WORLD ECONOMIC FORUM

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White Paper

Digital Transformation Initiative
Oil and Gas Industry

In collaboration with Accenture

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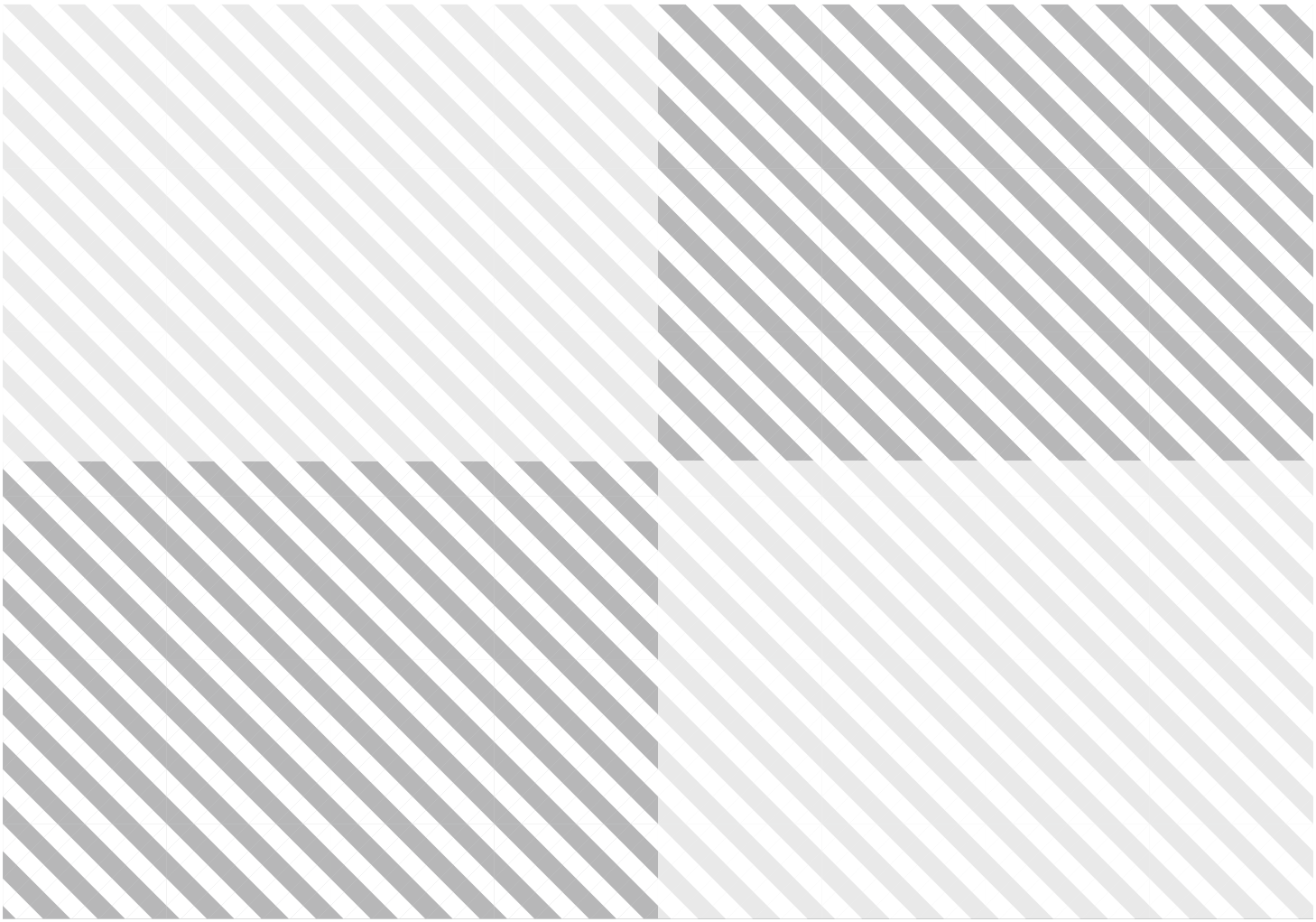

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The Digital Transformation Initiative

The Digital Transformation Initiative (DTI) is a project launched by the World Economic Forum in 2015 as part of the System Initiative on Shaping the Future of Digital Economy and Society. It is an ongoing initiative that serves as the focal point at the Forum for new opportunities and themes arising from latest developments in the digitalization of business and society. It supports the Forum's broader activity around the theme of the Fourth Industrial Revolution.

To find out more about the DTI project, visit
http://reports.weforum.org/digital-transformation

Contents

Foreword

Digital transformation is emerging as a driver of sweeping change in the world around us. Connectivity has shown the potential to empower millions of people, while providing businesses with unparalleled opportunities for value creation and capture.

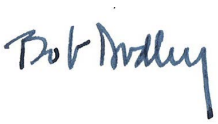
Since the industrial revolution, the Oil & Gas industry has played a pivotal role in the economic transformation of the world, fuelling the need for heat, light and mobility of the world's population. Today the Oil and Gas industry has the opportunity to redefine its boundaries through digitalization. After a period of falling crude prices and, frequent budget and schedule overruns, together with greater demands of climate change accountability and difficulties in attracting talent, the Oil & Gas industry can provide practical solutions. Digitalization can act as an enabler to tackle these challenges and provide value to all its stakeholders.

While digitalization could be a source of positive change, there are a number of challenges that need to be overcome to realize its full potential for both business and society. In some cases, the gains from digitalization have been inequitable with the benefits not reaching those who need it most. At the same time, the exponential increase in global information flows have created new risks around data privacy and security and businesses across sectors are grappling with challenges related to changing customer expectations, cultural transformation, outdated regulation, and skill shortages – to name a few.

Through the collaboration with the World Economic Forum, leaders gather to better understand the implications of these changes. The Digital Transformation of Industries (DTI) project, launched by the World Economic Forum in 2015, is an ongoing initiative that serves as the focal point for new opportunities and themes arising from latest developments and trends from the digitalization of business and society.

In 2015, DTI analysed the impact of digital transformation on 6 key industries – automotive, consumer industries, electricity, healthcare, logistics and media - as well 3 cross-industry topics focused on Digital Consumption, Digital Enterprise, and Societal Implications. In 2016, the initiative was extended to cover 7 additional industries, including oil and gas, and 2 new cross-industry themes – Platform Economy and Societal Value & Policy Imperatives. Through its broad focus, DTI has driven engagement on some of the most pressing topics facing industries and society today and provided business and policy leaders with an informed perspective to take action. This report does not only look into the challenges and opportunities digitalization creates for the Oil & Gas industry, but also how this potentially can be translated to societal value.

I would like to thank the Oil & Gas Community Steering Committee and the experts from industry partners, government and academia who were involved in shaping the insights and recommendations of this project. I am confident that the findings will contribute to improving the state of the world through digital transformation, both for business and society.



Bob Dudley
Group Chief Executive, BP
Chair, Oil and Gas Community
World Economic Forum

Digitalization: A New Era for Oil and Gas
Executive Summary

A new era for the Oil and Gas industry

The Oil and Gas industry is no stranger to big data, technology and digital innovation. As early as the 1980s, Oil and Gas companies began to adopt digital technologies, with a focus on better understanding a reservoir's resource and production potential, improving health and safety, and boosting marginal operational efficiencies at oil fields around the world. A wave of digital oilfield initiatives swept through most of the industry in the 1990s and the early part of this century. However, for most of this decade, the industry has not taken advantage of the opportunities that derive from using data and technology in a meaningful way. A single drilling rig at an oilfield, for example, can generate terabytes of data every day, but only a small fraction of it is used for decision-making. As other capital-intensive industries (such as aviation and automotive) have revolutionized their business and operating models through a holistic application of digital technologies, the opportunity for the Oil and Gas industry to leverage the transformational impact of digitalization has become more evident.

The industry is now beginning to pay heed. The growing consensus is that the Oil and Gas sector is on the cusp of a new era. A second wave of business and digital technologies looks set to reshape it, propelled by a series of macroeconomic, industry and technology trends:

- **Disruption in supply, demand and commodity prices.** The industry is witnessing one of its worst downturns, driven by a supply-side disruption. At one point, commodity prices had fallen by more than 70% compared with June 2014 levels. Just as some early signs of recovery have emerged, another disruption may be on the horizon, driven, on this occasion, by peak demand for oil.[1] [2] This disruption will maintain pressure on hydrocarbon prices and prompt energy companies to focus more intensely on reforming their portfolio and taking a greater role in the energy transition.
- **Rapid advances in technology.** The growing sophistication of platforms, as well as mobility, surveillance, connectivity and storage technologies, coupled with the ability to process and analyse data rapidly, enhance agility and support real-time decision-making and execution.
- **Changing consumer needs and expectations.** Across industries, consumers expect increased engagement, personalization and speed. They are also paying more attention to environmental issues, which influences their energy choices; seeking transparency from companies in different areas (e.g. emissions or hydrocarbon sources); and growing in technical sophistication by being connected to multiple technology and digital platforms.

Despite these fundamental shifts, many of the digital initiatives to date within Oil and Gas could be seen as conservative and with limited impact on existing operating or business models. Much of the effort so far has been evolutionary; companies are making incremental performance improvements through the selective use of business and digital technologies. These include basic proactive maintenance procedures, reviews of completed operations and the use of rudimentary data sets for all parts of the Oil and Gas value chain.
At present, the traditional approach of selectively adopting a set of technologies and unsystematically implementing digitalization might not be suitable. Instead, the industry could benefit more by pursuing a revolutionary agenda with digital as a backbone. Digital transformation has the potential to create tremendous value for both the industry and society as a whole. Such a transformation will require organizations to implement a focused digital strategy, sponsored by the chief executive officer and executive teams, and a culture of innovation and technology adoption. It will also need investment and commitment to revisit and revamp processes, infrastructure and systems; and, a willingness to collaborate across the ecosystem. All the enablers required for a successful transformation will have to come into play for the industry to harness digital's true potential.

Digital themes

Four themes are central to the digital transformation of Oil and Gas over the next decade:

Digital asset life cycle management. New digital technologies combined with data-driven insights can transform operations, boosting agility and strategic decision-making, and resulting in new business models.

Circular collaborative ecosystem. Applying integrated digital platforms enhances collaboration among ecosystem participants, helping to fast-track innovation, reduce costs and provide operational transparency.

Beyond the barrel. Innovative customer engagement models offer flexibility and a personalized experience, opening up new revenue opportunities for Oil and Gas operators, and new services for customers.

Energizing new energies. The digitalization of energy systems promotes new energy sources and carriers, and supports innovative models for optimizing and marketing energy. To remain relevant to customers, the Oil and Gas industry must understand the full impact of these changes on the broader energy system.

Putting a value on digital transformation

This value-at-stake analysis[3] aims to assess the potential for digitalization in the Oil and Gas sector to unlock benefits for the industry, its customers and society more generally over the next decade (2016-2025). Key findings from this analysis include the following:

- Digital transformation in the Oil and Gas industry could unlock approximately $1.6 trillion of value for the industry, its customers and wider society.
- This total estimated value from digitalization can further increase to $2.5 trillion if existing organizational/ operational constraints are relaxed, and the impact of "futuristic" technologies, such as cognitive computing, is considered (for which there is insufficient evidence to make a definitive value assessment at this time).
- Digitalization has the potential to create around $1 trillion of value for Oil and Gas firms.
- Digital transformation in the industry could create benefits worth about $640 billion for wider society. This includes approximately $170 billion of savings for customers, roughly $10 billion of productivity improvements, $30 billion from reducing water usage and $430 billion from lowering emissions.
- Environmental benefits include reducing CO_2-equivalent (CO_2e) emissions by approximately 1,300 million tonnes, saving about 800 million gallons of water, and avoiding oil spills equivalent to about 230,000 barrels of oil.

Inhibitors

Barriers to change include regulatory frameworks that are struggling to adapt to a new era of data sharing along value chains; a lack of standardization in data coming from sensors; an inability to share information across the ecosystem; and the challenge of recruiting millennials to replace an ageing workforce. Moreover, some senior industry leaders have not yet made the necessary shift in mindset to embrace digital's potential value. This is particularly so when digital is considered at odds with deeply entrenched safety concerns, which can be triggered, for example, by discussion of unmanned assets. Structural inhibitors that may result from such a conservative approach are another key barrier to digital transformation, as in the industry's lack of desire to take a more experimental, "fail-fast" approach because of concern about the potential consequences of change.

Recommendations for successful digital transformation

Digital transformation could transform the way people work and live at a scale comparable to major industrial revolutions of the past. While digital transformation has tremendous potential to benefit industry and society, it is by no means guaranteed that its full value will be unlocked. To do so, all major stakeholders – including coordinated regulatory efforts to maximize the value of digitalization for society and across industries – must engage in focused collaboration and determined action. Successful digitalization will require collaboration between industry leaders, communities and policy-makers. A series of recommendations for both the industry and other stakeholders have been developed:

Recommendations for the industry

- **Make digital a priority for senior executives.** Digital transformation, like any other transformation, needs to be sponsored from the top. This includes setting a clear vision, committing funding and resources, and actively championing the change-management effort associated with it.
- **Drive a culture of innovation and technology adoption.** While not everything will be developed in-house, companies will need to open up to new ideas and ways of working.
- **Invest in human capital and development programmes that promote new, digital thinking.** Ultimately, a digital-savvy workforce is both a foundational enabler of transformation and a key driver for maximizing value capture.
- **Put in place a methodical approach for developing and/or industrializing new capabilities.** This includes decisions about whether to build or buy capabilities, and a programme-management approach to scale up technology and digital platforms.
- **Reform the company's data architecture.** Data sits at the heart of digital transformation, so the harmonization, integration and interoperability of data platforms are critical.
- **Identify opportunities to deepen collaboration and understanding of sharing-economy platforms.** This will allow for sidestepping the potential pitfalls brought by changing customer preferences shaped by the rise of the sharing economy.

Recommendations for policy-makers, governments and broader society

- **Develop global data standards.** This includes policies related to data sharing and security, and encouraging transparency in operations.
- **Foster an ecosystem for innovation.** Policy-makers, governments and wider society have an important role in driving future prosperity. The onus has shifted today onto governments to not only help build the innovation ecosystem, but also innovate within their organizations to unlock value and meet their constituents' ever-changing and diverse needs.
- **Create clear regulatory frameworks.** These will promote the shift towards the low-carbon economy

and support a more inclusive society. Such frameworks can contribute to a broader reform agenda for greener, more resilient and inclusive growth.

Data generation, sharing, analysis and storage are important enablers of digital transformation – for example, in adopting the Industrial Internet of Things, or collaborating within the ecosystem. Governments should ensure that current concerns on the privacy, usage, security and interoperability of data can be resolved. Today, governments are expected to observe the development of digital technologies and be open to a dialogue with the industry on best practices related to collecting, sharing and using data.

Finally, the industry, governments and civil society will not maximize the benefits of digitalization to the industry, wider society and the environment if they each act separately on these important topics. Instead, addressing digital transformation with a multistakeholder approach stands to reap potential gains that have never been greater.

Bruce Weinelt
Head of Digital Transformation
World Economic Forum

Industry Context and Digital Trends

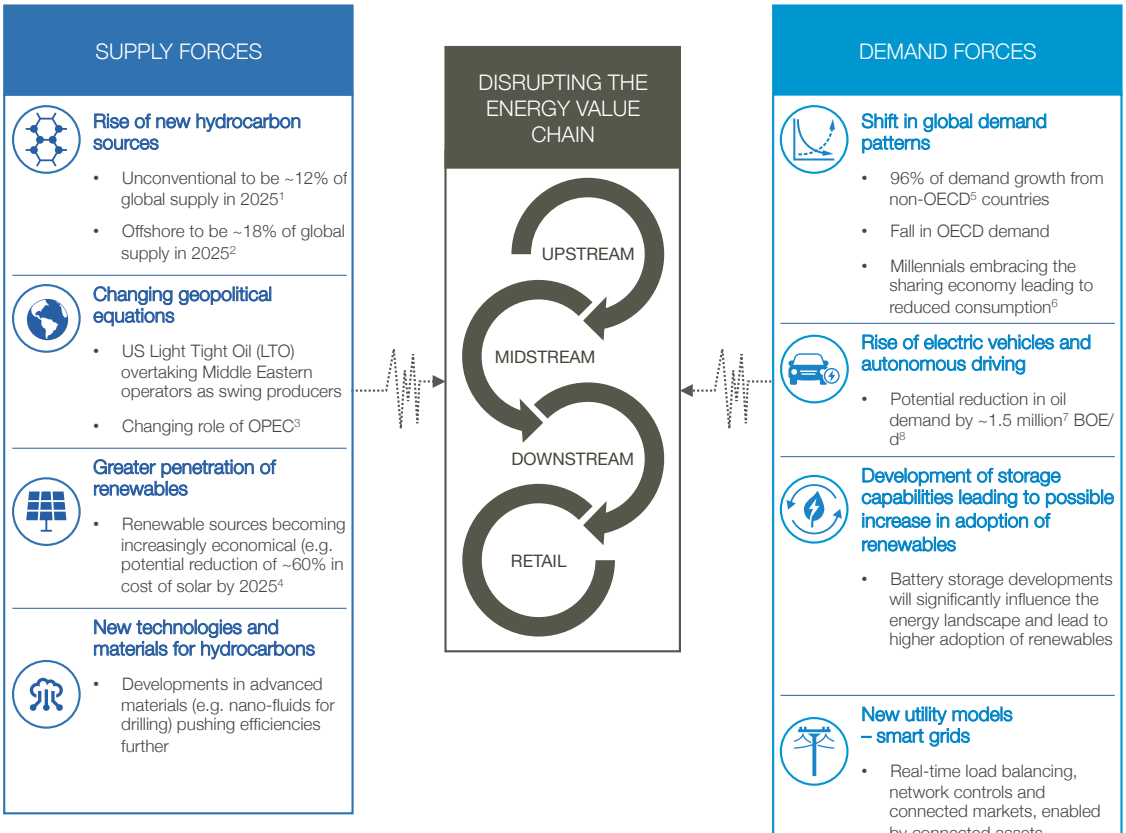
Industry forces and digital innovations are reshaping the Oil and Gas industry. An unsystematic adoption of new technology may no longer suffice; a holistic approach to digitalization could create significant value.

This White Paper focuses on how digitalization will enable the Oil and Gas industry's current and future transformation. It also aims to understand the impact that the digital transformation of adjacent industries, such as automotive and electricity, will have on the Oil and Gas sector. Digitalization's impact on Oil and Gas was considered across the value chain, from exploration and production to midstream, downstream (refinery) and retail. The value analysis excluded market operations and trading, which were considered qualitatively.

a. Industry trends

Several powerful supply and demand forces are shaping the Oil and Gas industry and the broader energy value chain (see Figure 1). These include technological advances such as horizontal drilling and hydraulic fracturing, which are unlocking shale resources and playing an important role in creating the oversupply responsible for persistently low crude prices. Other factors, such as the growing interest in electric vehicles, are affecting demand. The impact of these forces, combined with the potential disruption of digitalization, can be felt within Oil and Gas and adjacent industries.

Figure 1: Shifting Trends in Supply and Demand Are Reshaping the Oil and Gas Industry



Notes: [1] Unconventional = Light Tight Oil and Shale gas, based on 2025 projection (BP Energy Outlook); [2] Offshore projection from 10% in 2013 to 18% in 2025 (BP Energy Outlook); [3] OPEC = Organization of the Petroleum Exporting Countries; [4] Forecasts by the International Renewable Energy Agency; [5] OECD = Organisation for Economic Co-operation and Development; [6] Hynek, Ann, "How Millennials Are Changing the US Economy", *Market Realist*, 1 March 2016, http://marketrealist.com/2016/03/millennials-driving-sharing-economy/ ; and Cardinal Financial, "Millennials and the Sharing Economy", 14 September 2016, https://cardinalfinancial.com/2016/09/14/millennials-and-the-sharing-economy/; [7] Based on 100 million electric vehicles as per the International Energy Agency's *Global Electric Vehicle Outlook 2016*; [8] BOE/d = barrels of oil equivalent per day; [9] COP21 = 21st Conference of the Parties

Source: World Economic Forum/Accenture analysis

Disruption in supply, demand and commodity prices, combined with persistent market volatility, have made investors wary of the industry, which has a lower total return to shareholders (TRS) compared to other industries (see Figure 2).

Figure 2: Total Return to Shareholders across Industries

10-Yr TRS CAGR (09/2006 – 09/2016)		5-Yr TRS CAGR (09/2011 – 09/2016)		3-Yr TRS CAGR (09/2013 – 09/2016)		1-Yr TRS CAGR (09/2015 – 09/2016)		MARKET CAP (09/2016; USD Bn)	
Technology	9.0%	Healthcare	17.1%	Technology	13.6%	Mining	32.0%	Bank	5,351
Healthcare	8.8%	Technology	14.4%	Healthcare	11.1%	Technology	19.8%	Healthcare	4,506
Retail	8.2%	Machinery	11.6%	Machinery	6.9%	Chemicals	15.5%	Technology	4,241
Machinery	7.1%	Retail	11.5%	Utilities	4.8%	Oil and Gas	14.9%	Oil and Gas	2,567
Chemicals	6.8%	Bank	9.2%	Retail	4.3%	Machinery	11.6%	Telecom	2,523
Telecom	6.8%	Auto	8.5%	Telecom	3.6%	Telecom	11.0%	Retail	2,421
Mining	4.3%	Chemicals	8.0%	Chemicals	2.9%	Utilities	7.4%	Utilities	1,831
Auto	2.7%	Telecom	7.5%	Bank	0.6%	Healthcare	5.9%	Chemicals	1,608
Utilities	2.3%	Utilities	5.2%	Auto	-1.7%	Auto	4.3%	Auto	910
Oil and Gas	0.0%	Oil and Gas	0.2%	Oil and Gas	-5.3%	Retail	0.6%	Mining	823
Bank	-0.3%	Mining	-7.8%	Mining	-6.3%	Bank	0.4%	Machinery	557

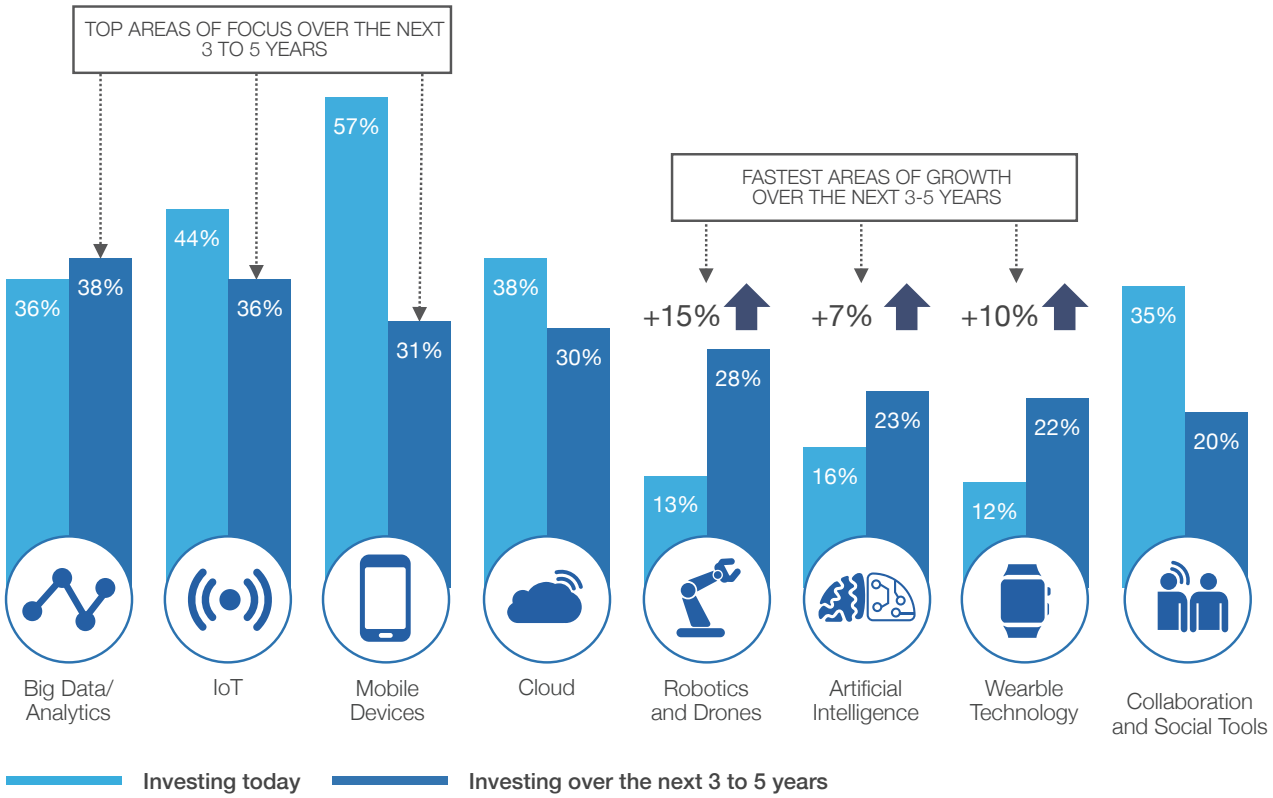
Note: CAGR = compound average growth rate.
Source: Accenture analysis based on Bloomberg data

b. Digital trends

In comparison to other sectors, the industry's approach to digital transformation is expected to be evolutionary rather than revolutionary. However, developments in technologies such as the cloud, social media, and big data and analytics are driving trends that have immense potential for Oil and Gas. Cloud computing can improve business agility by breaking down silos of corporate business functions. Big data and analytics can help with innovation by supporting companies in analysing large quantities of structured and unstructured data from disparate sources, and generating real-time insights. Mobile technology enables new business scenarios, while social channels enhance relationships with customers by potentially making these connections quick, direct and cheap. The falling cost of sensors and the emergence of the Industrial Internet of Things (IIoT) will vastly increase the volumes of data that companies can access.

Combining these technologies in innovative ways could magnify their capabilities exponentially, far beyond their effectiveness if deployed separately. This combined impact will soon add a new level of connected intelligence to Oil and Gas operations. Beyond improving efficiency, digitalization could allow companies to better reach out to customers. According to a recent Accenture survey (see Figure 3), big data and analytics, IIoT and mobile devices are emerging as top digital topics for Oil and Gas companies.

Figure 3: Investments in Digital Technologies*



* The percentages in the bars are the proportion of Oil and Gas companies surveyed.
Source: Accenture, The 2016 Upstream Oil and Gas Digital Trends Survey

Big data and analytics

Cheap sensors, widening connectivity and ever-greater computing power are driving the increase in data collected by Oil and Gas companies. Modern offshore drilling platforms have about 80,000 sensors, which are forecast to generate approximately 15 petabytes (or 15 million gigabytes) of data during an asset's lifetime.[4] Big data and analytics will help firms navigate this huge amount of data.
About 36% of Oil and Gas companies are already investing in big data and analytics. However, only 13% use the insights from this technology to drive their approach towards the market and their competitors.[5] This discrepancy highlights how these companies have not always embedded big data and analytics completely in their systems, but are just applying the technology piecemeal. Full-scale deployment could have far-reaching impacts on productivity and operations.

The Industrial Internet of Things

The IIoT (an application of IoT), is a "system of interrelated computing devices, mechanical and digital machines, objects, or people that are provided with unique identifiers and the ability to transfer data over a network without human-to-human or human-to-computer interaction".[6] In evolving from a convergence of different technologies, the IIoT has broken down the walls between operational technology (OT) and information technology (IT). This means unstructured, machine-generated data can be analysed for insights that drive improvements in design and execution, and lead to smarter, faster decision-making. IIoT also enables machine-to-machine communications.

One potential challenge with the integration and convergence of IT and OT is that companies must be equipped to tackle new issues and risks, such as malware and cyberattacks. For the upstream category, IIoT can help with optimization by providing new operational insights from analysis of diverse sets of operational data (such as drilling parameters) and cross-disciplinary data (such as geological models). Midstream companies – for example, transportation, including pipelines and storage that aim for higher network integrity and new commercial opportunities – are expected to benefit significantly from building data-enabled infrastructure. Downstream players (e.g. petroleum-product refiners and retailers) could see potential in new revenue opportunities, from expanding visibility of the hydrocarbon supply chain and targeting digital consumers with new forms of connected marketing.

Mobile devices

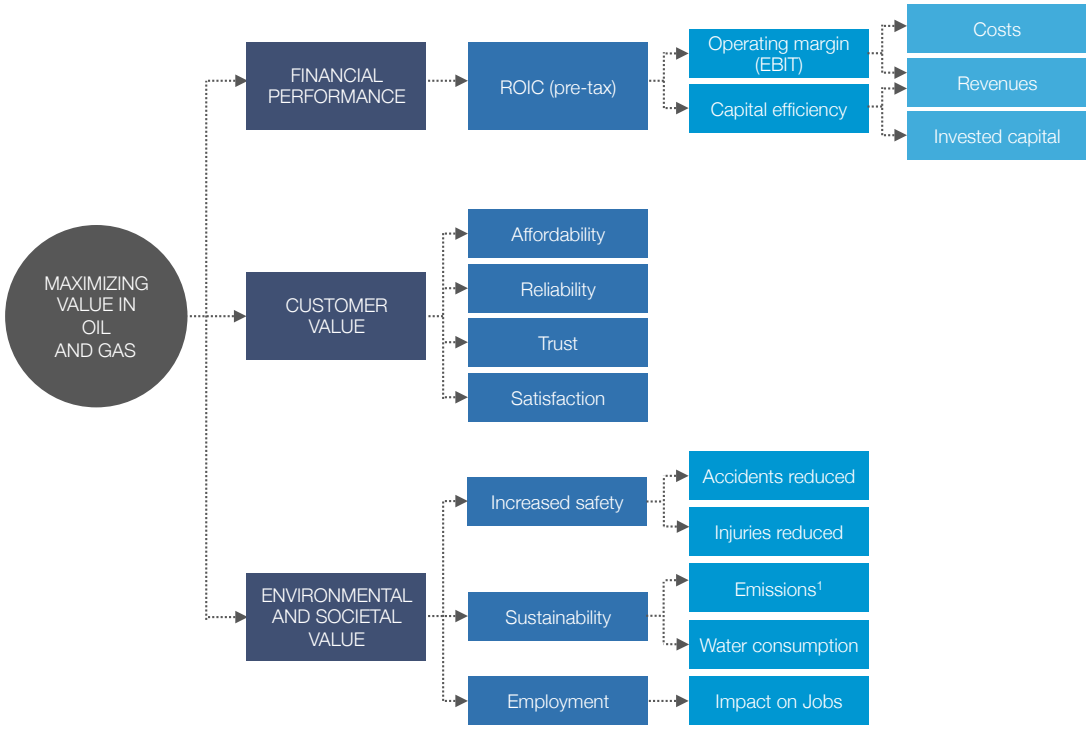
Oil and gas companies have invested heavily in fully integrating mobile devices into everyday operations. The major benefits of this integration include workflow improvements from better group communication, increased worker productivity and better recording of field data. Mobile technology also allows for real-time data monitoring via specialized software on smartphones, and can have a positive impact on health, safety and the environment (HSE). Companies have improved employee safety by using smartphone GPS coordinates to track workers in hazardous situations. Deploying mobile applications in combination with radio-frequency identification tags is making assets smart and their movements visible.

Value Framework

Successful digital transformation can boost the profitability of Oil and Gas firms, improve workforce safety, and benefit society through reduced emissions and water consumption, as well as savings for customers. A detailed model has been developed to quantify the digitalization's impact on the Oil and Gas industry and wider society.

Digital technologies have tremendous potential to move Oil and Gas companies beyond sluggish growth and deliver exceptional shareholder, customer and environmental value. Capturing this value does not have to happen outside or in lieu of organizational priorities and, indeed, can play an important role in forming a cohesive response to industry shifts. In the framework of this White Paper, value creation in the industry is a function of financial performance and customer, environmental and societal value (see Figure 4).

Figure 4: Maximizing Value in Oil and Gas



[1] Emissions refers to CO_2 equivalents, SO_2, NO_X and CO

Note: ROIC = Return on invested capital
Source: World Economic Forum/Accenture analysis

Calculating the value of digital transformation in Oil and Gas

Our value-at-stake methodology aims to assess the impact of digital transformation initiatives on industry, customers, society and the environment. It provides likely value estimates of global industry operating profits that are at stake from 2016 to 2025, and the contribution that digital transformation can make to customers, society and the environment within that time frame.

Value-at-stake for industry comprises two elements: first, value addition, or the potential impact generated by digital initiatives on an industry's operating profits; and second, value migration, or the operating profits that will shift between different industry players. Value-at-stake for society measures the value impact of digital transformation for customers, society and the environment.

The value of digitalization estimated here is based on existing constraints. The potential values could be amplified if Oil and Gas operators were to go beyond the digital initiatives highlighted in this White Paper, and if the impact of digital on the following were considered:

- How work gets done today
  - Digital could fundamentally change the way operations are conducted (e.g. by changing workflows).[5]
- How Oil and Gas operators manage their portfolio
  - Operators should decide in what way real-time data, decision-making and collaboration will shift how they manage their portfolio of operations and future investment considerations.6

For the purpose here, the above questions have not been quantified in depth. If those questions are considered thoroughly, however, value could potentially be magnified by three to five times.

The value-at-stake methodology is fully explained in the Appendix.

Future Horizons: Digital Themes and Initiatives

Digitalization in the Oil and Gas sector could be worth between $1.6 to $2.5 trillion for the industry, its customers and wider society over the next decade. The digital innovations with the greatest potential to create value are highlighted here.

Drawing on numerous interviews[7] and in-depth research for this White Paper, four digital themes have been identified that are expected to play a crucial role in the industry's digital transformation in the 2016-2025 period:

Digital asset life cycle management. New digital technologies combined with data-driven insights can transform operations, boosting agility and strategic decision-making, and resulting in new operating models.

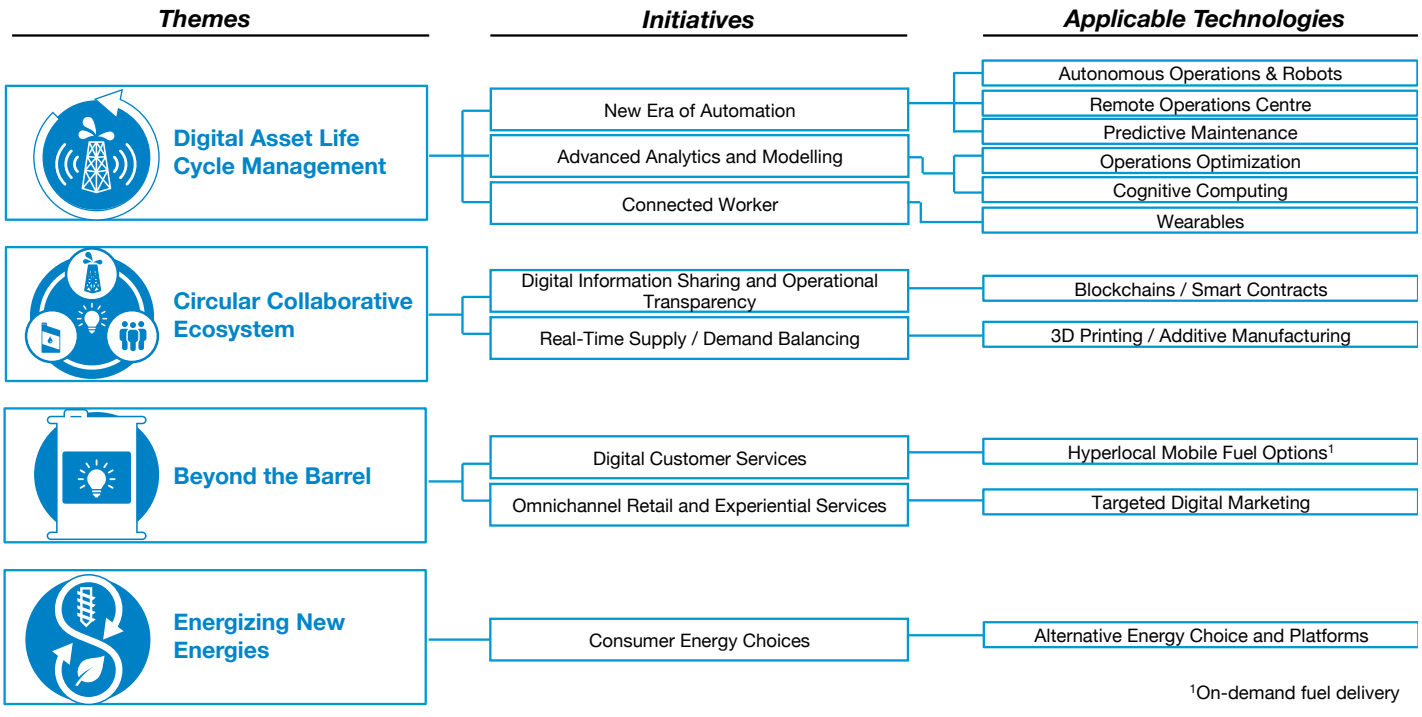
Circular collaborative ecosystem. Applying integrated digital platforms enhances collaboration among ecosystem participants, helping to fast-track innovation, reduce costs and provide operational transparency.

Beyond the barrel. Innovative customer engagement models offer flexibility and a personalized experience, opening up new opportunities for Oil and Gas operators, and new services for customers.

Energizing new energies. The digitalization of energy systems promotes new energy sources and carriers, and supports innovative models for optimizing and marketing energy. To remain relevant to customers, the Oil and Gas industry must understand the full impact of these changes on the broader energy system.

Within each theme, digital initiatives define the technologies expected to have a significant impact on the industry's value chain, its workforce, adjacent industries, the environment and wider society. These initiatives (see Figure 5) represent concrete steps that firms can implement as they deploy digital technologies to transform their business and operating models.

Figure 5: Digital Initiatives in the Oil and Gas Industry



Source: World Economic Forum/Accenture analysis

Value-at-stake headlines

The value-at-stake analysis employed[8] aims to assess the potential for these digital transformation initiatives to unlock value for the Oil and Gas industry, its customers, wider society and the environment over the next decade (2016-2025). The key findings include the following:

- Digital transformation in the Oil and Gas industry could unlock approximately $1.6 trillion of value for the industry, its customers and wider society.
- This total estimated value from digitalization can further increase to $2.5 trillion if existing organizational/operational constraints are relaxed, and the impact of "futuristic" technologies, such as cognitive computing, is considered (for which there is insufficient evidence to make a definitive value assessment at this time).
- Digitalization has the potential to create around $1 trillion of value for Oil and Gas firms. Of that amount, $580-$600 billion is expected to accrue to upstream companies, approximately $100 billion to midstream firms and $260-$275 billion to downstream companies.
- Digital transformation in the industry could create benefits worth about $640 billion for wider society. This includes approximately $170 billion of savings for customers, roughly $10 billion of productivity improvements, $30 billion from reducing water usage and $430 billion from lowering emissions.
- Environmental benefits include reducing CO_2e emissions by approximately 1,300 million tonnes, saving about 800 million gallons of water, and avoiding oil spills equivalent to about 230,000 barrels of oil.

The value-at-stake analysis was conducted for the themes and initiatives listed in the Table, where initiatives that were not quantified have also been listed explicitly. The rationale for excluding them is explained in the relevant section of this White Paper.

Table: Value-at-Stake Analysis for Themes and Initiatives

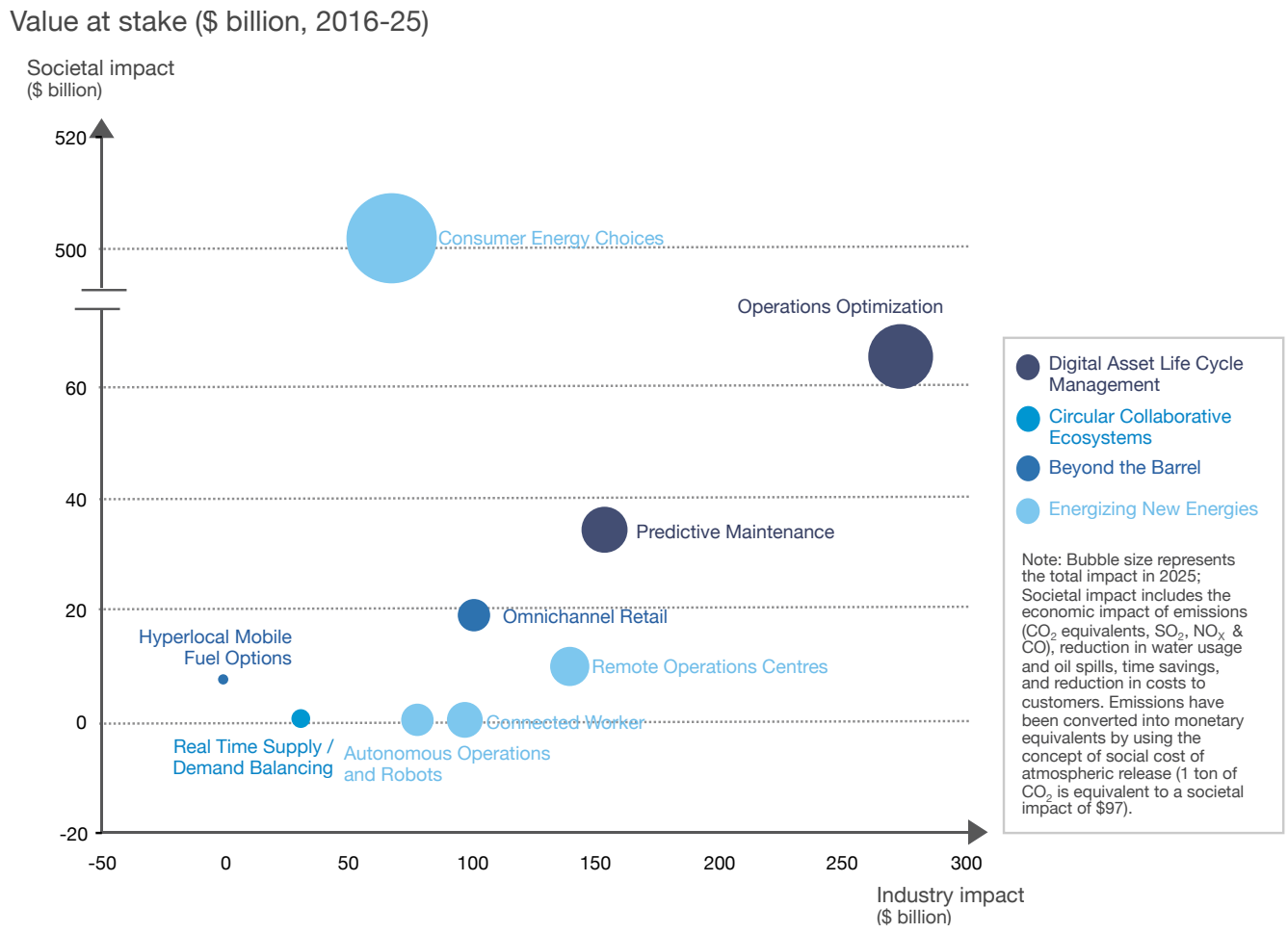
	HIGH-MATURITY, HIGH-CERTAINTY QUANTIFIED DIGITAL INITIATIVES AND TECHNOLOGIES	LOW-MATURITY, LOW-CERTAINTY UNQUANTIFIED DIGITAL INITIATIVES
DIGITAL ASSET LIFE CYCLE MANAGEMENT	• Autonomous Operations and Robots • Remote Operations Centres • Predictive Maintenance • Operations Optimization • Connected Worker	• Cognitive Computing
CIRCULAR COLLABORATIVE ECOSYSTEMS	• Real-Time Supply / Demand Balancing through 3D Printing	• Digital Information Sharing and Operational Transparency through Blockchains and Smart Contracts
BEYOND THE BARREL	• Digital Customer Services • Omnichannel Retail and Experiential Services	• Forecourt as a battery (electric vehicle charging)
ENERGIZING NEW ENERGIES	• Consumer Energy Choices	
TOTAL VALUE AT STAKE	$1.6 to $1.9 trillion (depending on adoption rates)	$0.2 to $0.5 trillion (estimated)

Source: World Economic Forum/Accenture analysis

Furthermore, and for the purpose of this White Paper, the subsurface impact of technologies such as 4D seismic or advanced drilling and completion methodologies have not been included and/or quantified. However, such technologies have tremendous potential to generate value and affect the Oil and Gas industry as a whole (see Figure 6).

- Within the digital asset lifecycle management theme, "operations optimization" has the potential to unlock the most value for the industry (approximately $275 billion). Within the upstream sector, 90% of this value is expected to accrue primarily by optimizing drilling and production, and from leveraging the data from end-to-end connected assets to feed advanced analytics algorithms. This reduces costs related to non-productive time and improves resource productivity.
- Increased automation, and the deployment of robotics and remote-operating capabilities, will lead to value-based decisions feeding into future design considerations (e.g. portfolio planning, where to drill, improved maintenance, optimizing artificial lift, making decisions about net present value).
- "Consumer energy choices" provide the largest benefit to society. A shift to renewables, along with an increase in capacity factors and the emergence of electric

Figure 6: Potential Value of Digital Initiatives and Technologies in Oil and Gas, for the Industry and Society



Source: World Economic Forum/Accenture analysis

cars, could lead to profits of $65-$70 billion migrating from Oil and Gas companies to the broader energy ecosystem. Upstream players stand to be most at risk, with approximately $60 billion of their profits potentially migrating to this broader ecosystem. This shift is expected to benefit the environment, however, leading to a potential reduction of 900 million tonnes in CO_2e emissions.

– Initiatives that enhance collaboration within the Oil and Gas ecosystem, such as "real-time supply/demand balancing", are also likely to unlock significant value. However, the impact expected from this theme (Circular Collaborative Ecosystem) would be significantly higher if the impact of "digital information sharing and operational transparency through blockchains and smart contacts" had been quantified.

a. Digital asset life cycle management

New digital technologies combined with data-driven insights can transform operations, boosting agility and strategic decision-making.

The Oil and Gas industry has spent trillions of dollars in recent decades building large infrastructures – including offshore projects, land development fields, and complex networks of pipelines and refineries – all with a view to meeting the world's energy demand. The ability to capture and interpret data, and then take effective action while minimizing risks to employees and the environment, lies at the heart of how the industry operates. The use of technology and core physical infrastructure, such as sensors and automation in the upstream, midstream and downstream areas of the industry, have made this approach to operations possible.

To date, however, data has been captured and analysed primarily to improve health and safety and unlock marginal operational efficiencies, such as reducing equipment downtime or improving a project's performance within a defined portfolio for a limited period of time. Over the decades, concepts such as the digital oilfield have matured, and the ability of piecemeal applications of digital technology to drive a step change in operational performance is approaching its limit.

In the future, a different management approach should be considered, that of: taking the entire life cycle of an asset into account, from design to operations; collecting and analysing data at each step; understanding how it would affect the next step in the sequence; and capturing lessons to inform future designs. It would drive the evolution of oilfield assets in two important ways:

– Advances in digital and cloud capabilities could allow operators to shift their cost base from expensive, disconnected and static instrumentation (e.g. sensors) to insight-driven decision-making through analytics. A greater share of resources can thus be invested in improving reliability, increasing flexibility and unlocking innovation.

– Operating models should be flexible and nimble, allowing for cross-disciplinary collaboration across assets to process data faster and more reliably. This development will underpin quicker, more effective decision-making while ensuring safety.

Digital asset life cycle management initiatives rely first on specialized sensors to capture real-time information from physical assets, and subsequently on cloud-based analytics to process this data. The decreasing cost and increasing power of these technologies is enabling the Oil and Gas industry to do more at the well site itself, giving rise to new operating models. One such concept, applicable in high volume locations such as US lower 48-states upstream sector (unconventional shale operations), could be the introduction of platform-based models to the oilfield. In this scenario, the well can be considered as the customer, with users and multiskilled workers equipped with digital wearables (e.g. mobility apps and smart glasses) as platform suppliers. An unmanned control centre, powered by artificial intelligence (the platform itself), coordinates operations in real time, bringing together supply and demand. Operating models of this kind can significantly extend the life cycle of Oil and Gas assets while also driving increases in operational efficiency and HSE performance.

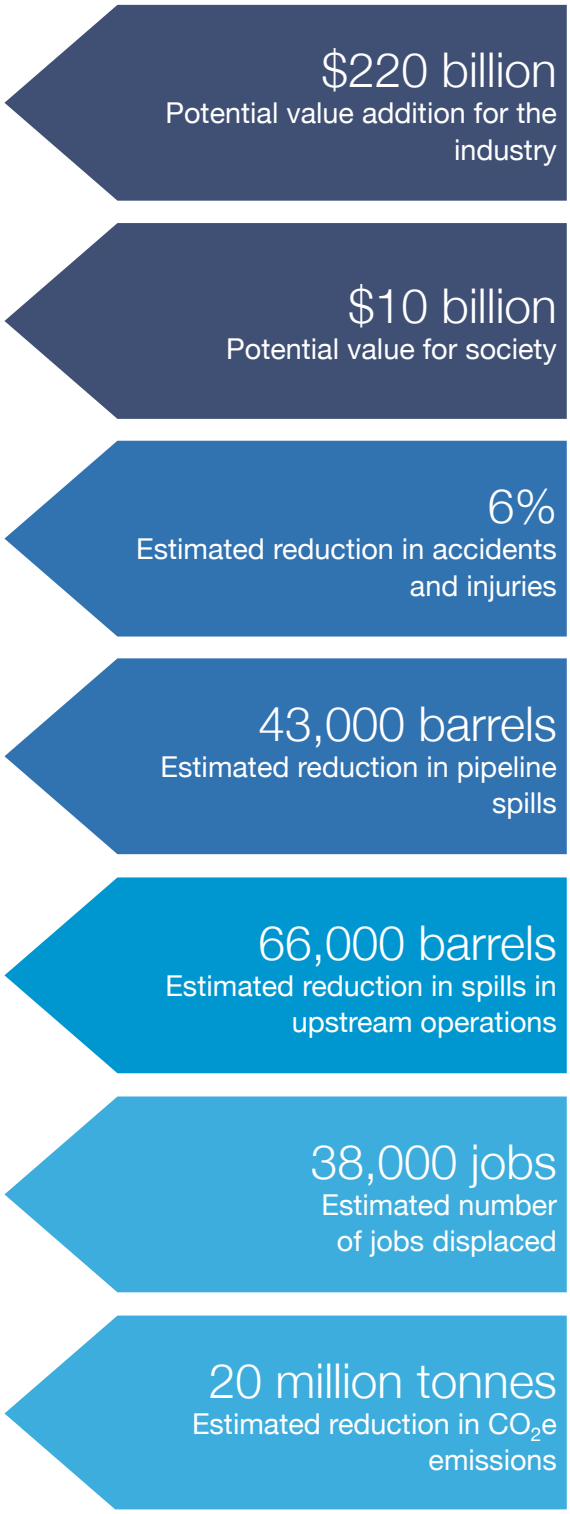
Three initiatives under this theme have been identified as central to unlocking value through digitalization in the industry over the next decade.

New era of automation

As lower oil prices continue to hamper margins, the Oil and Gas industry is facing intense pressure to improve operational efficiencies. Additionally, capital expenditures for exploration have dropped by about 25% since 2014, adding emphasis to maximizing production and throughput by "squeezing" existing assets. Companies that leverage digital technologies to simplify, automate and optimize operations will be at the forefront of transforming the industry to ensure they thrive in such volatile market conditions. Accidents and spills can also threaten an operator's profitability and survival, a reality that is expected to persist as regulatory oversight increases worldwide.

The 'new era of automation' digital initiative is built on the application of different technologies, like robots and drones, and the development of capabilities for autonomous and remote operations. It has the potential to transform how Oil and Gas companies operate. The combination of these technologies and capabilities will greatly facilitate the real time, data driven decision making process – for example, choosing where to drill, planning portfolios, improving well completions or deciding what form of artificial lift can maximize a project's net present value. On an industry-wide basis, leveraging IIoT could connect end-to-end operations across a well's life cycle and ensure that all systems, equipment, sensors and data are communicating and learning from actions across the industry. As a simplistic example, within the upstream sector, connected sensors (wellsite automation) can gather tank level measurements across multiple wellsites, trigger automated relief valves, and request liquid-hauling truck drivers automatically based on the optimal driving route. Currently, robots can only perform a single function and need supervision. Drones are the best example of single-function robots gaining increased popularity with applications in monitoring and inspection of field assets like offshore rigs, pipelines, storage tanks and flare-stacks. However, their adoption is plagued by regulatory issues. A future is envisioned where robots will be able to run multiple operations autonomously and, to a large extent, replace field workers. Together, drones and autonomous robots will help shrink various costs in upstream operations. They are expected to support a 20% reduction in drilling and completion costs (only in shelf and deepwater areas), a 25% reduction in inspection and

Value at stake: New Era of Automation
(All figures cumulative, 2016-2025.)



maintenance costs, and 20% lower employee costs across all areas. Autonomous operations could also help to cut downtime by 20%.
Leveraging remote operation centres (ROCs) to control operations and make decisions in real time (based on data collected from multiple assets), with limited physical presence on well sites, is another key example of how the Oil and Gas industry can benefit from digital transformation. Though not a digital technology in itself, ROC's provide the environment for the combination of technologies and allows for the use of analytics. Engineers within the ROCs will be able to optimize operations and prevent failures by leveraging advanced algorithms to evaluate the impact of multiple decision-making scenarios and selecting the best solution. Especially present today in shelf and deepwater operations, ROCs are limited in scope or capability elsewhere. However, in the future, these ROCs could become much more widely used and more capable. This development is expected to reduce the number of field personnel required, provide enhanced decision-making capability and shift highly skilled talent from fields and platforms to ROCs.

Based solely on the analysis of remote operations, they can shrink the costs associated with fly-in, fly-out workers and reduce the number of jobs for them by about 30,000. These job losses are expected to be partially offset by 20,000 new jobs in ROCs. Remote operations would also allow companies to detect issues early, resulting in increased production. The combined impact from these different benefits is expected to be approximately $140 billion.

Increased automation will also serve to mitigate risk and prevent HSE incidents, especially in remote or inhospitable operating environments, by reducing the number of people required to carry out the most dangerous aspects of fieldwork. As a result, it can improve efficiency and precision, and enhance safety, while maintaining production levels at a fraction of the current cost.

In the Oil and Gas sector, automation has a special relevance when related to the impact of the "big crew change", as the demographic shifts in the industry's global workforce have been described. As a large part of the workforce retires, the next generation of workers taking their place will not have the same depth and breadth of experience, and will also need different skills to succeed in a digital world. In such a scenario, automating industry processes and decisions could also help standardize them. Moreover, a cross-skilled workforce would develop faster because of automation, which would also minimize the time needed to perform previously manual or mechanized tasks.

Case Study: Robotic Drilling Systems – Using a Robotic Drill Floor for Unmanned Operations

Robotic Drilling Systems is developing a fully electric and robotic drill floor for fast, seamless and fully unmanned operation of pipes and tools. The company has collaborated with Energid Technologies and Odfjell Drilling to build and implement this robotic drilling system. When designing it, the company came up with three major innovations: electric drill-floor machines (such as electric roughneck and electric pipe handler, to allow for precise operation), a dynamic robot control system to add flexibility to operations, and a drill-floor robot to replace manual operations. The system can be used on new builds or retrofitted to existing rigs. Early studies indicate potential savings of up to 40 rig days per year per rig. Beyond decreasing rig time, improving HSE and reducing operating costs, a full robotic system provides other benefits, such as less downtime, faster installation, lower noise and energy consumption, and reduced CO_2 emissions.[9]

Advanced analytics and modelling

"In the next generation, technology will be much more robust and leap years ahead of the kind of information that is being collected today. As an example, we will be able to collect and process more information while we drill. A lot of the capability around visualization and modelling will take away a lot of the uncertainty, and bring more reliability. Perhaps as a consequence, companies will be able to deploy capex more efficiently. Similarly, the Internet of Things and convergence of IT and OT will have a big impact."

Archana Deskus, Vice-President and Chief Information Officer, Baker Hughes

In the past, modelling and predictive analytics (developing insights from data to predict trends) have relied mainly on large volumes of structured time-series data and/or previously collected static data. Thanks to advances in and the proliferation of sensors and data capture capabilities across the industry value chain, big data now plays an important role in the oil and gas sector. As a consequence, model-based predictive algorithms, which work well with time-series or static data, cannot fully realize big data's potential because they are less suited to processing diverse data sets that could be in structured or unstructured formats.

In the context of Oil and Gas, it is possible to quickly and automatically produce analytical models (e.g. reservoir models, drilling plans and production profiles) that can analyse bigger, more complex data, and deliver faster, more accurate results, even at a very large scale. By building precise models, companies have a better chance of identifying profitable opportunities and/or avoiding unknown risks. Industry applications for machine learning include exploring new energy sources, analysing hydrocarbons in the ground and predicting the failure of refinery sensors. They can also help companies respond to production failures, optimize the parameters of low-rate wells, carry out reservoir interpretation, and streamline oil distribution to make it more efficient and cost-effective. Advanced analytics throw light on new questions, such as how oil producers can combine real-time downhole drilling data with production data from nearby wells to adapt their drilling strategy; how maintenance strategies can be optimized; and when is the best time to replace parts with spares. Deploying advanced analytics allows for real-time operational adjustments and cost reductions to be made. Analytics algorithms will also learn autonomously over time to improve HSE performance.

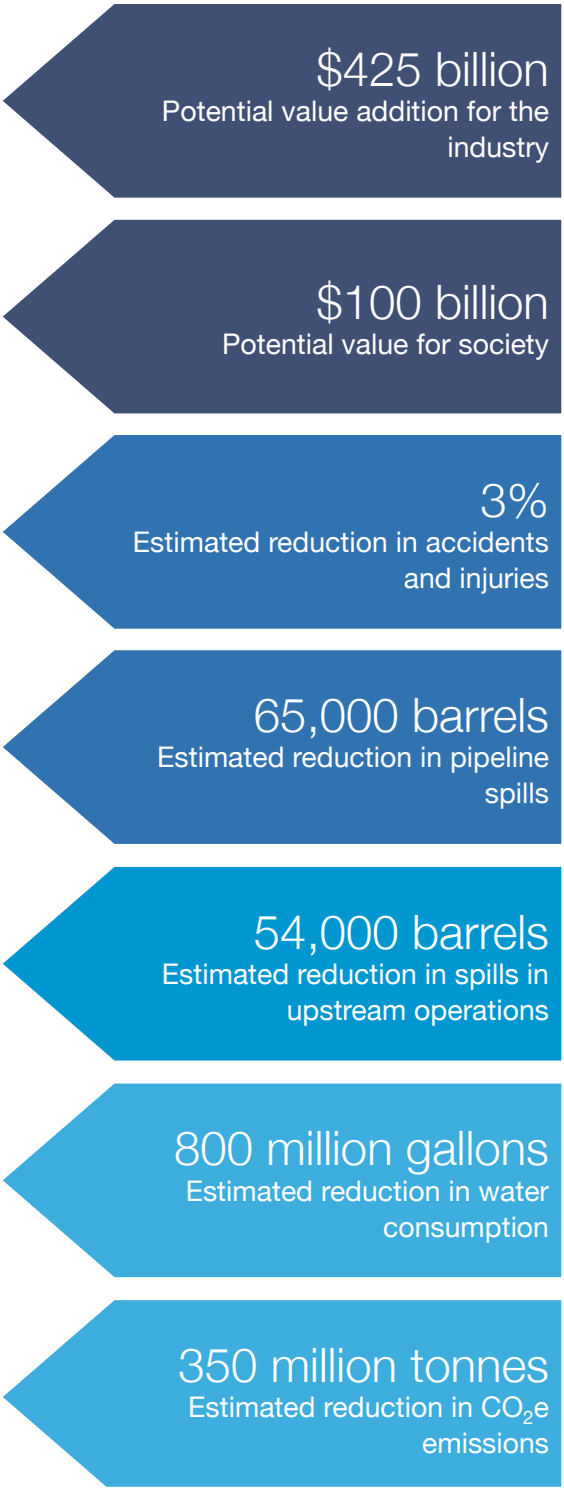
Predictive maintenance is a powerful tool for the industry to reduce costs and boost operational efficiency. While Oil and Gas companies already collect an abundance of real-time data across their operations, this data is still not being used to its fullest potential to predict equipment problems and failures. With exploration venturing into remote areas and hostile environments, equipment inspection has become difficult and expensive. Poor inspection paradigms can lead to unscheduled maintenance, lost time and HSE incidents, all of which carry high monetary and human costs. Predictive maintenance exploits real-time or historical data about equipment usage and maintenance to spot patterns about the performance and reliability of machinery. Ultimately, it creates an optimized, bespoke maintenance programme for each type of equipment.

Optimizing operations to increase efficiency is a counterpart to using predictive maintenance to keep equipment reliable. Technologies such as IIoT have helped the sector move towards optimizing operations in real time, based on data visibility from all assets and processes and drawing on sophisticated, dynamic scenario modelling. More evolved versions of optimized operations can even support the closed-loop control of assets and processes, without requiring people to intervene beyond simple supervisory control.

Case Study: Repsol – Deploying Cognitive Computing in Upstream Operations

Repsol has collaborated with IBM to bring cognitive computing to its upstream business. Currently, although companies spend $200 million to $400 million to drill a single offshore well, only 20 to 25% of wells will be successful because the decision to drill is made with extremely limited information.[10] Cognitive technologies can ingest varied data sets more fluidly and carry out target analysis and simulation, thereby reducing the risk involved with these operations. Repsol has invested in two prototype applications designed to augment its strategic decision-making in optimizing oil reservoir production and acquiring new oilfields. The cognitive technology helps to increase Repsol's current Oil and Gas field productivity and minimize exploration risks during searches for new resources.[11] Still under development, the project has a timeline of three years. Repsol, however, expects that by the end of Year 2, it will have a cognitive capability that improves production at its oilfields and, by the end of Year 3, optimizes the acquisition of new oilfields.

Value at stake: Advanced Analytics and Modelling
(All figures cumulative, 2016-2025.)



Case Study: BP – Developing Super-Specialized Sensors to Maximize Reservoir Yields

BP's special sensors, developed to help optimize reservoir yields, are sensitive enough to measure one-billionth of the level of Earth's gravity. The sensors are also small and robust enough to be sent deep into boreholes, where they can distinguish oil from water. BP has developed a partnership with Silicon Microgravity to manufacture and deploy these sensors. Using new, patented borehole microgravity-logging technology, the sensors help reservoir engineers mitigate the potentially damaging results of water reaching a production well, and so improve oilfield reservoir surveillance. Silicon Microgravity estimates that these sensors could improve yields of conventional reservoirs by up to 2%.[12]

Value-at-stake impact

Predictive maintenance and the optimization of operations both rely fundamentally on data gathered by sensors, and utilize advanced analytics to provide enhanced insights. The insights can be used to process and analyse data rapidly, improve agility and support real-time decision-making and execution. These innovations, with their potential to unlock more value for the industry than any of the other initiatives quantified, create a win-win situation for the Oil and Gas industry, wider society and the environment. Predictive maintenance and operations optimization encompass a range of technologies and tools. In upstream operations, these include reservoir modelling, well-design optimization, artificial-lift optimization, downhole monitoring, connected rigs and predictive analytics. Their combined impact can be significant in reducing operational costs and increasing production.
These efforts can reduce upstream operations' finding and development costs by 5% and maintenance costs by 20%; they can also lower the cost of overtime paid to field employees by 20%, and cut material costs by 10%. Predictive analytics are expected to reduce downtime by 5% and inventory levels for spare parts by 20%. The initiative would also boost production by a conservative 3% in conventional land operations, and by 1% in other asset classes.

Case Study: Apache – Using Predictive Maintenance to Anticipate Critical Equipment Failures

Apache Corporation, a US-based independent Oil and Gas company, is using predictive analytics to anticipate failure of critical pumping equipment, such as electronic submersible pumps (ESPs). The firm has tied up with Ayata, a company spun out of a research laboratory, to implement this solution. ESPs have been a source of operational challenges, and ESP failure had been causing losses of 10,000 barrels a day for Apache. To tackle these issues, a collaborative industry database (Electric Submersible Pump-Reliability Information and Failure Tracking System, or ESP-RIFTS) was set up to document and quantify the locations and operating conditions of more than 100,000 pumps. Apache looked at this data and identified 40 actionable variables to improve its ESPs. The result was reduced production losses and increased output, thanks to higher overall equipment uptime.[13]

Case Study: Columbia Pipeline Group – Pioneering Intelligent Pipeline Technology

The Columbia Pipeline Group partnered with Accenture and GE to develop intelligent pipeline technology for its natural-gas transmission pipelines. The solution integrates data from multiple sources, including geographic information, work management systems, control centres, one-call systems and external sources, such as the National Oceanic and Atmospheric Administration and the United States Geological Survey. The intelligent technology allows users to examine data in different ways to quickly locate areas of interest and evaluate threats and responses. It will help pipeline operators prioritize where resources are best applied to minimize the potential for unforeseen events. The tool currently provides Columbia with "an enterprise-wide, near real-time view of their more than 15,000 miles of interstate pipelines, including monitoring of pipeline threats, improving risk management and providing situational awareness".[14]

This initiative is predicted to reduce CO_2e emissions by approximately 350 million tonnes, and emissions of sulphur dioxide and mono-nitrogen oxides by a further 0.15 million and 0.2 million tonnes, respectively. Another environmental benefit of predictive analytics would be its role in reducing oil spills by 54,000 barrels in production and 65,000 barrels in transportation. Finally, these technologies should enable the industry to lower its water consumption, especially in light tight oil operations, with an estimated total reduction of 800 million gallons of water achievable by 2025.

Connected worker

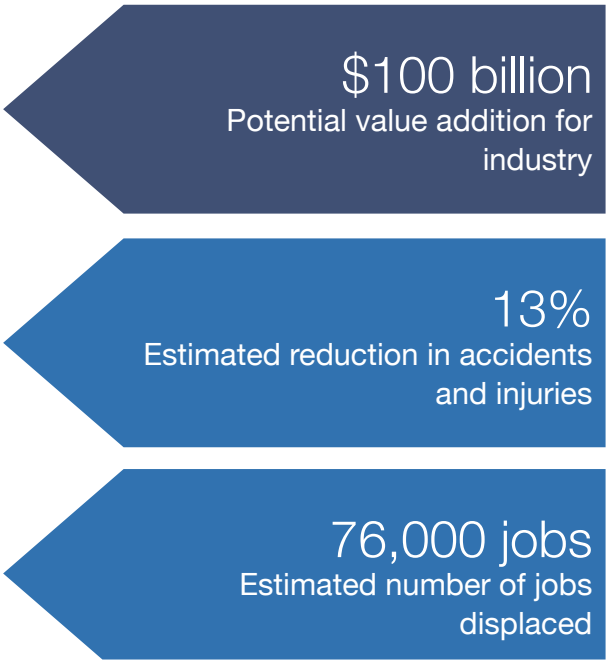
"A human in the middle of the digital environment is still using age-old technologies like walkie-talkies. We need to digitize the human. Digitalization is not about removing people but about making operations safer and efficient. It will create new jobs but will change the type of jobs ... Digitalization will enable safe, efficient, reliable and affordable access to energy."

Michael Lefenfeld, President and Chief Executive Officer, SiGNa Chemistry

Wireless sensors and personal monitoring systems that indicate when a worker is being exposed to unhealthy doses of hazardous substances already exist, and have continued to evolve and improve for several decades. However, one of the biggest challenges for the Oil and Gas industry is to create and adopt a technology that could process as much of the data from these monitoring systems as possible in equipment carried by the worker – a concept known as "at the edge of the internet". "Connected workers" are employees who not only are empowered with wearables, smartphones or connected products, but also are able to fully exploit the data these devices produce to carry out their jobs as safely and efficiently as possible.

Providing workers with on-demand, real-time push and pull information through mobility apps and wearable

Value at stake: Connected Worker
(All figures cumulative, 2016-2025.)



technology can fundamentally change how work is done in the industry. Connected workers with access to the right information at the right time can make more proactive decisions, improving productivity and reducing costs.

By 2025, connected workers in upstream operations, who benefit from improved safety in the field and have access to information on demand, could be up to 15% more productive than their non-connected counterparts (through the use of wearables and the availability of enhanced training at virtual-reality centres). Downstream operators are also expected to see a potential 15% improvement in employee productivity. In the analysis done for this White Paper, this initiative is predicted to potentially unlock an additional $40 billion in value within the industry's downstream sector, but also lead to the displacement of 44,000 downstream jobs.

The Oil and Gas industry entails risky activities, as evidenced by its 18 fatalities and approximately 1,600 injuries in 2014 alone. Against this backdrop, the potential for connected worker technologies to improve safety is particularly relevant.

Case Study: Schlumberger – Piloting Wearables To Improve Field Safety and Productivity

Schlumberger is piloting the use of wearables based on Google Glass to improve the safety and productivity of its field employees. The company has partnered with Parsable to create customized smart glasses that provide real-time information to workers. The solution will be part of a workflow management tool for oilfield workers, and will convey real-time metrics about worker performance to management. The glasses provide information on live gauge readings, inspection and safety checklists, inventory checks and step-by-step procedure videos. They also

help management optimize workflow by logging the time taken for each step as soon as it is completed. The glasses can help workers save time on routine tasks, such as completing checklists in the field.[15]

Case Study: Shell – Deploying Industrial Mobility Tools to Boost Worker Safety

To improve safety, Shell provides its fieldworkers with industrial mobility tools. It has created multiple "personas" of the connected worker, which are used to customize the tools to an employee's role. These tools help ensure that workers are properly trained and have access to the right information at the right time, boosting their confidence to operate in the field. Shell has partnered with Petroleum Development Oman and collaborated in the bigger ecosystem to build an industrial mobility platform, which has made fieldworkers 20% more efficient.

b. Circular collaborative ecosystem

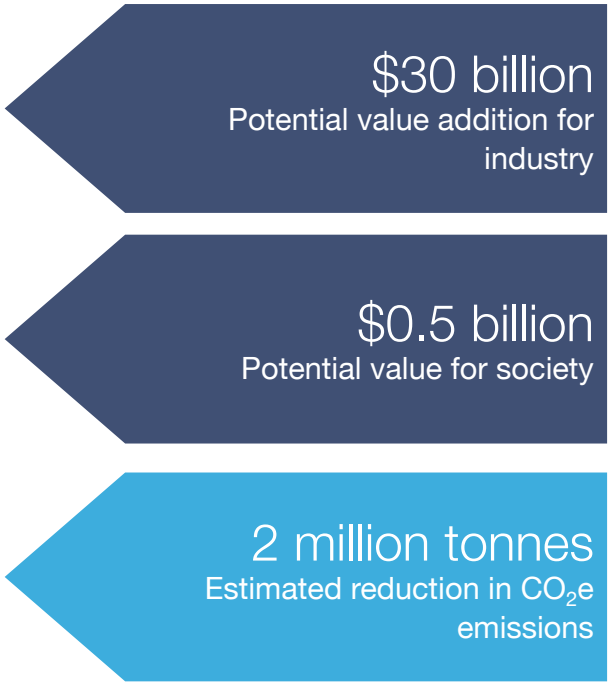
Integrated digital platforms can enhance collaboration among participants in the Oil and Gas ecosystem, while also accelerating innovation, reducing costs and making operations transparent.

Continuous innovation has always been fundamental to the Oil and Gas industry, but digitalization opens up the possibility of collaborative innovation. Digital platforms allow Oil and Gas companies to connect better with their vendors, customers and wider society. By creating a "top layer" of information-sharing across the industry, ecosystem participants will be able to collaborate in more advanced ways. For example, "communities of interest" within the ecosystem can work together to improve designs and innovate faster, from idea generation to production of mutually beneficial projects. Initiatives of this kind pave the way for secure and transparent operations, enhanced service partnerships, proactive engagement, optimized real-time supply and demand balancing, as well as reduced costs.

Case Study: North Sea Oil and Gas Companies – Reducing Lead Times and Inventory Costs through Collaboration

Spurred by the huge fall and continued dip in oil prices, Oil and Gas producers in the North Sea have collaborated to establish a shared online trading platform for managing tools and spare parts. They have set up a pool of spares, ranging from nuts and screws to valves and compressors, and have catalogued and stored more than 200,000 parts in warehouses in Aberdeen, Scotland. Managed through a common platform set up by Ampelius Trading, the collaborative model has helped companies to reduce lead times and inventory costs for spare parts. The project has been promoted by the industry-led Efficiency Task Force, set up by Oil and Gas UK in September 2015.[16]

Value at stake: Real-time Supply / Demand Balancing: 3D Printing
(All figures cumulative, 2016-2025.)



Underscoring the benefit of having common digital platforms across the industry, two initiatives are fundamentally changing how Oil and Gas operators engage with the broader ecosystem: real-time supply/demand balancing (through 3D printing technology), and digital information sharing and operational transparency (using blockchain technology).

Real-time supply/demand balancing through 3D printing

Additive manufacturing, or 3D printing, refers to a computer-assisted process that creates three-dimensional objects by depositing successive layers of material. Objects can be of almost any shape and are produced from digital 3D models or other electronic data sources. From printing human body parts to food, the applications of 3D printing are varied. It has now reached an inflection point, edging into mainstream manufacturing. Driving this trend is the convergence of increased technological sophistication, lower equipment costs and a rapidly growing range of 3D-printable materials.

In the not-so-distant future, 3D printers could transform a supply chain into one that is globally connected, yet still totally local. In essence, 3D printing creates a close relationship between design, engineering, marketing and manufacturing, opening up the possibility of shifting some manufacturing away from low-wage countries and closer to the customer base in developed economies. This would allow companies to respond more quickly, but could also have an impact on Oil and Gas operators. As the industry's operations grow in technical complexity and size, demand for replacement parts at remote production sites increases.

The conventional approach to supplying these parts – shipping them from a centralized warehouse – can take several days and generate tremendous expenses (up to $1 million a day during drilling, and up to $300,000 a day once drilling is completed). This technology could bring great benefits to the Oil and Gas industry:

- In the upstream segment, the clearest benefits of 3D printing relate to optimizing and compressing supply chain operations: changing the point of manufacture, reducing inventory costs, minimizing delivery lead times and significantly reducing costly downtime by enabling on-demand, on-site production of machine components. Further collaboration with vendors could lead to the exchange of digital blueprints, allowing operators to print replacement parts on-site and reduce downtime costs. It would also help prevent obsolescence by allowing for instant printing of parts no longer in production, thus improving profitability of upstream assets. Prototyping would deliver major benefits to capital projects by shortening the development and retooling process, so that more accurate designs could be created more quickly.
- 3D printing of spare parts, as and when required, will reduce inventory levels by an estimated 2%, and the cost of repairs, maintenance and transporting parts by an estimated 3%. However, a major barrier to adopting 3D printing for this purpose is that companies do not want to be liable for potential part failures, and require warranties on their parts. Another inhibitor is that specialized materials are often required for these parts, making it difficult to produce them via 3D printing.
- In the downstream segment, 3D printing can create new revenue streams and disrupt new markets. Oil and Gas companies are ideally positioned to supply the chemical powders and plastics used as "ink" by 3D printers. As the technology becomes more widely adopted in the consumer market over the next decade, 3D-printing powders and materials could be sold from gas station forecourts. Companies that move into this space early could dominate the market.
- In midstream operations, it is estimated that companies might be able to print 50% of spare parts, leading to a 15% reduction in repair and maintenance costs.
- Based on the analysis for this White Paper, a major environmental benefit of 3D printing could be the reduction of 2 million tonnes in CO_2e emissions, thanks to the reduced need to transport spare parts to and from remote areas.

Additional applications for 3D printers could alter the supply chain and lead to benefits that include:

- Substantially reduced research and development lead times (in some cases, from days to minutes)
- Faster time to market for new products and equipment
- Quicker fulfilment of operator/customer demand
- Elimination of inventory as transportation and logistics adjust to printing parts on demand

Case Study: Shell – Speeding Up Prototyping with 3D Printing

Shell has used 3D printers to prototype its Stones Oil and Gas station in the Gulf of Mexico – the deepest drilling station in the world. The team used a 3D printer to produce a scaled-down plastic version, including all components, in only four weeks. This version helped the team understand how to improve components before building the real-life buoy in the construction yard, and even helped to work out the most efficient assembly sequence for the buoy. Shell saved $40 million by highlighting design flaws at an early stage. The 3D-printed prototype also showed US authorities exactly how the finished design would function in a rough sea environment, and helped Shell secure government approval.[17]

Digital information sharing and operational transparency through blockchains and smart contracts

"Blockchain technology and smart contracting will not only disrupt the financial sector, but will also automate transactions and deliver more transparency in the Oil and Gas global value chain. As these innovations allow for direct transactions between parties in the value chain, they will be an enabler to lower the costs for all parties."

Eelco Hoekstra, Chairman of the Executive Board and Chief Executive Officer, Royal Vopak

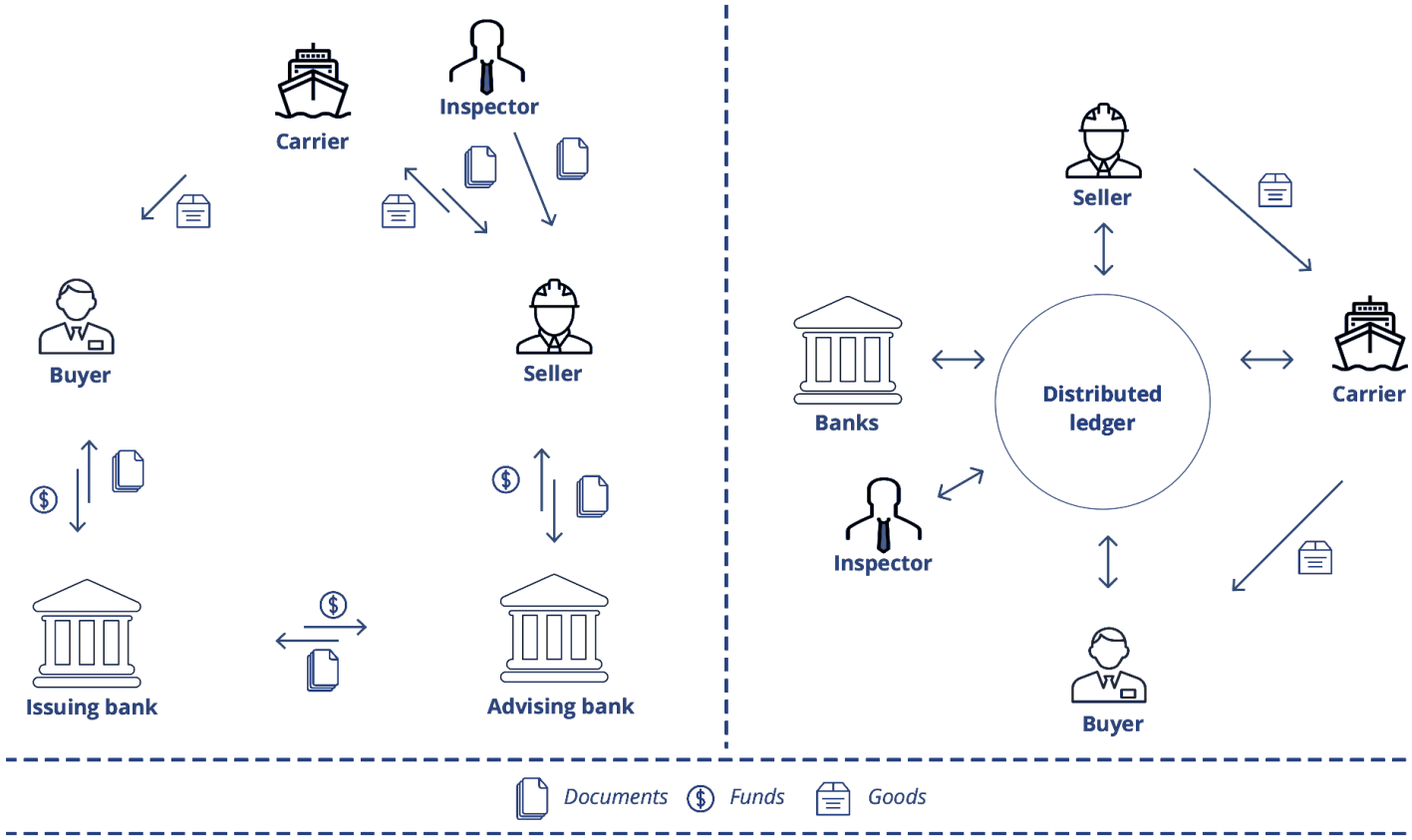
Blockchain is a form of digital triple-entry bookkeeping. It acts as both a database and a network by allowing both data and value to be transferred via a distributed system that runs, records and compares multiple copies of secure, encrypted transactions; it does so in near real time on multiple computers. No single machine contains all the information needed to extract information and value from a transaction. The only way to convince the system to believe a false transfer is to gain control of more than half the devices in the network. Thus, the more devices that run blockchain software, the more secure it becomes.

At present, the development of an oilfield or platform might require the sourcing of thousands of parts from hundreds of suppliers. This complexity can make it hard to track risks and responsibilities, leading to complications in exchanging proprietary data. At the same time, it can also be difficult to track the money flowing through this huge framework of contracts and suppliers, increasing the risk of corruption and resources being siphoned off illegally. Smart contracts are computer programmes for facilitating the negotiation and enforcement of agreements built on blockchain technology. They allow for real-time tracking of contractual obligations and responsibilities, as well as the flow of money around the supply chain. By adding transparency to Oil and Gas operations in this way, they create a "single source of truth" in the industry ecosystem.

Further, because blockchain offers an easy way to transfer information and automatically tracks each transaction, it enables some accounting, finance and compliance

tasks to be automated, reducing operating expenses and the frequency of transactional errors. More broadly, any confidential administrative paperwork can be handled more efficiently and cheaply. Blockchain transactions also lend themselves easily to the cross-border transactions common in the highly globalized Oil and Gas industry. Commodity markets can also benefit by shifting to blockchain payments and reducing the cost of payment transactions.

Figure 7: How Blockchain Can Revolutionize Trade Finance



Source: Mercuria Trading and ING

In-Depth Case Study: ING and Mercuria – Introducing Blockchain into Commodity Trading

''Blockchain has the potential to establish trust along the supply chain, which would reduce the risks and the costs associated with them. There are many useful applications for blockchain, and we believe that we are at the dawn of a new era in the global commodity trading industry. For this reason, Mercuria has chosen to be part of a pilot project led by the Dutch bank, ING. This project aims to improve the efficiency of the still-traditional commodity-trade finance sector by using blockchain technology.''

Marco Dunand, Chief Executive Officer, Mercuria Energy Group

Blockchain, or distributed ledger technology (DLT), is currently attracting increasing interest and investment from a variety of industries.

Commodity trading and finance in the 21st century still rely largely on paper-based processes. Normally, banks are involved in injecting not only this trust, but also liquidity into the system. The practices have adapted to the digital age to some extent, allowing the use of scanned copies of documents where trust levels between parties are high, but this depends on the jurisdiction and the level of risk that parties (including financing banks) are prepared to take with each other. Many parties understand the potential for DLT to digitize commodity trading and financing, and the rate of innovation is high. A challenge for individual companies or start-ups will be to get sufficient traction and critical mass to trigger the virtuous cycle of change. It will require a "coalition of the willing", with key industry players uniting to jointly develop and operate the platform. ING, as a leading trade and commodity finance bank, is taking the initiative to bring together this coalition to coordinate the industry drive and provide the necessary seed investment. The vision includes hosting a distributed ledger platform (see Figure 7), with nodes run by and inside the

participating banks to provide the necessary level of control and data protection. Core functionality will be co-created with market participants, including large trading houses such as Mercuria, which represent large volumes of trade and can help shift the market. The platform must be subject to a broadly trusted and regulated governance structure to prevent market abuse and ensure that no individual parties can obtain a dominant position. The platform will be agnostic to vendors of third-party solutions, and will welcome them to enrich the functionalities.

To validate the many assumptions underlying the vision and the technology solution, ING has teamed up with Mercuria. They run the initiative as a start-up that includes teams in the bank's innovation lab and involves legal experts, industry bodies and other market participants.

The aim now is to validate some of the DLT platform's promises, which include:
- Sellers get their money faster, and buyers get their product sooner
- Fraud, courier, demurrage, performance, operational and credit risks are reduced
- Operational costs can be reduced, e.g. staff, paper handling, couriers
- Financing can be made more secure

The parties are targeting early February 2017 for running several representative trades and financing structures on the DLT.

Value-at-stake impact

Despite this technology's significant potential, the value-at-stake for this initiative was not quantified because the technology is not yet operational in an Oil and Gas industry use case.

c. Beyond the barrel

Innovative engagement models that provide personalized experiences and flexibility for customers can drive new revenues for Oil and Gas operators.
Market volatility, fluctuating fuel prices, the invention of mobile apps for fuel delivery and growing interest in electric cars are all calling into question the future of traditional petrol stations. As conventional fuel retail changes, retailers need to evolve to keep pace with these developments. During the past 25 years, the fuel retailing sector has undergone a major shake-up, with the number of forecourts in the United States declining from 202,800 in 1994 to just 150,000 in 2015.

In the current digitally connected on-demand economy, petrol stations must work harder than ever to attract customers, as price and location have always been more important than brand loyalty. Connected customers are more demanding ones, using their electronic devices to quickly and easily find the best price and most convenient location.

In the future, customers may not refuel at the pump, but charge their electric car while doing their grocery shopping. Those who do continue to purchase fuel for their vehicles may prefer petrol stations that provide services and experiences that go beyond the norm. This shift in customer expectations provides an opportunity for Oil and Gas companies to develop innovative business models that extend "beyond the barrel". These new models eschew a business-as-usual approach to find ways of engaging customers more effectively. For instance, firms could analyse fuel purchasing patterns to develop behavioural marketing and personalized offers. Incumbents will need to innovate in this area, as start-ups are entering the market with disruptive offerings, such as "fuel-on-demand" services.

Digital customer services

Instead of customers driving to petrol stations, digital services, such as hyperlocal mobile fuel offerings, aim to bring the fuel station to the customer. Additional services, including tyre pumps and maintenance check-ups, can be bundled with the mobile fuel station to enhance safety and raise vehicle mileage for customers. While Oil and Gas incumbents have yet to embrace this business model, several start-ups (e.g. WeFuel, Filld, Mobile Fuel, Yoshi) have already begun to operate in this way.

Case Study: Booster Fuels – Providing Mobile Refuelling Services for Employees

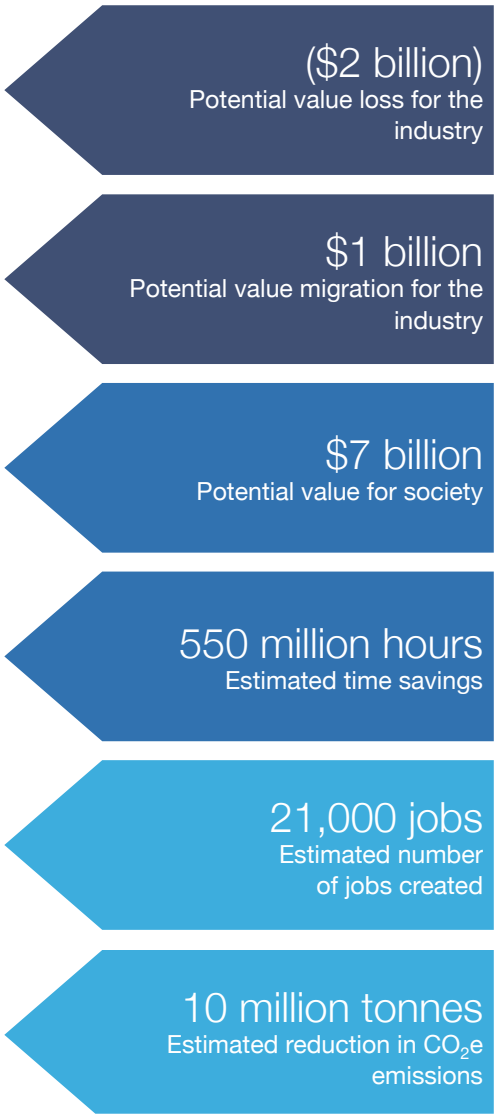
Booster Fuels has a mobile fuel business model that offers corporate programmes, allowing companies to make use of Booster's mobile refuelling services for their employees. The start-up says it eliminates the need for drivers to visit the petrol station. Instead, users can book a refuelling time via Booster Fuels for a tanker to come to them and fill up their cars. Booster is focusing its marketing efforts on attracting clients at corporate campuses, where employees' vehicles can be refuelled while they work. In early 2016, the start-up raised $9 million in funding.[18]

Value-at-stake impact

Digital customer services: Hyperlocal mobile fuel options
"Uber for fuel" – or hyperlocal mobile fuel options – is already here. A few start-ups have begun offering this service for a fixed fee. The fee may take the form of either monthly subscriptions or a charge per delivery. By 2025, it is estimated the hyperlocal fuel delivery channel could capture as much as 3% of the North American business-to-consumer (B2C) fuel market, as well as 1.5% of the Middle Eastern B2C and 2% of the North American business-to-business fuel markets. Only a limited adoption of this service has been considered, as the larger oil marketing companies are not interested in offering it because of potential liabilities from fuel spillage and accidents.

However, even with limited adoption, this initiative could cause approximately $1 billion of profits to migrate from traditional fuel retailers to these start-ups, which try to attract customers by offering free ancillary services, such

Value at stake: Digital Customer Services
(All figures cumulative, 2016-2025.)



as tyre pressure checks. This would further impact the margins of oil marketing companies by reducing demand for these services. Value-at-stake calculations show that fuel retailers would incur a larger loss (of $2 billion) from a reduction in sales at petrol-station convenience stores. Typically, companies earn higher margins on sales of products other than petrol.

Omnichannel retail and experiential services

"[With regard to a new customer engagement model] … You have got people in a place [fuel retail] for five minutes. There is an opportunity for a few things: interact with customers and get to know more about them [connecting with the customer and understanding customer behaviour]; bundle things together and make the experience a little less unpleasant by providing an enhanced convenience retailing experience [personalized experience]; or try other innovative engagement models such as goods and services being delivered."

Ed Daniels, Executive Vice-President, Commercial and New Business Development, Shell

Omnichannel retail aims to capitalize on the time customers spend at petrol stations; it seeks to help fuel retailers learn more about their customers so they can develop personalized offerings. To take advantage of omnichannel opportunities, petrol stations can offer additional services, such as digital banking or allowing customers to pick up parcels bought online. Loyalty programmes can also be used to improve customer retention. At present, convenience stores selling gasoline in the US generate on average approximately 30% of their revenues[19] and 66% of their profits[20] from sales of non-fuel products.

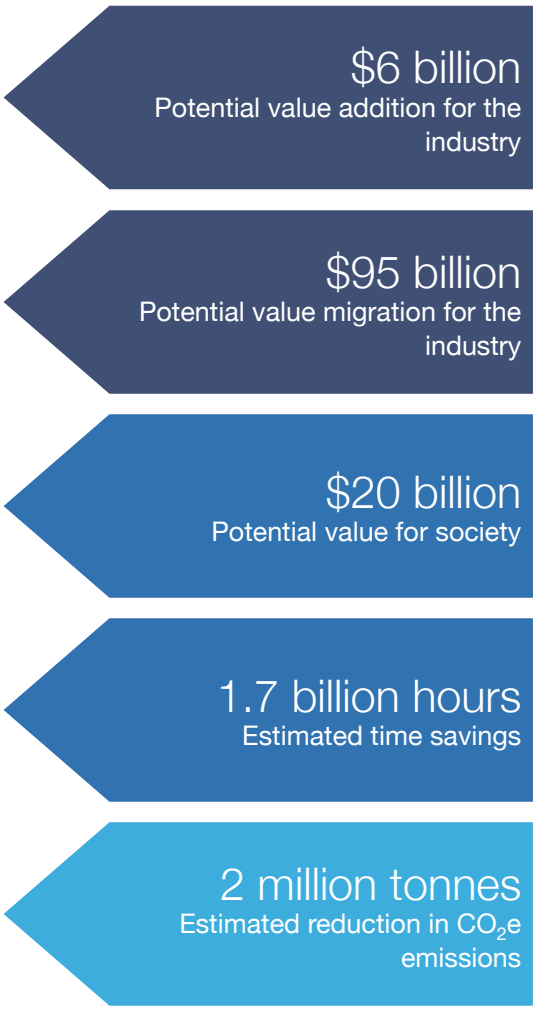
Case Study: Kwik Chek – Making Omnichannel Retail a Success

Kwik Check, a Texas (US)-based convenience store and petrol station chain, has partnered with a mobile commerce solution producer, P97 Networks, to launch Petrozone, a cloud-based application based on Microsoft Azure. Petrozone personalizes customer experiences with the aim of profiting from increased engagement levels and improved loyalty. The app helps customers locate the nearest Kwik Chek, reserve a pump and check the availability of a car wash or other services. Petrol pumps, store point-of-sale terminals and the company's loyalty programme are all connected to Petrozone, allowing customers to pay for fuel directly from their checking accounts. Kwik Chek has also integrated its existing infrastructure with this system, making it easier to track fuel inventory. The app allows the retailer to gain better insights into customer habits and desires, resulting in improved sales and more loyal customers. Users can also opt in to receive discount offers based on their mobile purchase history, and sent to their phones while they are still on-site. As well as enabling better insight into customers' habits and desires, the app has increased in-store sales to formerly fuel-only customers, who save money on things they are likely to buy anyway.[21]

Value-at-stake impact

A series of rapid technological advances have transformed customer expectations by making them fluid across industries and service categories. This shift is fundamentally changing the way Oil and Gas firms need to interact with their customers. Traditional fuel retail is no longer enough; companies will need to provide omnichannel offerings.
The Oil and Gas industry can learn from other industries and implement digital technologies to gain a better understanding of consumer preferences and buying patterns. Likewise, it could optimize pricing structures, and manage logistics and procurement accordingly. Such capabilities are expected to gain significant traction in the future, helping the sector's companies to boost their share of customer spending. Omnichannel allows retailers to bundle new services and tailor offers for every customer, based on their purchase history. Personalized offers are anticipated to cause $95 billion of value to migrate to omnichannel fuel retailers from other stores. Moreover, it is estimated these specialized offers will increase same-store sales by 5% and generate an additional $6 billion for fuel retailers.

Value at stake: Omnichannel Retail and Experiential Services
(All figures cumulative, 2016-2025.)



d. Energizing new energies

Digitalization is promoting new energy sources and carriers, as well as innovative models for optimizing and marketing energy. To remain relevant to customers, the Oil and Gas industry must understand the full impact of these changes on the broader energy system.

Certain trends are accelerating the introduction of new sources and delivery platforms into the global energy system. Four developments in particular have the potential to transform the global energy landscape:

– Electric vehicles are accelerating into a new era with the launch of affordable models, including the Nissan Leaf, Chevrolet Volt and Tesla Model 3. The cost of electric cars is expected to fall further, boosting their popularity. Greater use of electric vehicles is also seen as an important part of the strategy to tackle climate change. At the 2015 United Nations Climate Change Conference in Paris (the 21st Conference of the Parties, or COP21), the United Nations Environment Programme issued a call to action for at least 20% of road transport vehicles to be driven electrically by 2030. This would require an increase in the number of electric cars (including hybrids) on the road from 1 million today to 100 million in 2030. This could result in a reduction in demand for oil by 1.5 million barrels per day.

– The utilities industry has made progress in reducing the cost of power generation from renewable sources. For example, the cost of solar panels has fallen by 26% each time global solar-panel capacity has doubled, and solar capacity has increased sevenfold over the past 15 years. Investment in renewables is expected to reach $7.8 trillion by 2040, dwarfing predicted spending of $2.1 trillion on fossil-fuel projects during the same period.[22] Over the next decade, the average levelized cost of electricity generated from renewable sources, such as solar photovoltaics and onshore wind energy, is expected to come down by 59% and 35%, respectively.[23]

– Demographic shifts in many major economies have led to robust growth in the number of millennials (those born between the early 1980s and early 2000s). Projected to make up 75% of the global workforce by 2025,[24] millennials bring their own expectations to the workplace about technology, collaboration with colleagues, the pace of work and accountability. They are more likely to embrace the sharing economy, with new digital business models providing efficient solutions to transport, accommodation and food delivery, leading to greater use of such assets as shared vehicles. These developments are affecting demand for oil and natural gas. As energy consumers, millennials have different preferences for energy sources than other generations. Start-ups are capitalizing on these trends and offering consumers a choice of sources.

– Energy supply has shifted from monolithic, one-way and centrally-driven supply (from energy producers' large power plants to consumers) to diffuse and bidirectional supply (consumers selling excess energy back to the grid).

Consumer energy choices

"In the developed world, we have an enormous existing infrastructure that performs well; however, the rapid adoption of distributed energy resources introduces new complications in running the system, and doesn't always reduce costs. As we move forward we are going to have to go through a very rigorous process involving redesigning and digitizing the grid to support this transition in order to unlock the full value potential these new technologies offer."

Francis O'Sullivan, Director, Research, MIT Energy Institute

Existing energy delivery infrastructure and platforms are often ill-suited to take advantage of "new energies". Digitalization can drive the evolution of these new energies by offering them to consumers through digital platforms and ecosystems that reshape customer experiences and expectations. The future will not be about a single type of energy, solution or service. Rather, energy consumers will have a range of platforms to choose from: data and information platforms, home-management platforms, energy aggregators, energy marketplaces, energy optimizers, customer service platforms and digital transaction processors.

Oil and Gas companies can position themselves at the leading edge of digital transformation by partnering with their B2B customers to develop these platforms, and by engaging with the end consumers "beyond the meter". Companies can optimize the energy mix they sell, based on the prevailing market prices of different energy types and on the associated costs of generation and transmission to B2B customers. Oil and Gas firms can grow revenue and profits by granting access to their energy trading platforms to those companies in the industry that may not have had the business need or capability to develop a platform themselves. Offering new energies on innovative digital consumer platforms can lead to transformational change in the operating models of Oil and Gas companies.

Case Study: Tesla – Storing Electricity with Powerwall

Tesla, a US automotive and energy storage company, has launched Powerwall, an automated, compact and simple-to-install domestic battery that stores electricity generated by solar panels at a customer's home during the day and makes it available in the evening. This bridges the time gap between peak solar generation and peak demand, allowing customers to use the energy when they need it most. It also reduces the risk of power outages at the customer's home by acting as a backup supply of electricity. Tesla has also launched Powerpack, a larger version designed for commercial use.[25]

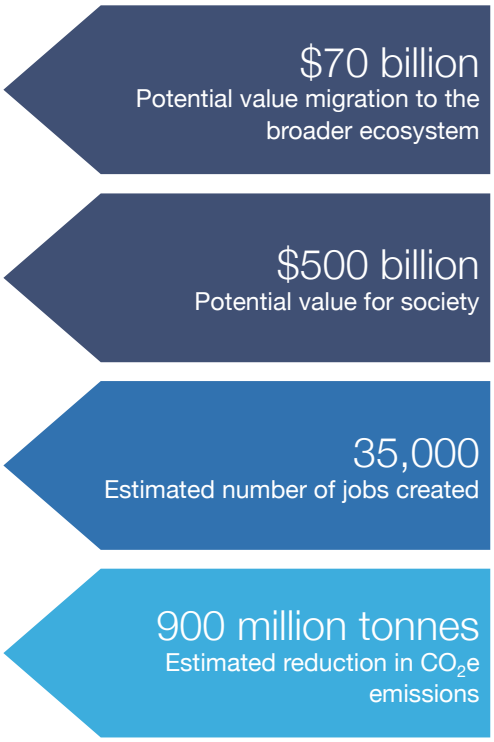
Case Study: Total – Investing in Solar Power and Energy Storage

Total is actively developing alternative energy sources, with a major drive into solar power and energy storage. The $1.4-billion purchase of solar panel maker SunPower in 2011 helped turn the oil company into a major player in solar energy. Its acquisition in 2016 of battery-maker Saft reinforced this shift in strategy by propelling Total into the big league of companies offering solar-plus-storage and distributed-generation technologies.[26]

Case Study: Stem – Making Energy More Efficient for Customers

Stem, a Silicon Valley-based developer, offers a cloud-based energy optimization solution that aims to reduce energy costs for businesses and electricity grid operators. The company's technology combines storage hardware with intelligent software to not only provide capacity at times of peak demand, but also allow for real-time actionable intelligence to manage supply and reduce costs. Stem aims to dramatically improve energy efficiency by using big data and predictive software to understand a customer's energy profile. Energy savings for customers are automated, as the software platform is able to manage energy usage and cost. In the case of facility and plant manager ShoEi Foods, Stem's software was applied to modify its energy profile, helping it to qualify for a more cost-effective rate plan, resulting in estimated savings of $6,000 a month.[27]

Value at stake: Consumer Energy Choices
(All figures cumulative, 2016-2025.)



Value-at-stake impact

Millennials in general are very focused on global issues, such as climate change and air pollution, and are willing to make bold changes, such as switching to eco-friendly energy providers or brands to help tackle these challenges. Approximately 76% of millennials prefer an eco-friendly car, while 50% have plans to purchase an electric car.[28] This preference for electric cars could help in reaching the target of 100 million electric cars by 2030, as set by the Paris Declaration on Electro-Mobility and Climate Change.

This preference for eco-friendly sources is also being followed in the broader energy landscape. A recent Accenture survey found that 56% of millennials are interested in investing in solar panels, and 69% in energy trading marketplaces (which enable peer-to-peer energy trading from distributed energy sources, such as solar PV systems)[29]. This trend is driving start-ups to create platforms that give consumers the freedom to choose their energy source.

This shift to renewables, along with the emergence of electric cars, could lead to profits of $65-$70 billion migrating from Oil and Gas companies to the broader energy ecosystem. Upstream players stand to be most at risk, with approximately $60 billion of their profits potentially migrating to this broader ecosystem. However, this shift is expected to the benefit the environment, with a potential reduction of 900 million tonnes of CO_2e emissions. A positive societal impact will be the creation of approximately 35,000 jobs, as generation from renewables tends to be more people-intensive than that from fossil fuels. Several super majors are already taking steps to mitigate the impact of this trend by investing in green or alternative energy, but this has been excluded from the analysis.

Inhibitors and Key Questions

To unlock the full potential of digital transformation, the Oil and Gas industry needs to tackle a series of historic and structural inhibitors.

Oil and Gas companies face significant barriers to realizing the full value of the digital initiatives discussed in the previous section. These key inhibitors represent a starting point for efforts to overcome the challenges in unlocking the value of digitalization for industry and society.

- **Regulation**
  Data security regulations are no longer fit for purpose. Intellectual-property frameworks have not yet adapted to a new era of data sharing along value chains, in which companies must feel confident that, by dispersing their data, they are not compromising it.
- **Lack of standardization**
  Much of the data coming from sensors is not standardized or integrated across platforms. Moreover, ownership of or access to data between suppliers, operators and contractors is often uncertain. There is a lack of standardization and, even when data is accessible, it is often too complex or large, obscuring any clear insights.
- **Ecosystem**
  For digitalization to deliver all its potential benefits, it must be integrated in an industry from end to end. For Oil and Gas, efficiency, productivity, and health and safety will only be maximized if systems, equipment and sensors from across the industry's value chain are sharing data and learning from one another. As things stand, that "top layer" of information sharing has not been fully realized.
- **Culture and mindset**
  Oil and Gas companies are very people-centric. Because of this – and because some chief executive officers are sceptical about digital – leaders are not prioritizing opportunities to automate. In response to other technologies, many disparate small systems and solutions have cropped up to deal with local problems; and, lower down organizations, employees often use manual workarounds and are distrustful of technology and its proponents. Furthermore, the industry is inherently unable to take more of an experimental, "fail-fast" approach because of its conservative nature and concern about the potential consequences of change.
- **Talent**
  Technology and innovation often fail – not through lack of investment or weakness in the technology, but through a lack of cultural change. Tomorrow's digital worker must be engaged and prepared today. Ahead of the "big crew change", young workers need to be actively pulled into the industry. However, millennials, projected to constitute most of the US workforce by the early 2020s, currently favour working in industries perceived to be "greener" than Oil and Gas.[30]
- **Cybersecurity**
  The scale of cyberattacks by hackers, criminals and governments continues to grow. Companies and their assets will be at increased risk of attack as the Oil and Gas cyber environment expands to include connected computing devices, personnel, equipment infrastructure, applications, services, telecommunications systems, and the totality of transmitted and/or stored information.

Recommendations

Incremental change alone is no longer sufficient to unlock the full potential of digitalization and prepare for the challenges associated with it. The following recommendations serve to help the Oil and Gas industry keep up with – and stay ahead of – digital transformation.

To be fully prepared for the transformative changes ahead, the Oil and Gas industry should consider adapting and, in some cases, revolutionizing established ways of working. The largest pools of value in the future are likely to be driven not just by advanced analytical models, but by the ability of the industry's ecosystem to adopt digitalization rapidly across all aspects of the industry itself, as well as in internal organization, customer experience and innovation. At the same time, the sector should work proactively – and, possibly, more closely than in the past – with both governments and policy-makers at a global level to overcome the key inhibitors to unlocking value for itself and wider society, and to foster a truly multistakeholder approach.

a. Recommendations for the industry

- **Make digital a priority for senior executives: develop a digital strategy roadmap**
  For the industry to be prepared, digital should be on the strategic agendas of Oil and Gas companies, and at the highest level. Digital transformation, like any other significant change, needs to be sponsored from the top. This includes setting a clear vision, committing funding and resources, and actively championing the change-management effort associated with it. The digital strategy that supports overall corporate strategy should ensure that digital is fully integrated into a company's core business. The value-at-stake analysis in this White Paper offers guidance on the relative value that digital initiatives can realize.
- **Drive a culture of innovation and technology adoption: create digitally powered, multidisciplinary teams**
  Leaders direct by example and by instilling a culture of challenging the status quo. Ways of achieving this include creating an open channel for ideas and encouraging new ways of working by using technology to crowdsource ideas from more junior employees. Enhancing a firm's capabilities by establishing more fluid, multidisciplinary teams is vital, and will help it shift away from a rigid hierarchical structure. Some companies are creating a chief digital or data officer, and others are taking a different approach. But, irrespective of the path chosen, it is critical to have clear accountability for delivering the digital agenda.
- **Invest in human capital and development programmes: promote new, digital thinking**
  Lack of talent is often the missing piece in the puzzle of how to translate better insight into tangible strategy. A company can better understand its needs and skill gaps by assessing current personnel capabilities and building a digital strategic workforce plan to address any shortage of skills (e.g. in data analysis or synthesis). A plan to upgrade talent – for example, deciding between organic upskilling of existing staff or hiring externally – could deal with deficits in digital expertise. This could include instructions on how to change current working approaches with a comprehensive set of associated actions.
- **Continue to develop digital capabilities: invest, build, buy or partner**
  Evaluating the investment necessary to digitize the company's core activities and/or capabilities is an important step. Development of a multiyear budget will help balance economic benefits with the financial burden on cash flow in the near and long term.
  To capitalize on the opportunities presented by digitalization, companies could build in-house digital capabilities; form partnerships through corporate venturing; create innovation hubs, accelerators or incubators; or acquire firms with existing digital capabilities.
- **Reform the company's data architecture: optimize use of data platforms**
  Data sits at the heart of digital transformation, so the harmonization, integration and interoperability of data platforms are critical to supporting effective decision-making.
- **Invest in the collaborative ecosystem: use partnerships and platforms that work in the sharing economy.**
  The changing consumer preferences shaped by the sharing economy present potential pitfalls. To sidestep these, industry players could develop collaborative partnerships and invest in sharing-economy platforms. Partnering with peers and competitors to innovate, developing digital capabilities quickly, and leveraging new business models will become core business activities for energy companies.

b. Recommendations for communities, policy-makers and governments

- **Develop global data standards and policies related to data sharing and security**
  This also entails encouraging transparent operations.
- **Foster an ecosystem for innovation**
  In the current, disruptive world, policy-makers and governments also need to drive future prosperity. The onus has shifted onto governments to not only help build the innovation ecosystem, but also innovate within their own organizations to unlock value and meet their constituents' ever-changing and diverse needs.
- **Create clear regulatory frameworks to promote the shift towards the low-carbon economy**
  Promoting a more inclusive society should lead to a related impetus to create a broader reform agenda for greener, more resilient and inclusive growth.

Generating, sharing, analysing and storing data are collectively an important enabler of digital transformation (e.g. in the adoption of IIoT, or in ecosystem collaboration). Governments should ensure that current concerns over data privacy and usage, security and interoperability can be resolved. Today, governments are expected to observe the development of digital technologies and be open to a dialogue with the industry on best practices related to the collection, sharing and use of data.

Finally, the industry, governments and civil society will not maximize the benefits of digitalization to the industry, wider society and the environment if they each act separately on the important topics above. Instead, addressing digital transformation with a multistakeholder approach stands to reap potential gains that have never been greater.

Appendix

Value-at-stake: Methodology overview

Value-at-stake is a framework for assessing the impact of digital transformation initiatives on the industry, customers, society and the environment. It provides a differentiated and evidence-based understanding of the extent of digital transformation's future impact on the industry, and where potential opportunities for value creation exist. It provides likely value estimates of global industry operating profits that are at stake, from 2016 to 2025, and the contribution that digital transformation can make to customers, society and the environment in that time frame.

Industry value

Value-at-stake for the industry comprises two elements: first, the potential impact on the industry's operating profits that will be generated from digital initiatives (value addition); and second, operating profits that will shift between different industry players (value migration). To estimate its impact, the industry was further subdivided into three categories: upstream, midstream and downstream.

1. Upstream: The analysis of upstream has been focused on estimating the impact on a barrel of oil equivalent of production. The analysis has been further divided into the following different oil play areas:

a. Onshore Middle East

b. Shelf

c. Onshore Rest of the World

d. Deep Water

e. Extra Heavy Oil

f. US Light Tight Oil

g. Onshore Russia

h. Oil Sands

2. Midstream: The analysis has been focused on pipeline companies, and the impact has been calculated on operating profits.

3. Downstream: The analysis considered the impact on the refining throughput, as well as the impact that digital could have in increasing throughput or reducing costs.

Value to society

Value-at-stake for society includes three elements: customers, society and the environment. Each element is measured as follows:

1. Value impact for customers: the potential gain to customers (B2C), in cost and time savings as well as discounts
2. Value impact for society: the impact (both financial and non-financial) of digital initiatives on productivity gains, jobs, reduction in injuries and accidents at the work place
3. Value impact on the environment: the impact on emissions (of CO_2e, SO_2, NO_X and CO), as well as on water usage and oil spills

Approach

The value-at-stake has been calculated using a top-down approach involving three key steps:

1. Identifying the total addressable market and the adoption/penetration rates over the next 10 years for each digital initiative, based on secondary research, industry reports, existing use cases and interviews with subject and industry experts
2. Creating of a value tree to represent the different industry and society value categories mentioned above
3. Testing, revising and validating assumptions and results with Accenture experts, DTI working group members and select Industry Partners of the World Economic Forum

Acknowledgements

Interviewees

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Fay Cranmer, Senior Vice-President, Process and Information, Suncor Energy

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Ed Daniels, Executive Vice-President, Commercial and New Business Development, Shell

Archana Deskus, Vice-President and Chief Information Officer, Baker Hughes

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Ahmed Hashmi, Global Head, Upstream Technology, BP

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