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How tapping connectivity in oil and gas can fuel higher performance

Price and demand pressures in the oil and gas sector make the potential value embedded in advanced connectivity for exploration and production more important than ever.

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Despite having many of the technologies enabled by advanced connectivity already at its disposal, the oil and gas sector has yet to realize much of connectivity's potential—and the potential is significant. According to our estimates, making use of advanced connectivity to optimize drilling and production throughput and improve maintenance and field operations could add up to $250 billion of value to the industry's upstream operations by 2030.[1] Of that value, between $160 and $180 billion could be realized with existing infrastructure, while an additional $70 billion could be unlocked with low-Earth orbit (LEO) satellites and next-generation 5G technologies. McKinsey's work with the oil and gas sector suggests offshore operators can reduce costs, including operational and capital expenditures, by 20 to 25 percent per barrel by relying on connectivity to deploy digital tools and analytics.

Such a dramatic technological lift can't come soon enough. The oil and gas industry is experiencing its third price collapse in 12 years. After the first two shocks, the industry rebounded, and business as usual, including a lack of focus on efficiency and costs, continued. The current collapse is different, with the sector facing a supply shock combined with an unprecedented demand drop and a global humanitarian crisis.

Additionally, the sector's financial and structural health is worse than in previous crises. The advent of shale, excessive supply, and forgiving financial markets that overlooked limited capital discipline have all contributed to poor returns. Today, with prices touching 30-year lows and increasing societal pressure, oil and gas executives sense that change is inevitable. The COVID-19 crisis accelerates what was already shaping up to be one of the industry's most transformative moments.

Longer term, reducing carbon emissions is another major factor driving the need for significant operational improvements. Investors are more attentive to environmental issues; the price of renewable energies is falling, and more and more countries are imposing carbon taxes on businesses. The industry's operations account for 9 percent of all Scope 1 and Scope 2 greenhouse gas emissions generated by humans, while the fuels it produces create one-third of Scope 3 emissions.[2]

Technologies are evolving fast and currently have the potential to transform operations and deliver increased value. These technologies range from devices that enable and enhance connectivity to those that link the core network (the global internet) to small subnetworks around its edge, known as the backhaul. Access technologies connect users to their service providers or, in the case of the oil and gas industry, to the backhaul. Many of these technologies exist currently and are rapidly becoming more reliable and affordable (see sidebar, "The future of connectivity," and Exhibit 1).

While the depth and duration of the current crisis are uncertain, our research suggests that without fundamental change, it will be difficult to return to the attractive industry performance that has historically prevailed. The most resilient organizations will be those that boldly reposition their portfolios and overhaul their operating models, making the best use of emerging technologies.[3]

Current connectivity in the oil and gas industry

In the industry today, connectivity maturity is widely divergent. On the one hand, newer deepwater platforms are highly connected by fiber or microwave.

[1] Based on a projected 2030 global demand of 103 million barrels per day for oil and 69 million barrels of oil equivalent per day for gas, using current cost levels (June 2020, McKinsey Energy Insights, COVID-19 A1 scenario: "Muted Recovery").
[2] Scope 1 covers direct emissions from owned or controlled sources. Scope 2 covers indirect emissions from the generation of purchased electricity, steam, heating, and cooling consumed by the reporting company. Scope 3 includes all other indirect emissions that occur in a company's value chain.
[3] Filipe Barbosa, Giorgio Bresciani, Pat Graham, Scott Nyquist, and Kassia Yanosek, "Oil and gas after COVID-19: The day of reckoning or a new age of opportunity?" May 2020, McKinsey.com.

The future of connectivity

As the world experiences a quantum leap in the speed and scope of digital connections, industries are gaining new and enhanced tools to boost productivity and spur innovation.

Over the next decade, existing technologies like fiber, low- to mid-band 5G networks, low-power wide-area networks (LPWANs), and Wi-Fi 6—as well as short-range connections like radio-frequency identification (RFID)—will expand their reach as networks are built out and adoption grows. At the same time, new generations of these technologies will appear with upgraded standards. In addition, new types of more revolutionary and more capital-intensive frontier connectivity like high-band 5G and low-Earth orbit (LEO) satellites will begin to come online. Together, these technological developments will unlock powerful new capabilities across industries. Near global coverage will allow the expansion of use cases even to remote areas and enable constant connectivity universally. Massive IoT advances will be enabled as new technologies allow high device densities, and mission critical services will take advantage of ultra-low latency, highly reliable, and highly secure connections.

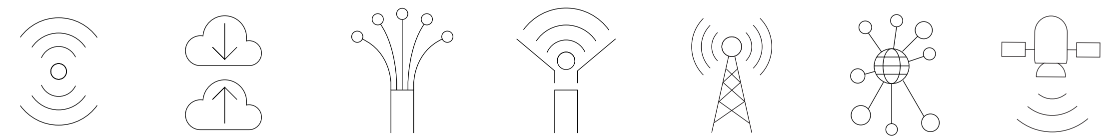
From healthcare and manufacturing to mobility and retail, there are hundreds of promising use cases for the emerging generation of enhanced connectivity, as detailed in a recent report from the McKinsey Global Institute and McKinsey Center for Advanced Connectivity. Together, advanced and frontier connectivity could help seven sectors add a total of $2 trillion to $3 trillion in additional value to global GDP.

Exhibit 1

Advancements in existing connectivity and the emergence of frontier connectivity will unlock new capabilities across industries over the next decade.

Connectivity spectrum and value proposition

Short range (eg, RFID[1]/ Bluetooth)	**LPWAN[2]** (eg, NB-IoT,[3] LoRa, Sigfox)	**Fiber/ DOCSIS[4] 3.x**	**Wi-Fi 6**	**Low- to mid-band 5G**	**High-band 5G** (eg, millimeter wave)	**LEO[5] constellation**
Short-range, efficient device-to-device connectivity, storage, and identification	Low-power, low-maintenance networks that support high densities of connected devices	High-speed, low-latency fixed networks that support other connectivity	Next-generation Wi-Fi with improved speed, device density, and features to increase device efficiency	High-speed, low-latency cellular-connectivity overlay on existing 4G infrastructure	Highest-speed, low-latency, and highly secure cellular connectivity	Global coverage with significantly reduced latency vs existing satellite offerings
ADVANCED					FRONTIER	



[1]Radio-frequency identification. [2]Low-power wide-area network. [3]Narrowband–Internet of Things. [4]Data-over-cable service interface specifications. [5]Low-Earth orbit.

These offshore operations account for one-quarter of oil and gas production today (Exhibit 2).

Some 40 percent of offshore production volume—like that in Canada, Norway, and deepwater sites in the United States—is connected to shore by fiber, while 56 percent is connected by microwave. That means backhaul capacity is in place for telecom operators to begin building 4G networks. Already, 4G LTE[4] networks cover a majority of the North Sea and the Gulf of Mexico, giving all vessels and unmanned transport passing through those regions access to reliable and high-capacity coverage. Only 5 percent of offshore operations connect to the core network by very-small-aperture terminals (VSATs). These sites continue to experience bandwidth bottlenecks and reliability issues.

On the other hand, more mature onshore assets in regions like the Middle East and Mexico, from which three-quarters of the world's oil volume emerges, have poor connectivity and little instrumentation. About 60 percent of this onshore production volume is connected via microwave signal and the rest by VSAT. This is much the same case for tight gas, shale oil, and light tight oil—also known as "unconventionals"—in areas where connectivity by VSAT and microwave experiences bandwidth constraints, such as in the Permian Basin. For the 30 percent of global onshore oil and gas production connected by VSAT, any material upside from digital and analytics is out of reach at current connectivity levels.

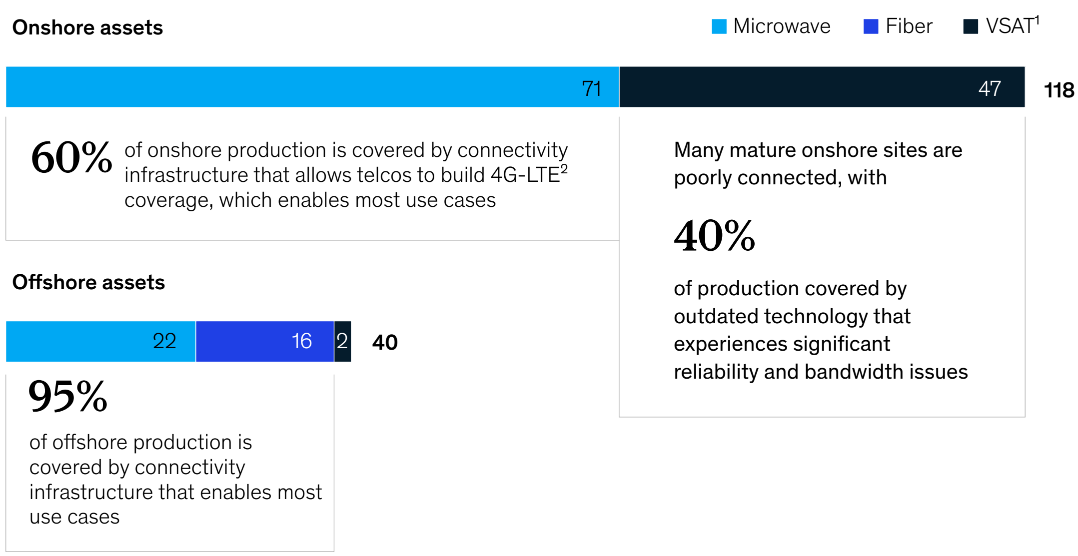
Opportunities for value creation using enhanced connectivity

Technology has potential to boost performance across the entire upstream oil and gas value chain by enabling optimization and automation.

Exhibit 2

Over two-thirds of the world's oil production has access to advanced connectivity but is making limited use of it.

Connectivity coverage of production, million barrels of oil equivalent per day



[1]Very-small-aperture terminal.
[2]Long-term evolution.

[4] Long-term evolution

Optimization involves using all the relevant data to inform better decisions at a certain regular frequency. Pushing the limits on optimization means getting more data and crunching it faster, which requires more sensors to collect data, more bandwidth, and more computing capacity.

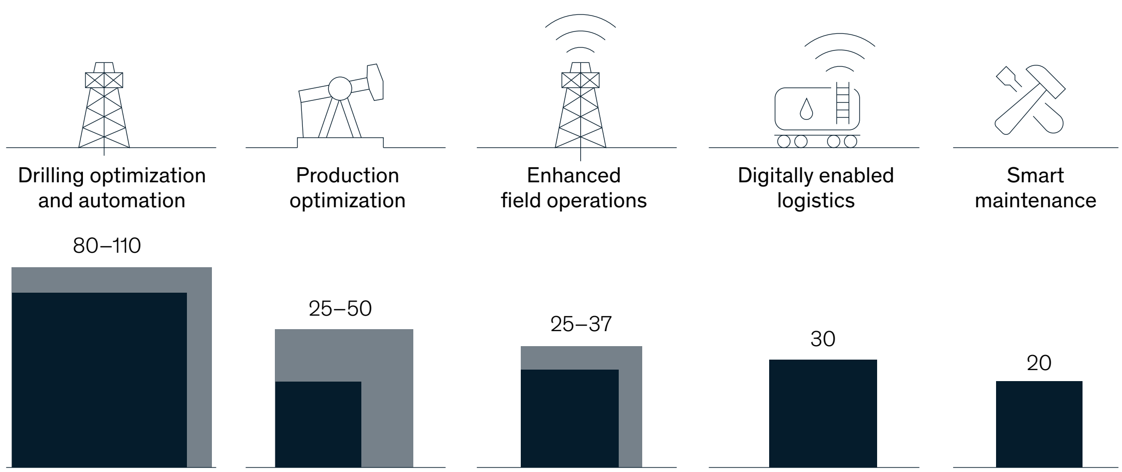
Automation involves using automatic or semi-automatic machines instead of individuals to drill, inspect, and maintain equipment in high-risk operating environments offshore or on sites of drilling and production. These machines can monitor themselves and share data with an onshore control center where most of their activities are managed remotely, though it requires bandwidth and, potentially, edge computing, to transfer the most relevant data back to base.

To illustrate the diversity of the opportunity facilitated by advanced connectivity, we have focused on five use case themes: drilling time, production (throughput), smart maintenance, enhanced field operations, and logistics enhancement. Each one is a combination of smaller use cases that (in our experience of working with the oil and gas sector) have the largest upside potential for a typical upstream oil and gas operation. They all have an element of optimization and automation and drive down cost per barrel. In these areas alone, some $250 billion of additional or incremental value is at stake,[5] as well as the potential reduction of greenhouse gas emissions and greater operational resilience (Exhibit 3).

Exhibit 3

Five broad types of connectivity-fueled oil and gas use cases could contribute up to $250 billion in incremental value to global GDP by 2030.

Oil and gas connectivity use cases, estimated range of potential incremental value, $ billion



Drilling optimization and automation	Production optimization	Enhanced field operations	Digitally enabled logistics	Smart maintenance
Advanced analytics could increase drilling operations productivity by improving drilling speed, while remote or semi-automatic drilling could reduce the number of people required on a rig.	With the help of timely data collection across the production system, this use case creates value by increasing throughput and reducing the energy consumed and emissions produced.	Connectivity advances, such as "connected worker" solutions and technologies offering virtual enhancements, could help reduce time spent on maintenance and repairs.	Enhanced connectivity can radically transform end-to-end logistics and the supply chain with improved demand management, transparent material tracking, and more efficient logistics operations.	A greater density of sensors deliver real-time, high-volume data on equipment status and anomalies to improve prediction of failure and offer remedial actions to operators.

[5] Throughout our analysis, we used production costs (capital expenditures plus operating expenditures) of $15 per barrel for onshore conventionals, $22 per barrel for onshore unconventionals, and a weighted average of $20 per barrel for offshore sites (deep water and shallow water combined).

Use case 1: Drilling optimization and automation

Optimization

Drilling is a major expense in oil and gas production, representing between 20 and 30 percent of total production costs. Deploying advanced analytics could increase drilling operations productivity across all asset types, helping reduce unproductive time, say when a drilling rig is idle, and making the rig's productive time even more effective by improving drilling speed. For production of unconventionals in particular, the use of advanced analytics would increase productivity in well fracking at the end of the drilling phase by prescribing the quantities of water, chemicals, and sand to use, and where exactly to target efforts.

In the experience of organizations we have worked with, advanced analytics can help operators cut idle time in half during the drilling of a well. Drilling speed could increase by 25 percent or more, driving down cost per well while also reducing emissions tied to drilling and associated activities by nearly 10 percent. A large oil and gas company confirmed speeds were 50 percent higher when drilling in the most challenging section of a high-pressure, high-temperature well in the North Sea because of advanced analytics that used historical data to suggest optimal drilling parameters.

This use case primarily requires high system resilience, which today is possible wherever fiber or microwave connectivity is available—in other words, at almost all offshore assets and roughly 60 percent of onshore assets. The associated incremental value of this use case, realizable today, is $30 billion, representing a 2 to 3 percent reduction in cost per barrel of oil equivalent (BOE).

Automation

Enhanced connectivity could also enable remote or semi-automatic drilling, drastically reducing the number of people required on a rig itself. An automated rig floor will mean replacing hazardous operations such as pipe handling and assembly, which currently are carried out manually and are a primary source of incidents in drilling rigs.

With increased automation, an offshore rig would require ten to 15 full-time employees, compared with approximately 100 employees at present. Onshore rigs currently staffed with ten to 15 full-time workers could get by with a staff of five to ten full-time workers.

Automation also would reduce human error during the lifting of drill pipe, in the assembly of the drill string, and in moving tools in the rig floor, resulting in higher efficiency. We estimate productive drilling time would increase to 94 percent from the current 90 percent, which in turn would reduce emissions by cutting the energy consumed in rework and repeated operations.

As with optimization, automation requires highly resilient connections, which can be achieved by fiber or microwave today for the same assets and regions as outlined for optimization. The incremental value of drilling automation to the industry could be $50 billion today, which represents a reduction of 3 to 7 percent of cost per BOE.

Even remote onshore and offshore assets that currently rely on VSAT could tap these use cases if LEO satellites become available, thus unlocking an additional $30 billion of value and bringing the total value at stake to $100 billion.

Use case 2: Optimizing production

A major production facility of a large oil and gas company operating in the North Sea gained a 2 percent increase in production without increasing emissions after it used real-time advanced analytics to improve the settings of the production facility's booster, export compressor, and component splitter. The operator is now seeking an additional 3 percent production improvement by rolling out advanced analytics to the rest of the system, from well to export.

As the example illustrates, this use case creates value by increasing throughput and reducing the energy consumed and emissions produced in the process. Achieving these benefits requires accurate and timely data collection across the entire production system, from reservoir to export, data processing,

Technology has potential to boost performance across the entire upstream oil and gas value chain by enabling optimization and automation.

and analytics. Therefore, more sensors would have to generate real-time data, which depends on high bandwidth and low latency that can only be partially realized with current industry technology. Today, for example, downhole measurements, which could boost optimization, are not available in some cases because connectivity technology or instrumentation is not currently deployed.

The existing connectivity infrastructure, available at a majority of offshore assets and about 60 percent of onshore assets, could deliver about $20 billion of incremental value, equal to a 2 percent reduction in cost per BOE. Enhanced, high-band connectivity like 5G could generate an additional 3 percent improvement in production. Upgrading the connectivity infrastructure at scale, say by installing 5G capabilities, could add a further $30 billion of value, bringing the total value of this use case to $50 billion.

Use case 3: Smart maintenance

In this use case, a greater density of sensors deliver real-time, high-volume data on equipment status and anomalies to improve prediction of failure and offer remedial actions to operators. As a result of this better monitoring, maintenance could be based on equipment status rather than simply scheduled at regular intervals or conducted after incidents. Maintenance typically accounts for between 10 and 15 percent of total production costs, and prescriptive plans could reduce these outlays by 10 percent. Additionally, fewer shutdowns for unscheduled maintenance events could increase production volumes by 1 percent. For example, an operator of several floating production and storage facilities in Latin America was able to reduce its total operating expenses by 15 percent by using analytics to shift to condition-based maintenance. (A possible follow-on impact of smart maintenance is a reduced need for intermittent flaring and fewer fugitive emissions and venting.)

Current technologies, including VSAT, make these enhancements possible across regions and asset types. Deployed at scale, they could create $20 billion of value, or a 2 to 3 percent reduction per BOE.

Use case 4: Enhanced field operations

Optimization

Industry tool time—the share of total time spent working on target activity—for field operators is roughly 25 percent, but connectivity advances could help push these rates up to 40 percent by reducing time spent on maintenance and repairs. Technologies offering virtual enhancement, like glasses or screens providing digital representations of equipment and systems, could help quickly identify troubled components and parts not easily visible. Such technologies could reduce the cost of maintenance and operations by 10 to 15 percent. Even without virtual reality, we estimate offshore operators could improve tool time by roughly 10 percent using “connected worker” solutions such as digitizing reporting and communication between frontline employees and experts in the back office.

Current fiber connectivity makes some of this possible, although augmented visual technologies would require installation of high-bandwidth microwave, which is limited across industry production today. Deployed at scale, better connectivity could produce $20 billion of value or a 2 to 5 percent reduction in cost per BOE, depending on the asset type.

By replacing the VSAT connections relied on by onshore assets in Australia, Canada, and Mexico, for example, with more reliable fiber, microwave, or LEO connections to the backhaul, the industry could realize an additional $10 billion of value, bringing the total value at stake to $30 billion.

Automation

Deployment of fixed cameras, drones, and land and subsea robotics could significantly reduce—or even eliminate—the workforce needed to conduct surveillance and inspection of remote assets and do scaffolding work onboard platforms. Today, that work represents 10 to 25 percent of overall maintenance costs, onshore and offshore respectively, or as much as 4 percent of total production costs. Such technologies could decrease the cost of inspection by 35 percent, improve the health and safety of such workers, and cut emissions.

Deployment of semi-automated field operations within oil and gas is less mature than in other industries, such as mining. However semi-autonomous inspections by an operator in the North Sea, used only to monitor difficult-to-access equipment, has reduced the cost of onboard personnel and outage time, lowering maintenance costs by 5 to 10 percent.

Current fiber and microwave connectivity make this use case accessible to the majority of offshore assets and about 60 percent of onshore assets. When deployed at scale where fiber or microwave connectivity is available, the incremental value at stake is $5 billion, or less than a 1 percent reduction in cost per BOE. The health, safety, and environmental improvement, however, is transformational. If VSAT was replaced by fiber or microwave connection to the backhaul or, eventually, LEO satellites, the industry could realize an additional $2 billion of value by connecting hard-to-reach offshore and onshore assets.

Use case 5: Digitally enabled logistics

Enhanced connectivity can radically transform end-to-end logistics and the supply chain with improved demand management, transparent material tracking, and more efficient logistics operations. Materials purchasing accounts for half of operations and maintenance costs in the oil and gas industry, or as much as 15 percent of total production costs. Delivery logistics are especially costly for remote unconventional and offshore sites, representing 10 percent to 15 percent of total production costs.

Using digital technologies in logistics management could reduce the cost of delivery vehicle service by 20 percent and the cost of materials by 2 percent. Such technologies also could decrease staffing needs as well as emissions.

One oil and gas company deployed an extendable web application that allowed cross-functional users to interact and see materials moving along the supply chain. Transparent tracking and proactive management of material and equipment reduced materials costs by about 10 percent. This proof of concept was developed for rental equipment but is now evolving for use across all equipment types, including for physical—radio-frequency identification (RFID)—tracking of equipment as well.

Current connectivity, including VSAT, makes this use case possible across asset types. Deployed at scale, the new value to the industry could be $30 billion, or a 2 to 3 percent drop in the cost per BOE.

The bottom line

In sum, the adoption of these five use cases would deliver close to $250 billion of value to the oil and gas industry, or a 20 to 25 percent reduction in cost per BOE, with 60 to 70 percent captured by using available connectivity technologies.

Some $180 billion value is at stake from enhancing relatively well-connected assets—such as onshore assets in the Netherlands and the United Kingdom and most offshore assets worldwide—which benefit from microwave or fiber connections that enable existing technologies to drive incremental value.

A further $70 billion of value is at stake from migrating all assets worldwide toward 5G and, eventually, LEO technologies, thus driving incremental value across all five use case categories (Exhibit 4).

How and where to begin

We expect adoption of these use cases to accelerate in the coming years. Leading companies will redouble their efforts in this moment, protecting or even scaling up technology, digital, and artificial-intelligence investments. The COVID-19 crisis, which has forced companies to operate in new ways, may be a catalyst to rethink the size and role of the teams and management processes needed to run an efficient oil and gas company and to invest in new digital and technological capability and talent.

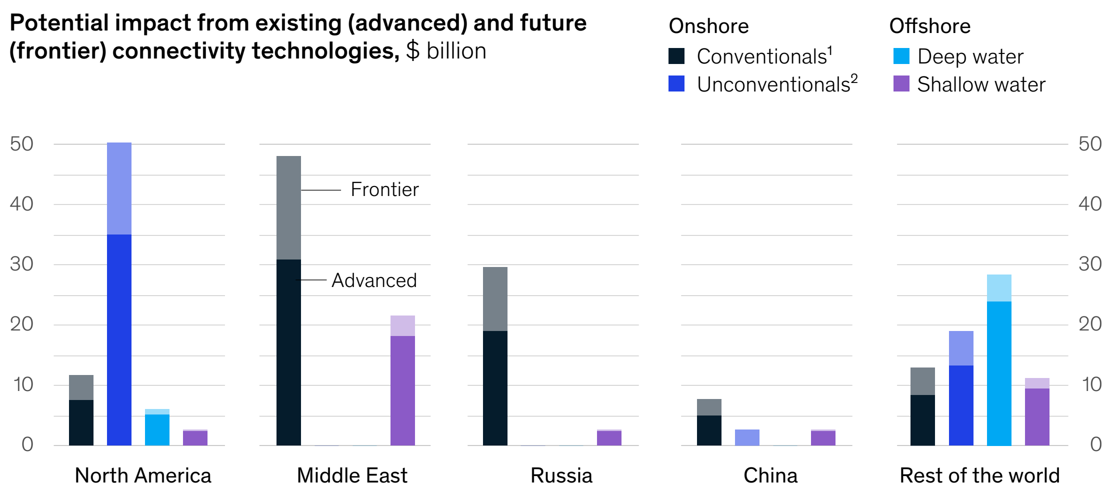
From the perspective of an operator with a diverse portfolio of assets—and an existing connectivity infrastructure—there is a potential sequence to capturing value from this technology. The operator may start with advanced facilities in already well-connected locations, leveraging the connectivity it already possesses before developing new infrastructure. Next, it could ramp up connectivity programs for assets with high potential that have heretofore fallen “out of reach” for technical or economic reasons. Once connectivity is in place, aggressive dissemination of best practices from the most innovative facilities can occur.

Since mature onshore sites are the “low hanging fruit,” we expect to first see onshore connectivity advances in pioneer regions like North America, where demand for advanced digital solutions and

Exhibit 4

Most of the potential new value from connectivity in oil and gas upstream operations comes from onshore assets.

Potential impact from existing (advanced) and future (frontier) connectivity technologies, $ billion



[1]Conventional oil is a category that includes crude oil and natural gas and its condensates.
[2]Unconventional oil is petroleum produced or extracted using techniques other than the conventional method (oil well).

As 5G private networks become more affordable, investment will be crucial to unlock the full benefit of digitized production operations.

the ability to deploy capital is high. Once the returns of advanced connectivity are demonstrated there, upgrades should roll out across other connectable regions such as the Gulf, Western Siberia, and the South American basins. To date, offshore assets are better connected, on average, but cannot be ignored. As 5G private networks become more affordable, investment will be crucial to unlock the full benefit of digitized production operations.

The oil and gas industry, however, cannot fully capitalize on advanced connectivity without help from other players and sectors. Operators could wait a long time for telcos to build the necessary infrastructure, and while LEO satellites could save the day for all but those with the highest latitude assets, their future is far from certain. Thus, oil and gas operators must take the initiative themselves or seek joint connectivity ventures—for example, to install fiber backhaul along gathering lines between wells and processing plants—starting with the highest-impact, greatest-feasibility facilities. With continued margin pressure and shifts in remote working brought on by the COVID-19 pandemic, significant tailwinds are currently behind any investment likely to enable remote or automated operations.

We see operators moving in two possible directions when it comes to the connectivity investments needed to enable the full potential of digital tools and analytics. On the first path, operators embrace an "if you build it, we will pay for services" model characteristic of fragmented basins like the Permian in the United States. The second path means direct collaboration with telco partners to establish dedicated capacity, which is a natural approach for those with material operations, a relatively mature digital and analytics track record, and the vision to understand the incremental technology required to push the limits of automation and optimization.

Remaining obstacles

Successful adoption of these use cases is far from a given, and barriers remain to unlocking their value. These challenges fall into three categories—organizational and technical deployment constraints, safety concerns, and labor redeployment.

With few exceptions, digital transformation in upstream oil and gas operations has been hit or miss to date. So far, the industry has experimented with various use cases, but few operators have succeeded in bringing digital and analytic technologies to a scale that meets the limits of existing connectivity. Digital tools and analytics—enabled by connectivity in the remote, hazardous, and complex operating environments of the oil and gas industry—will require hundreds of use cases to change traditional ways of working, and that has been difficult for the industry to date.

Data ownership in the industry is complex, with various pieces of equipment delivering different information and equipment manufacturers, service providers, and oil companies still resolving ownership of and access to data. Some technology service providers seek to lock operators into proprietary software to prevent data from becoming a commodity. Thus far, only drilling operations utilize a common data standard that facilitates sharing.

Safety concerns also inhibit the spread of advanced connectivity. Oil and gas assets pose inherent dangers to people and the environment, and safety protocols for some activities must be agreed to internationally. These potential risks slow down experimentation with even partial automation and create stronger barriers to reduce the labor required for drilling or production operations.

Finally, the employment impact of the industry in many countries can make efficiency initiatives harder to realize. Strong labor unions and countries with labor requirements may embrace technology enablement driven by connectivity later and only to the extent that technologies do not replace workers.

Strategic moves

The experiences of industries more mature in the deployment of connectivity suggests three approaches to unlock value from technology at scale, using enhanced connectivity.

1. ***Invest in human capabilities and future technologies***
   Digital enablement requires new skills to deliver the promise of our use cases in the oil and gas sector. Translators—individuals who can connect business problems with analytic approaches—will need training and, more broadly, industry mindsets and behaviors toward data-driven decision making will need to shift. Some talent, like robotics experts and product designers, may need to come from outside the industry.

   Capitalizing on the potential of connectivity technologies requires investment in data interoperability, augmented reality, autonomous vehicles, and robotics and instrumentation connected by wireless networks.

2. ***Rethink business models***
   Unlocking digital and analytics value using enhanced connectivity will require changes in the structure of the value chain. Using connectivity technologies, companies could begin relying on shared, basin-wide logistics and inspections, a radical departure from industry norms today. Relationships within the value chain will need to change too. For example, oil companies today pay drilling operators by the day, which provides contractors with less incentive to prioritize efficiency and reduce how long it takes to drill a well. The industry structure would need to change to release and share the value created with analytics and connectivity—among operators and drillers, in this case, and with suppliers, more broadly.

3. ***Incentivize digitalization***
   Regulation can create incentives for enhanced digital capabilities in the sector. For example, tighter regulation of emissions from operations and the supply chain could spur investment in connectivity to monitor and reduce emissions. Regulators could encourage data sharing and help orchestrate labor education and reallocation opportunities for workers affected by automation. In regions where driving down cost is imperative to remain competitive, regulation could be adjusted to accelerate robotics pilots.

The complete set of capabilities and technologies required to unlock the potential of digital and analytics is complex and reflects the complexity not only of technology itself but of the entire digital and analytics roadmap for individual players. For each operator, this roadmap covers hundreds of use cases, dozens of technologies, and many partners able to move fast and at scale. Most oil and gas companies are attempting to build ecosystems of partnerships to accelerate the impact of digital technologies and debating which core digital capabilities must really be in-house capabilities. Prominent examples of these ecosystems are partnerships among technology players like Total and IBM, which are working together to use a supercomputer to improve exploration operations, or Shell partnering with Amazon on big-data-analytics capabilities.

Succeeding will require a clear view on the value to be unlocked, as well as a structured and strategic approach to aligning the right capabilities—internal and external—to unlock it.

Oil and gas price and demand pressures in the wake of the COVID-19 pandemic make the potential value embedded in current advanced connectivity for exploration and production more important than ever. That will require sizeable capital investment in new capabilities and technologies, albeit not nearly as much as the industry has traditionally devoted to capital expenditures. It will also demand significant shifts in the industry's organizational culture, data and labor practices, and business models and ecosystems, as well as potential changes in regulation. It is, in other words, a tall order. Still, the hundreds of billions of dollars of potential value this could unlock make such investments and evolution worthwhile, particularly in the next normal that the world is now entering.

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