational execution
Encana Corp.	ECA	Buy	$8.24	$14	71%	DCF/M&A based	Production/cost execution, well results out of its four key plays, government pronouncements
EOG Resources*	EOG	Buy	$87.69	$117	34%	DCF/M&A based	Well results in the Permian and Eagle Ford, costs, exposure to commodity price volatility, government pronouncements
EP Energy	EPE	Neutral	$3.48	$5.25	51%	DCF/M&A based	Commodity price volatility, production, costs and government pronouncements
EQT Corporation	EQT	Neutral	$52.03	$77	48%	DCF/M&A based	Production/cost execution, Appalachia/Henry Hub gas prices, ability to access capital markets and government pronouncement
Gulfport Energy Corp.	GPOR	Neutral	$13.49	$17.50	30%	DCF/M&A based	Meeting netback expectations, asset concentration, strong drilling results and execution
Hess Corp.	HES	Neutral	$41.01	$58	44%	DCF	Commodity price volatility, production/cost execution and government pronouncements
Laredo Petroleum	LPI	Neutral	$9.69	$15	55%	DCF/M&A based	Production, lack of clarity on midstream value of Medallion, commodity volatility, costs, government pronouncements
Marathon Oil	MRO	Not Rated	$11.59	NA	NA	NA	NA
Murphy Oil	MUR	Sell	$24.52	$19	(18%)	DCF	Exploration results, cost, production/returns/FCF and government pronouncements
Newfield Exploration	NFX	Buy	$27.56	$45	63%	DCF/M&A based	Well results out of SCOOP/STACK plays, production mix, production/cost execution, government pronouncements
Noble Energy	NBL	Buy	$27.76	$45	64%	DCF/M&A based	Further delays to Israel projects, drilling results, midstream bottlenecks, commodity volatility, government pronouncements
Oasis Petroleum, Inc.	OAS	Sell	$7.66	$11	44%	DCF/M&A based	Commodity price volatility, higher production costs and elevated leverage profile
Occidental Petroleum	OXY	Neutral	$60.21	$69	20%	DCF/M&A based	Commodity price volatility, drilling results, production, costs, government pronouncements
Parsley Energy	PE	Neutral	$26.31	$34	29%	DCF	Commodity price volatility, higher production costs, strong drilling results and execution
PDC Energy	PDCE	Neutral	$42.51	$65	53%	DCF/M&A based	Commodity volatility, drilling results, well costs and government pronouncements
Pioneer Natural Resources	PXD	Buy	$154.75	$216	40%	DCF/M&A based	Well costs, ability to demonstrate benefit of investments in tank battery/saltwater disposal facilities, and government pronouncements
QEP Resources	QEP	Neutral	$9.11	$14	54%	DCF	Commodity price volatility, disappointing drilling results, costs and government pronouncements
Range Resources	RRC	Buy	$21.43	$42.50	99%	DCF/M&A based	Production/cost execution, Appalachia/Henry Hub gas prices, NGL prices and government pronouncement
Rice Energy	RICE	Buy	$24.03	$29	21%	DCF/M&A based	Meeting netback expectations, funding gap & potential dilution, disappointing drilling results, asset concentration
RSP Permian	RSPP	Buy	$31.03	$51	64%	DCF/M&A based	Commodity price volatility, operational execution, drilling results
Southwestern Energy	SWN	Neutral	$5.55	$11	98%	DCF/M&A based	Ability to sign low-cost firm takeaway solutions, production/cost execution, Appalachia gas prices and government pronouncements
Whiting Petroleum Corp.	WLL	Sell	$5.14	$7.25	41%	DCF/M&A based	Commodity price volatility, asset concentration, costs and government pronouncements
WPX Energy, Inc.	WPX	Buy	$9.13	$15.50	70%	DCF	Commodity price volatility, disappointing drilling results, costs and government pronouncements
Extraction Oil & Gas	XOG	Neutral	$13.06	$15.50	19%	DCF	Commodity price volatility, disappointing drilling results, costs and government pronouncements

**Note: Denotes on Americas Conviction List*

Source: FactSet, Goldman Sachs Global Investment Research.

Exhibit 33: Summary of ratings, price targets, methodology and key risks for select Oil Services stocks discussed in the report

Ticker	Price	Rating	12-m Target price	Target price methodology	Key risks
SLB	$65.47	Buy	$87.00	Normalized EV/EBITDA	Commodity prices, lower than expected E&P spending, lower than expected synergies from the Cameron transaction, geopolitical events
HAL	$42.23	Buy	$56.00	Normalized EV/EBITDA	Commodity prices, lower than expected E&P spending, geopolitical events
NBR	$7.42	Buy	$15.25	Normalized EV/EBITDA	Commodity prices, lower than expected E&P spending, lower than expected contribution from its Rig Services business
SLCA	$32.03	Buy	$64.00	Normalized EV/EBITDA	Commodity prices, lower than expected sand intensity per well
SOI	$10.90	Buy	$20.50	Normalized EV/EBITDA	New entrants into the business, market share losses, shortage of pneumatic trucks
NOV	$32.13	Neutral	$34.00	Normalized EV/EBITDA	Commodity prices, higher/lower than expected offshore activity, higher/lower than expected E&P spending

Prices are as of 6/20/2017; SLB is on the Americas Conviction List

Source: FactSet, Goldman Sachs Global Investment Research.

Pricing Information: General Electric Co. ($27.78)

Financial advisory disclosure

Goldman Sachs and/or one of its affiliates is acting as a financial advisor in connection with an announced strategic matter involving the following company or one of its affiliates: Baker Hughes Incorporated

Disclosure Appendix

Reg AC

We, Brian Singer, CFA and Waqar Syed, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

Unless otherwise stated, the individuals listed on the cover page of this report are analysts in Goldman Sachs' Global Investment Research division.

GS Factor Profile

The Goldman Sachs Factor Profile provides investment context for a security by comparing key attributes of that security to its conviction sector and the market. The four key attributes depicted are: growth, returns, multiple and an integrated IP score. Growth returns and multiple are indexed based on composites of several methodologies to determine the stocks percentile ranking within the region's coverage universe. The precise calculation of each metric may vary depending on the fiscal year, industry and region but the standard approach is as follows:

Growth is a composite of next year's estimate over current year's estimate, e.g. EPS, EBITDA, Revenue. **Return** is a year one prospective aggregate of various return on capital measures, e.g. CROCI, ROACE, and ROE. **Multiple** Multiple is a composite of one-year forward valuation ratios, e.g. P/E, dividend yield, EV/FCF, EV/EBITDA, EV/DACF, Price/Book. **Integrated IP score** is a composite of Growth, Return and Multiple scores.

Quantum

Quantum is Goldman Sachs' proprietary database providing access to detailed financial statement histories, forecasts and ratios. It can be used for in-depth analysis of a single company, or to make comparisons between companies in different sectors and markets.

GS SUSTAIN

GS SUSTAIN is a global investment strategy aimed at long-term, long-only performance with a low turnover of ideas. The GS SUSTAIN focus list includes leaders our analysis shows to be well positioned to deliver long term outperformance through sustained competitive advantage and superior returns on capital relative to their global industry peers. Leaders are identified based on quantifiable analysis of three aspects of corporate performance: cash return on cash invested, industry positioning and management quality (the effectiveness of companies' management of the environmental, social and governance issues facing their industry).

Disclosures

Coverage group(s) of stocks by primary analyst(s)

Brian Singer, CFA: America-Exploration & Production. Waqar Syed: America-Offshore Drilling Services, America-Oilfield Services & Equipment.

America-Exploration & Production: Anadarko Petroleum Corp., Antero Resources Corp., Apache Corp., Cabot Oil & Gas Corp., California Resources Corp., Chesapeake Energy Corp., Concho Resources Inc., Continental Resources Inc., Devon Energy Corp., Encana Corp., EOG Resources Inc., EP Energy Corp., EQT Corp., Hess Corp., Laredo Petroleum Inc., Marathon Oil Corp., Murphy Oil Corp., Newfield Exploration Co., Noble Energy, Occidental Petroleum Corp., Pioneer Natural Resources Co., Range Resources Corp., Southwestern Energy Co..

America-Offshore Drilling Services: Atwood Oceanics Inc., Diamond Offshore Drilling, Ensco Plc, Noble Corp., Oceaneering International Inc., Rowan Cos., Transocean Ltd..

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Goldman Sachs Investment Research global Equity coverage universe

	Rating Distribution			Investment Banking Relationships		
	Buy	Hold	Sell	Buy	Hold	Sell
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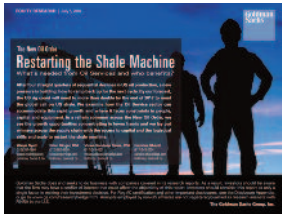

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