WHITE PAPER

Next Level oil, gas and chemicals
Harnessing the power of digitalization to thrive in the ‘new normal’ of low oil prices

Next Level oil, gas and chemicals
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Executive summary

The significant and sustained decline in commodity prices is forcing players throughout the hydrocarbon chain to rethink the way they have historically operated.

Digitalization allows oil, gas or chemical (OGC) companies to get a highly granular view of their assets which, when viewed in conjunction with data from more traditional business systems, can generate quicker and better insights to drive competitive advantage.

Better connected oil fields, pipelines and refineries mean OGC companies are poised to take their performance and productivity to the next level of efficiency, safety and security. Increasingly cost-effective digital technology will facilitate improved monitoring, more collaborative and integrated operations and remote management to drive greater productivity at reduced costs and risk.

However, to benefit significantly from the potential offered, companies will need to embrace digitalization on a bigger, much more holistic scale encompassing end-to-end processes throughout plants across the supply chain – not just in isolated pockets of change.

Network-connected assets, when thoroughly integrated, can significantly improve OGC risk, schedule and costs. Deploying the transformative power of digital, however, will not be easy. As outlined in this white paper, the scope of what is required is immense and technological solutions are evolving at fast pace.

A dramatic, fourth industrial revolution is underway and, unless OGC players embrace the Industrial Internet of Things (IIoT) throughout their organization, they not only risk delivering disappointing shareholder returns now but, longer term could put their companies in serious jeopardy.

OGC leaders need to make the right investments today to set them up for long-term success that can weather the industry's cyclical ups and downs. They need to take a hard look at how they will deploy technology to transform the rulebook by which they, and their customers, manage their operations to reduce costs and drive sustained profitability.

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"We need to think bigger and challenge ourselves by asking questions, such as could the future field developments be unmanned and how fast can all drilling be automated. I believe now is the time to re-invent our business models."

Anders Opedal
Statoil's Chief Operating Officer commenting on ONS session: "The new market reality - Simplification, standardisation and new business models"

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"Significant competitive advantage will fall to OGC companies who are able to develop an end-to-end digitalized ecosystem which delivers timely, manageable data-driven insights to optimize decision-making."

Guido Jouret
Chief Digital Officer

1.0 Oil, gas and chemicals: An industry in transition

Since 2000, international oil prices have been characterized by steep increases and a considerable amount of volatility. During these boom years, the focus was on production – almost at any cost. The oil price crash in late 2014, however, has heralded a heightened interest in cost reduction and production efficiency while maintaining ever higher safety standards.

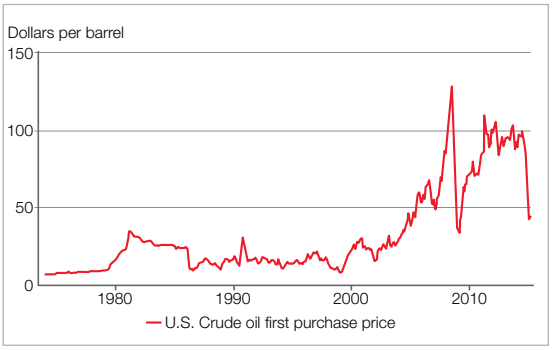

Figure 1. U.S. Crude oil first purchase price. Source: US Energy Information Administration.

To cope, there have been considerable industry layoffs and a dramatic shutdown of rigs across the globe, bringing levels down to those not seen since the turn of the century (See figure 2).

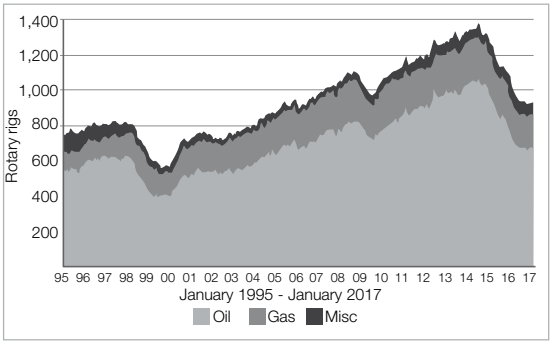

Figure 2. International rig count (excluding US and Canada) January 1995 to January 2017. Source: ©2017 WTRG Economics..

The fall in rig utilization rates, the ratio of working rigs to the number of available ones, has been consistently steep across various types as seen in figure 3.

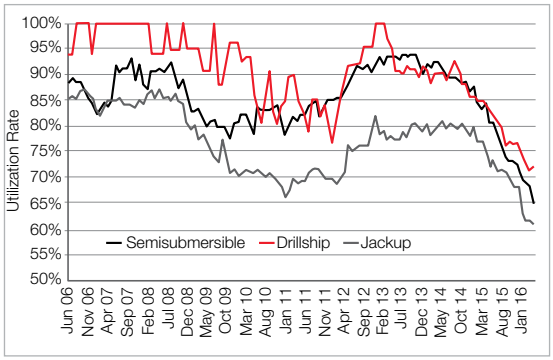

Figure 3. Rig utilization rate. Source: Rigzone.

But are such tried and tested responses to the downturn enough in the modern world? How sustainable is such a model long term, especially as the aging workforce retires and potential new workers may be put off, not only by the isolated location of many rig sites, but also by the industry's pattern of boom and bust?

Strategy& research suggests the performance of upstream, midstream and oilfield services companies (OFS) demands a new approach. For example, while revenues of these companies declined 40 percent between the third quarters of 2014 and 2015, operating expenses (OPEX), only fell nine percent.

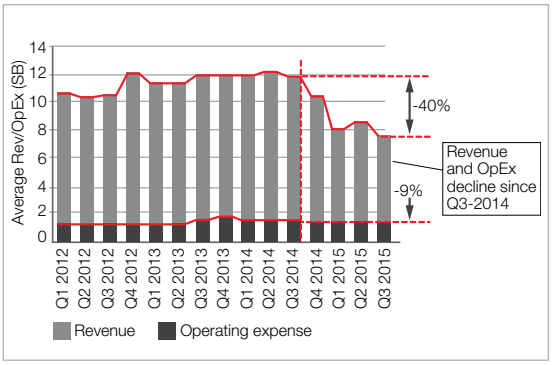

Figure 4. Average quarterly revenue and operating expense of upstream, midstream and OFS companies. Source: Strategy&, part of the PwC network.

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Industry 1.0 – 1712
Mechanical production with the help of steam

—
Industry 2.0 – 1870
Assembly lines with the help of electricity

—
Industry 3.0 – 1969
Further automation with the help of electronics and software-based control

—
Industry 4.0 – today and tomorrow
Smart equipment ecosystems powered by Industrial Internet of Things (IIoT) and enabled by cloud computing

Digitalization offers new options – digital solutions for old problems.
The fourth industrial revolution is set to transform businesses worldwide by making dumb machines smart, using sensors and advanced technology. Over the Internet of Things (IoT), smart assets and systems will communicate and cooperate not only with each other but also with humans in real time to improve performance through the entire value chain.

In this new world, OGC information systems can now create virtual copies of the physical world by enriching digital plant models with sensor data. These smart ecosystems can help human operators by aggregating, visualizing, analyzing and prioritizing big data sets to help people make informed decisions and solve problems quickly.

Increasingly these smart ecosystems are making decisions on their own and performing tasks quite autonomously – only escalating issues for human resolution when necessary (e.g,. conflicting goals, unusual results outside expected parameters).

These smart machines can further help humans by conducting a range of tasks that are unpleasant, exhausting, or dangerous. They will also be self-aware enough to tell operators when they need servicing, triggering maintenance on a just-in-time basis and facilitating near zero downtime.

Essentially, businesses are in the process of creating intelligent networks along the entire value chain that can control each other autonomously freeing up human operators for more value-added activities in safer environments.

From an OGC perspective the fourth industrial revolution is making it easier for companies to keep production going with fewer workers and increased safety – even during tough times.

Remote management, increased automation and cloud-based computing will enable companies to deploy fewer experts across a wider set of assets.

Additionally, machine learning and self-diagnosing equipment will help companies take action – the right action at the right time– significantly reducing operational expenditures while avoiding revenues lost due to unplanned shut-downs.

Extensive data analytics will help optimize daily operations across the hydrocarbon chain from drilling and artificial lifting, routing pipeline output in the most profit-maximizing manner or adjusting manufacturing levels to suit changing end-user demand.

Eventually boundaries between individual rigs, pipelines and factories will no longer exist. Instead, they will be interconnected across multiple sites or even geographical regions scaling production up or down as best suits existing market conditions.

While the transition to a more digitalized OGC environment is exciting, it will not be easy.

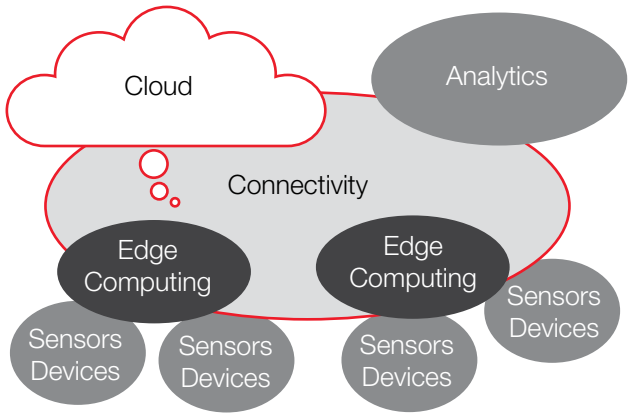
Winners in this new world will be those who turn intention into reality and leverage the opportunity digitalization provides to transform their companies – at a full enterprise level – to become leaner, quicker and safer as well as more responsive to supply- and demand-side conditions.

Those who use the current downturn to re-imagine their complete business and operational processes will be those who will not only survive but also thrive as prices inevitably rebound.

The time has never been better to invest in digital scale and drive better operational results and improve margins now and longer term.

This paper is designed to help provide some guidance along the way.

A model of digitalization



Sensors and devices: the “things” where information originates, such as a pressure or temperature, but also radio frequency identification (RFID) technology that uniquely identifies an object.

Edge computing: Often data needs to be processed at the edge to achieve enough speed or safety, like a compressor anti surge loop, a safety integrity level 2, 3 (SIL) loop or an electronic lock. Edge computing may happen in the device “thing” itself or across multiple things. In process control this is the distributed control system.

Connectivity is what ties the devices, edge and the cloud together across many standards and systems to one homogenous system. It may be integrated with the cloud such as the ABB Ability™ cloud based on Microsoft Azure.

The cloud is the secure but open central repository where all information is stored accessible to users and applications of many types. In other architectures, this was called a “Historian”, a “SCADA Database” or a “Central Database”.

Analytics or **big data** analytics are the many applications that process information in the cloud to deliver information about equipment diagnostics, logistics and inventory, trends and analysis; for example, data such as “this type of motor from manufacturer xx has an excessive failure rate when used for YY” or “use of consumable AA is particularly high on BB so we need to stock up before”

2.0 Four imperatives for OGC to thrive during the fourth industrial revolution

While specific challenges and solutions may vary by segment, we predict four imperatives will distinguish the winners from the losers in OGC's fourth industrial revolution.

2.1 Enterprise-wide digitalization and connectivity

The true benefits of digitalization will only be realized if it spans across the organization – beyond an individual piece of equipment, an individual plant or even an individual country. Winners will have a holistic view of their entire operations. While operators onsite will have more accurate information than ever before, technicians at remote control centers – and managers throughout the organization– will have a similarly clear picture of what is going on.

Machines will communicate with each other to optimize production and reduce risks, escalating issues requiring human intervention to the right individuals at the right time in a prioritized manner.

It will no longer be sufficient to have pockets of machine intelligence in an organization. For maximum results an entire ecosystem of smart equipment and appropriately informed human operators will need to be created. Over time those who take a piece-meal approach will be leapfrogged by those who deploy digitalization throughout the length and breadth of the operation.

That is not to say, however, that an entire organization must be digitalized all at once, however. Unless you are dealing with a greenfield site, this would be extremely difficult and costly. What successful companies will do, however, is have enterprise-wide digitalization as a defined long-term goal with a specific plan of how to get there in stages.

2.1.1 Bringing together information and operational technologies

The fourth industrial revolution provides greater integration visibility and intelligence within and among the operational technology (OT), production control systems and information technology (IT) that manage a company's critical assets, logistics, planning and operations. The result is unprecedented agility in operations as well as to supply and demand fluctuations throughout the hydrocarbon chain.

As IT and OT convergence brings more information from real-time systems into IT software, the following are among the four benefits that will enhance efficiency, responsiveness and profitability across the OGC companies –irrespective of segment:

- Smart production
- Intelligent response to critical asset condition
- Demand-driven planning
- Reduced energy consumption and waste

Yet a major challenge in achieving these goals is a lack of integration between IT and OT systems. A growing number of OGC companies see the single leading benefit of IT/OT data integration as optimizing for cost and efficiency. This directly addresses the challenges of:

- Managing ever increasing costs
- Minimizing schedule overruns
- Mitigating risk
- Optimizing or maximizing production
- Controlling energy expenditure and efficiency

Unfortunately, many companies have little or no data integration across the value chain and still operate in silos, with data not being shared with other departments. Many still rely on spreadsheets combined with human expertise for crucial decision support.

But, things are changing with several companies now taking steps to implement IT/OT data integration. These companies have a consolidated view of production systems and the most advanced can dynamically view and adjust operations across the value chain.

It would appear that a growing number of OGC operators understand that IT and OT cannot operate in silos if they are to continue to deliver good shareholder returns in light of increasingly difficult market realities.

Companies are coming to realize that addressing emerging challenges effectively, means transitioning to an environment which provides remote

asset diagnostics, continuous automation and production optimization made possible through a fully integrated approach to power, automation and telecommunication systems.

2.2 Simplification and standardization
To realize the objective of a fully digitalized organization, processes and equipment must become simplified and standardized. Obviously, simple solutions are easier to replicate than complex ones while standard approaches and equipment are more straightforward and considerably cheaper to monitor, manage, maintain and upgrade.

The need for simplification and standardization is best met by bundled, highly integrated solutions. For example, power, automation and telecommunications projects typically consist of nine packages:

- Motors and drives (medium and low voltage)
- Transformers (liquid-filled and dry-type)
- E-houses / PDCs (switchgear, MCCs etc)
- Substations (air or gas insulated)
- Automation platform
- Power management systems
- Safety systems
- Field telecommunications
- Analyzers and instruments

Historically, nine different bids would be put out for such work and selections which may appear cost competitive when viewed individually often work out more expensive overall.

Bundling the above with one supplier can often reduce direct and indirect costs initially, and for the life of the project, by making it easier to streamline the effort, space and equipment needed. ABB, for example, can deliver 20 to 30 percent CAPEX and OPEX savings in most projects and up to 50 percent in subsea ventures. Much of these savings come from ABB's integration activities across electrical, control, instruments and telecoms (ECIT) technology over more traditional models.

Such an integrated approach can also significantly mitigate risk through the elimination of disparate interfaces and data and by having a single point of accountability.

2.3 Deeper partnerships with suppliers
The scale of changes to come over the next 20 years of digitalization-driven change will be so large and disruptive it will be impossible to go it alone. The need to standardize and simplify explained above means there will be an increasingly symbiotic relationship between customers and vendors in order to extract optimal results across the value-chain. To that end customers will need to carefully select their long term partners. Things to consider will include:

- Breadth of portfolio: Many players exist who are experts in individual areas. The key will be to pick supplier partners who excel in more than one domain and can thus integrate multiple mission-critical elements
- Likelihood of vendor remaining ahead on the technological front: Supplier decisions will be long lasting and far reaching so companies need to have confidence their partner will evolve with the times
- Technical expertise and OGC track record: The more experience the supplier has, the more proven and effective the solutions are likely to be
- Service capabilities and geographic coverage: Every hour of production lost is costly so responsiveness is key

2.4 CEO leadership
The above are unlikely to be present without backing and support from the CEO and his or her executive team. Big calls will need to be made so priorities must be firmly communicated from the top and aligned down the decision chain.

There will likely be tremendous resistance within organizations where people have become used to operating in silos without considering the bigger picture. Digitalization in silos, however, will not provide the cross-asset, cross-functional insights needed to drive results which will transform performance to required levels. An enterprise-wide approach is needed.

Performance packages, for example, may need to be linked to longer term results and priorities than is currently the case – both for employees and suppliers. Too often we see companies focus on initial purchase price without sufficient consideration of ongoing running costs, integration with other systems and ease of upgrading over the full life cycle of a plant, rig or pipeline.

Additionally different parts of the organization find it challenging to communicate with each other as they have chosen, and gotten familiar with, different systems to their colleagues. It will take a clear direction from the top to drive the necessary changes which will make life easier and more profitable in the long run… but which will probably entail a somewhat difficult transition process to get through across non-greenfield sites.

3.0 Challenges facing the oil, gas and chemicals industry

Current market dynamics are being driven by many external market and internal business challenges.

3.1 External market challenges

Low oil prices squeezing margins
The sharp oil price drop in 2014, and expectations that prices will stay lower for longer, have rocked the industry. Reasons for the drop include weak global growth, shifts to alternative energies and considerable spare supply. For example, during the last few years Chinese economic growth slowed considerably and OPEC members consistently overshot their production ceilings to protect their market share, while US oil production from shale extraction nearly doubled versus 2008.

With already heavily indebted OGC companies seeing their market capitalization plummet by over 25 percent in 2014, they operate closer to break-even points than ever before. The situation is particularly difficult for upstream and integrated oil companies in Brazil, Argentina and Canada. Given the historically high prices, companies there began pursuing resources such as pre-salt and oil sands, which are amongst the most expensive to bring to market. Being locked into pursuing these plans, which are hard to start and stop, these companies need to ensure costs are minimized, most likely through technological innovation and better deployment of resources, to survive low-priced oil.

Large capital expenditure (CAPEX) projects have been put on hold as the industry tries to sweat existing assets more effectively until prices eventually recover.

Goldman Sachs sees the difficult investment climate continuing with 30 percent less CAPEX approved on the 420 largest projects over the 2015-16 timeframe as compared to the average for the four preceding years.

Harder to reach conventional deposits
Easily accessible deposits are being rapidly depleted. New reserves are more technically challenging to extract and are located in remote or politically complex regions. Getting to these reserves often means going deeper. As costs rise, so must productivity if firms are to stay profitable. Also, going deeper carries more risk requiring extra safety investment.

Growth in unconventional sources will keep prices low
Shale: Goldman Sachs observes that, if the three main US shale projects continue to improve their output, breakeven points for new wells could fall to $50/bbl by 2020. This means that global demand growth for the next decade could be met entirely by US shale oil and OPEC alone. This could make up to a trillion dollars' worth of production projects uneconomic.

Increased shale production complicates matters further for traditional oil companies since shale investment cycles are much shorter and less capital intensive. From beginning the drilling process to having an operational well only takes two to four months at a cost of only $8 million to $12 million per well. This makes this form of production much more flexible in response to changing market conditions than an offshore project which could take two to five years to produce first oil.

Liquefied natural gas (LNG): BP sees global demand for LNG doubling by 2025 from 250 Mtpa in 2015 to 500 Mtpa which is in keeping with EIA projections predicting five percent growth over the next decade.

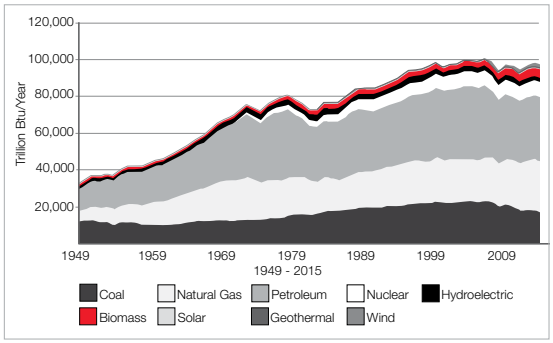


Figure 5. US energy consumption by primary fuel 1949 to 2015. Source: ©2017 WTRG Economics.

Renewables: The current energy mix is 85 percent fossil fuel. Over the next 25 years, its share will probably decrease to 50 percent and be primarily used for transport (ships and trucks). More specifically, there will probably be 50 percent less coal and 20 percent less oil and gas used versus today's levels. The rest of global energy needs will be met from alternative sources such as renewable energy. As a result the future oil price window is likely to be in the $40-$60/bbl range.

Continued strong demand over the long term, particularly in petrochemicals

Even if renewables are added to the energy mix, not only will the shift to these technologies take time to become mainstream but also they cannot replace hydrocarbon's use in a variety of products such as plastic bottles and various types of clothing. Demand for such products is projected to rise particularly as consumers in developing countries begin to exhibit similar spending patterns to their peers in the developed world.

Low ethane prices are also driving significant petrochemical growth in the US according to CB&I, something which is expected to continue as gas-fired contributions to US electric capacity are expected to contribute around 12 gigawatts (GW) per year to the national grid.

3.2 Internal business challenges

The industry is being driven by a plethora of business hurdles including, but not limited to:

- Fragmented communication
- Lack of collaboration between different departments and across the supply chain
- Maximizing aging capital assets
- An aging workforce
- Improving safety
- Energy volatility
- Cybersecurity challenges

The careful integration of technology can help overcome these challenges by increasing visibility, improving communication and eliminating duplication -all of which has a positive impact on the bottom line as well as employee safety and morale.

Challenge	Issues	Benefits of technological approach
3.2.1 Delivering large scale projects on-time, on-budget, on-schedule and with minimized risk	– 64 percent of projects today face cost overruns and 73 percent also report schedule delays – Leading to a significant impact on profitability in terms of actual costs incurred and foregone revenues from projects delivered late – Cost overruns of 20-30% range are common – As many as 30% of loops fail on commissioning due to errors in the engineering process – Primarily in the data from EPCs	– Helps streamline labor intensive activities, reducing opportunity for human error and speeding up schedules – Automated data management, standardization and cloud-based workbenches, for example, can: – Consolidate new project execution activities – Simplify documentation requirements – Reduce engineering man hours – Pave the way for virtual commissioning resulting in fewer on-site changes – Streamline equipment and shrink required footprint – Configurable I/O reduces marshalling and hardwiring significantly, generating large time and cost savings
3.2.2 Improving safety and security through better prevention and quicker ability to address problems effectively	– Dangerous conditions for workers, contractors and visitors, especially in offshore areas – Naturally hazardous environments – Possible accidents with machinery – Potential explosions and oil spills – Unstable, dangerous political environments – OGC operations are also high target areas for thieves and corporate mischief-makers – Pipelines are particularly vulnerable given the vast distances involved	– Cuts downtime, insurance costs and litigation, while improving employee retention, recruitment and morale by reducing injuries and fatalities – Alarm and safety systems identify hazardous situations and help prioritize response – Capturing information from many sources: Test reports, online measurement, shutdown reports, alarms, work permits etc. to see how well and how safe the plant is operating, ensuring critical safety barriers are maintained. – Automated identity and security management programs that centrally track employees' access rights, location, duration, training, safety certification, permissions and compliance to tighten security – Cybersecurity systems and services to ensure asset integrity and performance – Pipeline monitoring for quick leak and theft detection

Challenge	Issues	Benefits of technological approach
3.2.3 Overseeing highly complex operations	– Operations across wide geographic areas – Information overload – Chevron's daily internal IT traffic alone is 1.5 terabytes a day – A single drilling rig can generate 1 terabyte of data per day – BP says petabytes of data now more common – Insufficient visibility of key information – Only 1 percent of information collected is being made available to the key decision-makers – Engineers spend 70 percent of their time looking for and manipulating data	– Visibility possible onsite and from distant, centralized control rooms (e.g., both onshore and offshore, at a facility/plant and company headquarters etc) – With everyone viewing the same real-time data to facilitate effective decision-making – Dumb data is turned into analytic intelligence with the right information being channeled to the right person at the right time in a prioritized manner – Enabling employees to focus on the issues that matter, allowing the smart equipment to take care of the rest – Potentially boosting production by six to ten percent or up to 1.6 million barrels a day
3.2.4 Overcoming disjointed communication and information silos	– Many independent pieces of equipment and systems, each with its own data and interfaces – Hard to share information and expensive to upgrade – A gas company with thousands of wells looking to upgrade its SCADA system to deal with growing information complexity had to pay the new supplier to develop a driver to enable the old system to talk to the new one, at cost of $180,000 per driver per site – Duplicated activities and costs (eg. procurement) – Difficulty making timely, effective decisions to manage disturbances due to lack of common visualization at a field, pipeline and plant level as well as throughout the entire enterprise – Technology has grown in a diverse and chaotic way resulting in fragmented automation where: – Operators and control room staff see different screens and view separate pieces of information – Managers feel they are drowning in data but are unable to find the answers they need – Insufficient real-time information – Over-reliance on operator skill	– Easier information sharing to facilitate better business decisions – Collaborative operations leveraging open standards can help futureproof investments through easier upgrades – Changes how OGC employees view and interact with their operations and markets – Allows greater visibility by integrating information technology with that of operational technology – For example, information from sensors on refinery equipment can empower technicians to optimize decisions by quickly working through robust scenario planning factoring in the different crudes available along with pricing, availability, delivery and inventory information – Throughput maximized given operators can now use technology to juggle many more variables than before – More strategic and better integrated procurement programs – Enables OGC players to be more responsive and flexible – Enhances delivery performance As a result OGC companies can benefit from: – Increased production and revenue – Reduced operations cost and improved margins – Better return on capital employed
3.2.5 Leveraging collaboration across the entire supply chain	– Elements of the supply chain are isolated – Suppliers, customers and partners rarely interact – OGC teams in remote locations hardly ever talk with a central control room – Missed opportunities to develop novel approaches – Insufficient best practice sharing: Reinventing the wheel	– Enhances productivity and performance – Helps resolve common issues more quickly and effectively – Shared knowledge can result in more accurate plans (eg, forecasting) – Potentially builds customer loyalty and may identify new revenue streams – Due to technology, innovation and R&D being shared more easily and frequently throughout the company and with partners, suppliers and customers
3.2.6 Dealing with an aging, difficult-to-replace, workforce	– It is estimated that as much as 50 percent of the oil and gas workforce will retire within the next decade – Transferring their knowledge and experience to the new generation is a challenge, especially as the experts are dispersed – Difficult to retain competent staff to work operations in remote locations – Stagnant recruitment pool and an average of five jobs for every candidate – Newer employees have different attitudes and expectations – The oil and gas industry has an image problem with new recruits – History of layoffs, tough working conditions and perceived as not environmentally friendly	– Knowledge is captured and delivered to the right workers at the right time thereby expediting execution to generate higher productivity and improve margins – Optimizes expertise of global workforces through virtualization, training simulators and remote operations – Promotes an optimized management setup with centralized organization and reduced cost structure via efficient and rapid decision-making – Makes OGC appear an attractive career option for high-tech graduates by demonstrating industry focus on environmentalism and corporate responsibility – Ability to work remotely from less hostile environments could also help recruit more workers

Challenge	Issues	Benefits of technological approach
3.2.7 Managing aging assets to minimize downtime risk and its impact on profitability and workforce safety	– Across North America, Europe and Asia Pacific key assets are already beyond their expected life span – According to an Economic Intelligence Unit report of global process industry executives, three quarters of which were from the OGC industry, 77 percent stated that aging infrastructure impacted operations in terms of time and cost – And oil and gas executives said that roughly 50 percent of maintenance projects in mature oil fields are caused by aging infrastructure – In the US alone, 55 percent of 135,000 miles of pipeline is almost 50 years old meaning there is a high risk for safety incidents – The cost of decommissioning facilities has risen from $18 to $52 million since 2008 – With most operators keen to extend the lifetime of their facilities as much as possible – The operational cost of downtime in an oil and gas facility can be up to $1 million per hour – The reputational damage of major incidents, e.g. spills and explosions, can be significant, and have a dramatic effect on the bottom line – Reactive and time-based maintenance are dominating maintenance strategies – As a result of a fragmented, often manual, approach to asset management – Lack of data acquisition systems and real-time data complicates more proactive strategies – Isolated from other business planning functions	– Reduces time, expense and downtime through real-time condition and health monitoring – Assets are instrumented, interconnected and intelligent, reporting their location, status and other key metrics remotely and automatically – Facilitates preemptive condition monitoring using systems with predictive data modeling to trigger maintenance orders and prevent breakdowns before they happen – Helps determine the optimal way for these assets to behave and interact with each other by providing a view of the entire asset management life cycle – Asset management is integrated with other business functions and systems, such as enterprise resource planning and documentation, thereby enabling better control over costs
3.2.8 Coping with energy volatility	– Increased government regulations globally: – Paris Agreement – Australian Emission Trading Scheme – European Union Emission Trading Scheme – Kyoto Protocol – Manual management of carbon, water, energy and waste with currently little automation or integration – Perception that OGC is environmentally unfriendly – Little or no integration between the processing and power parts of many OGC operations, making it difficult to determine where energy is actually used	– Helps reduce energy expenditure and regulatory costs – Track and monitor carbon, water and fuel from end to end and extend to footprint management, waste management, ecosystem risk management, well closure and re-habitation – Processes, information and analytical tools are used proactively to manage environmental and energy consumables, such as modeling carbon trade-offs, carbon trading, water management, fuel optimization and waste control – Tighter compliance with regulations and reduced costs of meeting/monitoring regulations

By embracing the potential offered by the fourth industrial revolution, companies have the opportunity to change how they do business and leapfrog competitors rather than simply tinker at the edges optimizing things in the way they have always done.

The solution to all these challenges, and thus the future of the OGC industry, lies with the full digitalization of the hydrocarbon chain and the use of knowledge gleaned from connected devices for real-time optimization of processes and operations

4.0 Future vision for the oil, gas and chemical industry

4.1 Accelerated digitalization

As discussed earlier, while digitalization has been gradually making inroads, it has primarily been at an asset level or in pockets throughout an organization split by function and/or geography. Existing market dynamics and challenges are forcing a massive change in the OGC industry's approach to technology. That said, business objectives will remain the same:

- Optimize operations
- Improve reliability
- Generate value through competitive differentiation by streamlining costs, staying on schedule and managing risks effectively.

The way they achieve these objectives is what will change over the next two decades.

Why now?

It is only recently that its potential to revolutionize the OGC industry has become viable due a confluence of factors:

- Companies needing to make cost savings of up to 40 percent to cope with low oil prices
- Sensor prices having declined significantly over the last decade due to the digital device explosion in consumer markets
- Increasing viability of secure, cloud data storage solutions
- Wireless networking technologies capable of delivering up to 1 gigabit per second (Gbps)
- Computer processing power sufficient to handle the petabytes of data being generated.

Accenture estimates that automation, SCADA and internet-enabled devices can lead to production gains of one to four percent in the OGC industry optimizing and remote-controlling equipment, for example by optimizing pump speeds to react more effectively to well conditions.

There is also a rising acceptance of cloud computing in this sector – a trend which will continue provided that service providers and users remain vigilant in data protection. Many of today's business leaders see the benefits of easily adjustable storage as a way of tamping down IT costs as well as facilitating more lucrative interactions with suppliers and customers. For example, at ABB we use cloud computing to work more collaboratively with our customers to bring projects online much faster. The explosion of social media interactions in the consumer sector has helped to normalize the idea of online co-creation with OGC employees.

And, according to a 2015 Accenture survey, 60 percent of the 229 professionals surveyed say they are investing the same or more in digital technologies to improve performance, despite the market downturn. 80 percent expect to continue doing so for the next three to five years and nearly everyone, or 90 percent, agreed that investing in digital technology would increase business efficiency and value.

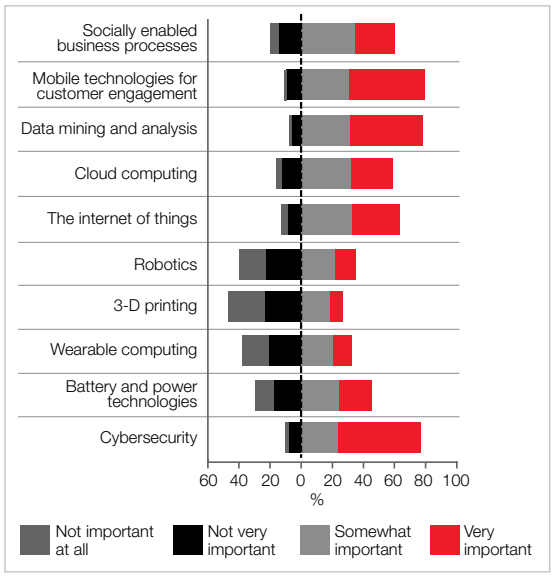


Figure 6. Strategic importance of digital technologies. Source: Strategy&, part of the PwC network.

Indeed, driving digitalization is a high priority for OGC executives. According to a global survey of oil and gas CEOs, 86 percent personally champion the use of digital technology and a similar percentage of US CEOs say that technological advances will transform their businesses over the next five years.

Winners will also be those who take the right steps to ensure that the telemetry data being relied upon to improve decision-making is sufficiently comprehensive and reliable. In our experi-

ence many well sites, for example, still lack a robust and advanced enough communications network, if any, to meet today's digitalization needs –let alone those in the future.

Operators have told us about losses of up to one million dollars per day for shut-ins due to communications problems, often caused by out-of-date technology. Additionally, if there are gaps in the data, decisions taken by engineers will likely be suboptimal and profits will suffer – albeit in a slightly less obvious way.

4.2 Upstream

Digitalization in this sector varies greatly ranging from unmanned, automated, robotic drilling platforms with robotic crawlers inspecting dangerous flare stacks to oil fields where sensors hardly exist and some operations are still paper-based.

A key obstacle to wider digital deployment has been the time it takes for such initiatives to reach maturity and deliver results. And, given the earlier boom in oil prices there was little incentive to make such investments industry-wide.

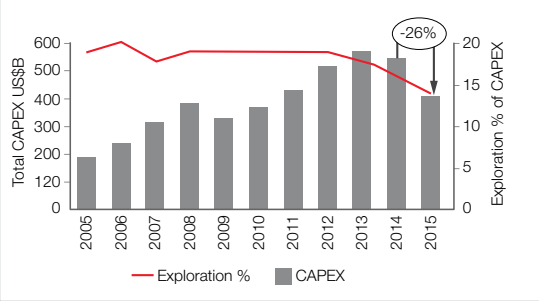


Figure 7. Recent decline in global CAPEX spend on exploration. Source: Strategy&, part of the PwC network.

In an era of low-priced oil and burgeoning unconventional sources, companies are decreasing capital expenditure (CAPEX) in favor of sweating existing assets to do more with less. In exploration, for example, it is estimated that global CAPEX spend on exploration fell 26 percent from 2014 to 2015.

In the short term, upstream players will need to review their megaprojects and seriously consider the benefits of more fully integrated approaches leveraging standard, leaner designs which are easier, cheaper and quicker to deploy in the downturn and quickly replicate when market conditions improve.

To that end, the industry will also continue to explore concurrently new business models which make it easier to deploy more digitalized solutions. For example, newer, smaller players such as Lundin Petroleum or joint ventures such as Aker BP have the scope to develop more disruptive business models. Smaller and more nimble, such operators can more easily explore non-traditional, fully automated production solutions.

The 2016 Upstream Oil and Gas Digital Trends Survey by Accenture and Microsoft, found that:

- 72 percent of the respondents believe cost reduction is an important (27 percent) or the most important (45 percent) challenge digital can help address.
- 36 percent are investing in Big Data and analytics today but only 13 percent feel their company's analytics capabilities are fully mature with almost two thirds of them having an objective to resolve this within three years
- 80 percent plan to invest the same or more in digital technologies over the next three to five years
- With 56 percent planning to use the cloud to enable analytical capabilities in the next three to five years

For sites that are already up and running, the focus will thus be on optimizing processes by analyzing a wide range of data sets to gain enhanced operational insights – a task made significantly more complicated by the increasingly wide range of resources currently available to explore. Traditional on- and off-shore exploration and production are markedly different enterprises compared with subsea, oil sands and shale oil and gas production. Unconventional extraction technologies have improved the viability of non-traditional sources but often bring with them new challenges and higher costs.

In the upstream sector there is considerable potential for equipment and assets to self-optimize and improve production. Some have projected that leveraging the Internet of Things, could save integrated oil and gas companies with an annual production of 270 million barrels more than $500 million in production and lifting costs.

Consider, for example, that a single pump breaking down on an offshore rig can lead to $100,000 to $300,000 per day in lost production, and that large companies typically handle more than 50,000 wells at a time. Predicting failures with smart sensors and control systems and being able to fix issues proactively makes compelling financial sense by maximizing rig uptime.

Leading oil and gas companies have already begun treating drill and production data as key company assets as they realize analyzing big data can help shift focus to their more productive wells resulting in significant revenue growth. Longer term, the offshore industry is likely to be unrecognizable from what it is today, with most of the offshore equipment invisible from above water. Companies are looking to cut costs 30 to

40 percent and this will be extremely difficult, if not impossible, without reconfiguring operations in a spectacular manner. Also, offshore oil fields will be explored beyond the convenient continental shelves currently being developed and running FPSO vessels or non-traditional platforms in waters deeper and more inaccessible than they do today. We will see an increasing number of subsea projects. As a result, life cycles will need to be longer, with lower maintenance and improved efficiencies over current standards.

With entire production lines moved to the seabed, more autonomous, remote-controlled equipment will be deployed and managed by onshore operators taking decisions from miles away based on data from the source with long step-outs. To that end, technological boundaries will need to be stretched to ensure equipment such as transformers, switchgear, motors and variable-speed drives can function well without intervention for up to five years.

Less than a decade ago, being able to step-out 10 kilometers (km) was considered an achievement. The difficulty inherent to long step-out systems means that only some 40 such systems have been successfully installed to date, most within 40 km from shore, and these by a small number of companies.

ABB, however, has mastered the technology that allows long step-out systems beyond 40 km. The Åsgard subsea gas compression project for example has a 47 km long step-out (2 x 15 MVA).

And, under a joint development program with Statoil, Total and Chevron, ABB is developing new subsea power solutions which will able to transmit power (from shore) up to 100 MW over distances up to 600 km and to power equipment at depths of up to 3,000 meters (m). It is anticipated that this solution will be ready for first pilot installations in 2019, enabling operators to extract oil and gas in considerably longer and deeper areas than currently achievable.

4.3 Midstream (i.e., pipelines and storage)

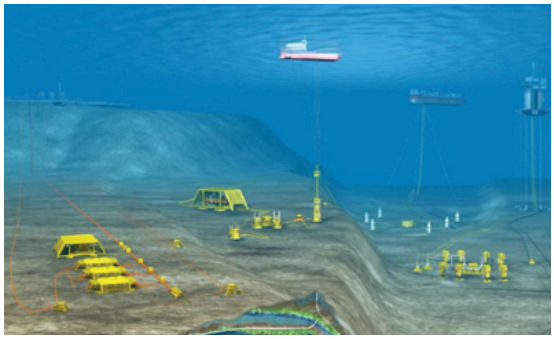
Many midstream operators already deploy a substantial amount of digital components with advanced measurement devices such as electric flow metering and data-intensive pipeline inspection gauges (PIGs). However, there is still room to optimize operations further through the better distillation of the data they currently collect to generate new insights and by gaining additional information through the deployment of drones to conduct pipeline flyovers where regulations permit. Better fleet optimization will also improve through greater use of increasingly sophisticated tracking technology.

Additionally the market environment has changed significantly with the growth in unconventional energy which needs to be transported, particularly in the form of liquid petroleum gas (LPG) and natural gas, from well sites to refineries, processors or storage facilities. Midstream players will need to expand capabilities, or adapt aging infrastructure to track and optimize greater flows of an increasingly complex array of product from and to a variety of new locations.

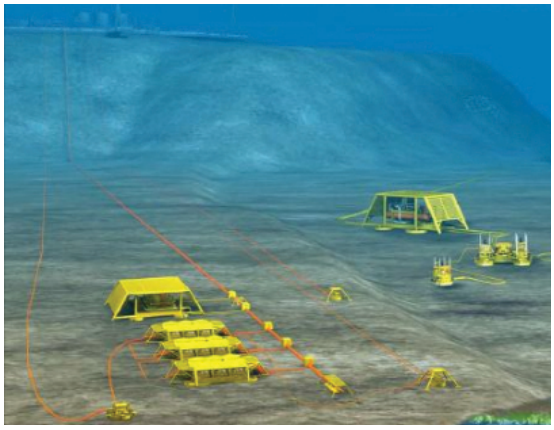
Cloud-based systems, for example, can be used to track and manage thousands of kilometers of pipelines. Machine and sensor data, weather information, geolocation data can be more effectively mined to improve predictability and performance.

Better deployment of technology will help companies use their pipeline data to optimize routes to market and react quicker to changing volumes and fluctuating prices. For example, careful surveillance of electricity market indicators may signal increased future demand for gas. Being able to leverage insights from big data models will help savvy operators steal a march on competitors slower to read the market signals due to an outdated method of forecasting.

On the supply side, it may be that by analyzing flow history and better tracking existing conditions, midstream companies may become better at predicting where and at what pressure



Current situation. (Photo Courtesy of FMC Technologies)



Future state: As above but without FPSOs, offshore rigs etc. (Photo Courtesy of FMC Technologies)

and volume the product to be transported will arrive. Improved forecasting algorithms will mean they can better optimize their configuration plans and increase revenues from their assets.

It will also help with theft protection and leakage detection. The former is a key issue both for financial and safety considerations. Theft from pipelines and other sources, alone, is estimated to cost over $37 billion globally. And, given a tanker can be filled in less than 15 minutes, prompt illegal tap detection through accurate, real-time monitoring, is a useful tool in the battle to keep revenues where they belong.

Detecting and deterring illegal tapping can also save lives as there are many instances where such thefts have led to loss of life. An oil pipeline explosion in San Martin Texmelucan, Mexico in 2010, for example, caused by inept thieves killed 27 people, injured another 52 and destroyed over 115 homes.

Other costly, potentially dangerous risks that the Internet of Things can mitigate are undetected leakages or spills which not only add to operator costs but result in more stringent regulations for everyone else.

As outlined in figure 8, pipelines can fail for a variety of reasons, many of which can be minimized through increased automation and real-time surveillance.

In short, midstream companies will increasingly use advanced analytics to improve profit margins through initiatives such as better pressure monitoring, more efficient transportation fuel cost management, more accurate supply and demand forecasting and a better view of overall operations.

4.4 Downstream, including chemicals

Downstream players, frequently plagued by long periods of low margins, are comparatively more mature in their pursuit of standardized solutions and already have a long track record of using digital technologies to improve performance and manage risk. Already much of this segment's systems are under surveillance via sensors on equipment sending real-time data to control room technicians. They have control loops that adjust themselves and process analytics or simulation capabilities that help employees to make predictions on system changes.

However, sluggish global growth and the highly commoditized market for petroleum products mean downstream companies will need to explore new areas of process optimization and

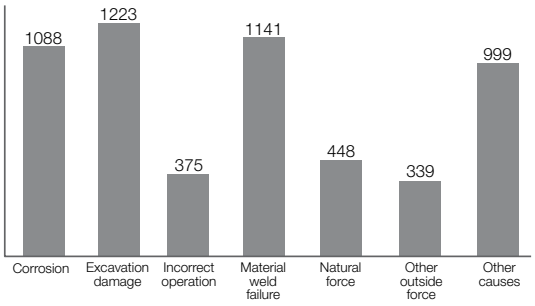


Figure 8. 1994-2013 Significant pipeline incidents. Source: US DOT. Pipeline & Hazardous Materials Safety Administration.

market development. McKinsey estimates that petrochemical producers can increase their return on investment (ROI) by an additional 10 percent through optimizing each element of their operations.

Adding new technology alone on an asset-by-asset basis, however, will not be enough. Not only must it be tied to delivering the key business described above, it must be deployed on a holistic basis in order to realize its full potential. In fact, ABB has proven that by integrating automation, safety and other systems companies can save 20 to 30 percent in CAPEX and OPEX investments.

For example, integration can simplify selection to not only assemble the most efficient equipment mix but also it can reduce the footprint by up to 60 percent meaning less civil work, construction and materials are required. Additionally, projects are more likely to come together more quickly and with less risk.

Of course, once things are up and running, a critical part of managing the bottom line is to ensure refinery downtime is minimized since unplanned refinery shutdowns lead to expensive repairs and foregone revenues from lost production. And yet, such shutdowns remain relatively common.

According to the US Department of Energy, refinery shutdowns from 2009 to 2013 in the US alone averaged 1.3 incidents per day. And, electrical problems accounted for 20.6 percent of these shutdowns with electrical equipment failures and power supply problems leading to over 80 percent of the disruptions.

In addition to power outages, ineffective maintenance practices are hitting refinery profits hard. ARC consultants estimate that suboptimal maintenance procedures cost refiners $60 billion per year globally due to unscheduled downtime.

Strategically integrated systems standardize and streamline the parts involved making ongoing repairs more straightforward and providing for easier upkeep and system expansions. For example, if making updates is a matter of configuration, rather than program, there is significantly less risk of a process disruption.

Another way to minimize downtime is to take advantage of today's availability of inexpensive, non-intrusive sensors, advanced wireless mesh networks and real-time asset-monitoring systems. These make it possible for OGC companies to shift away from a time-based maintenance strategy – which may repair equipment too often or too little – to one which is based on the actual needs of a given piece of equipment. Avoiding unnecessary repairs is not only cheaper, due to its happening less often, but also it minimizes the opportunities for things to go wrong. It is not uncommon for equipment which has been maintained not to be put back to the correct parameters, for example.

Additionally, if your equipment tells you it is likely to break down soon, you have the opportunity to take proactive action before it fails. Not only do you avoid the opportunity costs of an unplanned shutdown but also your repair costs will be cheaper as they will be undertaken on a non-emergency basis.

Why then is predictive asset monitoring not more widespread in the OGC industry? At the moment companies appear to be tracking individual assets; it is much rarer to see plant-wide operations, let alone multi-site tracking. Those companies able to step back and see the bigger picture of enterprise-wide integration will achieve a significant cost advantage over those who stick to more traditional, more narrowly-focused approaches.

In addition to improved maintenance strategies, another way technology can help downstream players generate competitive advantage is by improving their visibility beyond an individual plant or group of refineries into the wider hydrocarbon supply and demand chain. Doing so can yield benefits from a cost-saving and revenue-generating point of view.

For example, technology is making it easier for refiners to optimize their raw material costs. Investing in information systems which give refiners clearer visibility into the complete hydrocarbon supply chain makes it easier to optimize the quantity and quality of crude blends purchased. For example, the level of bitumen and sulfur in cheap crudes can offset any price benefits due to the increased operating and maintenance expenses which may be required. Having sensors on refinery equipment, which enable it to gather information on the trade-offs in processing the different crudes available, combined with pricing, availability, delivery and inventory information empower refiners to optimize purchases by quickly working through robust scenario planning.

Likewise, deeper insights into the end-user needs will help petrochemical manufacturers adjust more nimbly to changing demand patterns.

4.5 Opportunities offered by high fidelity simulation: digital copies of entire plants

Many companies are currently able to use simulators in a low and medium fidelity manner, for example with respect to simulating parts of processes.

ABB, however, is now providing customers with the opportunity to create 1:1 copies of their physical plant in a digital form. This means customers can simulate decisions and know exactly what such actions will deliver if applied for real.

This can be particularly useful in the development phases of a new plant or platform. By being able to simulate the entire electrical side of a plant early on customers can better predict, plan and budget for the required power needs.

4.6 The rising importance of cyber security

While harnessing the IoT has the potential to generate significant competitive advantage for those who deploy it correctly, companies must be even more vigilant than ever before in protecting their assets.

In the pre-digital world, it was easier to see the threats coming as they typically had a physical presence. Now, operations can be disrupted by unseen players from thousands of miles away.

Indeed, as indicated in figure 9, globally, energy sector cyber crime costs are second only to financial services and nearly as high. And, according to the US Department of Homeland Security, of the 245 major cyberattacks reported by asset owners and industry partners in 2014, 32 percent were against the energy sector – topping the list that year. In the equivalent 2015 report energy cyberattacks remained high at 16 percent, second only to critical manufacturing.

Fortunately, solutions exist to protect assets from cyber crime but OGC companies will need to ensure their assets are protected correctly from the very start and are vigilant on an ongoing basis. This may sound obvious but it is not uncommon for us to find, when we conduct cybersecurity reviews for clients, that their protection software, particularly in the area of process control, is not up to date.
Also, in many cases, cybersecurity measures have been bolted on after the fact which can provide potential cracks for attacks to wedge their way through.

Recognizing such risks early on, ABB, for example, has for many years built cybersecurity into its systems, conforming to draft rules and standards long before such regulation became official.
Many other players are now playing catch up. In fact, a recent cybsecurity analysis by Shell identified ABB systems as being head of the curve in this area.

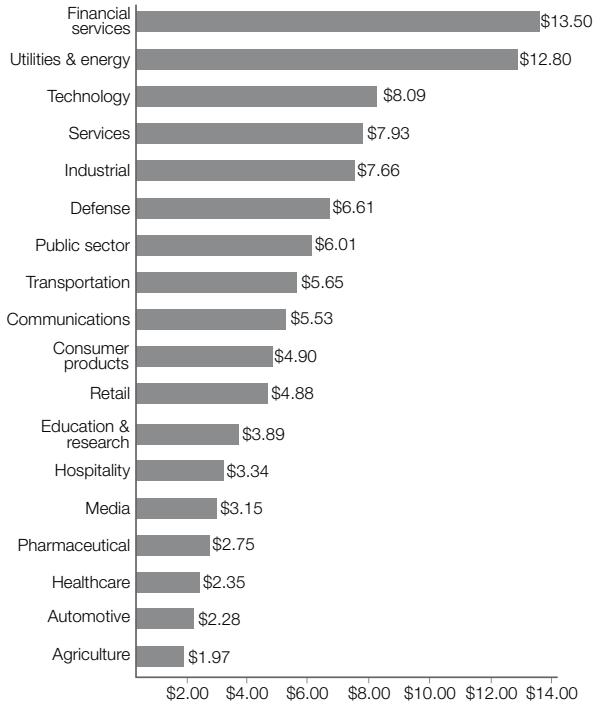


Figure 9. Average annualized cost of cyber crime by industry sector. Source: Ponemon Institute, 2015 Cost of Cyber Crime Study, September 2015.

5.0 The digitalized hydrocarbon chain 2

5.1 An optimized operation from well to market
Digitalization can be described as smart devices speaking directly to each other, object-to-object, with little, if any, human intervention. In the OGC industry this can manifest itself as measuring devices, sensors and actuators embedded in items, such as drills, wellheads, pipelines, compressors and tanks, that exchange information in real-time.

Telecommunications networks, increasingly wireless and leveraging cloud-computing options, connect the various elements and help to run the data through a range of applications. They can also highlight issues for human consideration, before taking actions calculated to optimize performance.

Data can thus be processed in real-time with applications monitoring and controlling production processes by performing predictive analyses, automating decision-making and reacting to alarms. Control room technicians can oversee and interact with a virtual representation of the field, pipeline or plant – onsite or remotely – intervening when required.

Today, integration across upstream, midstream and downstream is limited, except for a handful of large players.

Each segment operates as its own silo. A common term for this in OGC and other industries is “islands of automation”. And, even within each segment there are further islands of automation within and across production sites, as discussed earlier.

The challenge is to optimize the whole value chain, so that there is a comprehensive and unified view of production, from oil and gas extraction to transporting, storing, compressing or refining, processing, and delivering to market.

Digitalization will help close the gaps in the value chain. The integration of IT and OT coupled with cloud computing and the IoT, will make it possible, practical and, eventually, imperative to streamline operations throughout segments and even along the full hydrocarbon chain.
Automating every part of the value chain brings significant benefits including:

- Higher productivity, enhanced collaboration
- Holistic commercial view of the whole enterprise
- Increased energy efficiency
- Improved safety

The future of OGC lies in bringing equipment, systems and people together so that they talk the same language and are integrated into one system where all information is available. While local control rooms may still exist, the trend is towards centralized, often remotely controlled, operations.

With modern control room designs, people with different roles can work together in the same environment. Barriers are torn down, control rooms are consolidated and experts can collaborate in one place.

This creates a safe, reliable and predictable production process with better visibility from wellhead to pipeline, compressor, refinery and petrochemical plant.

The result is an optimized operation from well to market.

5.2 ABB’s enabling approach and technologies
For over five decades ABB has been at the forefront of equipping OGC companies across the hydrocarbon chain with a wide range of technologies to support some of the world’s largest and most challenging projects including:

- Power for the world’s first subsea compression system, Åsgard, which set a world record for distance, voltage and frequency between topside drive and seabed compressor
- Motors, drills, drives and telecommunications on the largest float-out ever built, ExxonMobil Hebron, Canada
- Power and automation for the Maersk and Statoil Peregrino FPSO – one of the world’s largest and most complex FPSOs
- PMS, electricals and analyzers for Shell Pearl, the world’s largest gas to liquids facility
- Automation, electrification and telecoms for the world’s first coal seam gas to LNG plant and its associated pipelines – Queensland Gas Company (QGC)

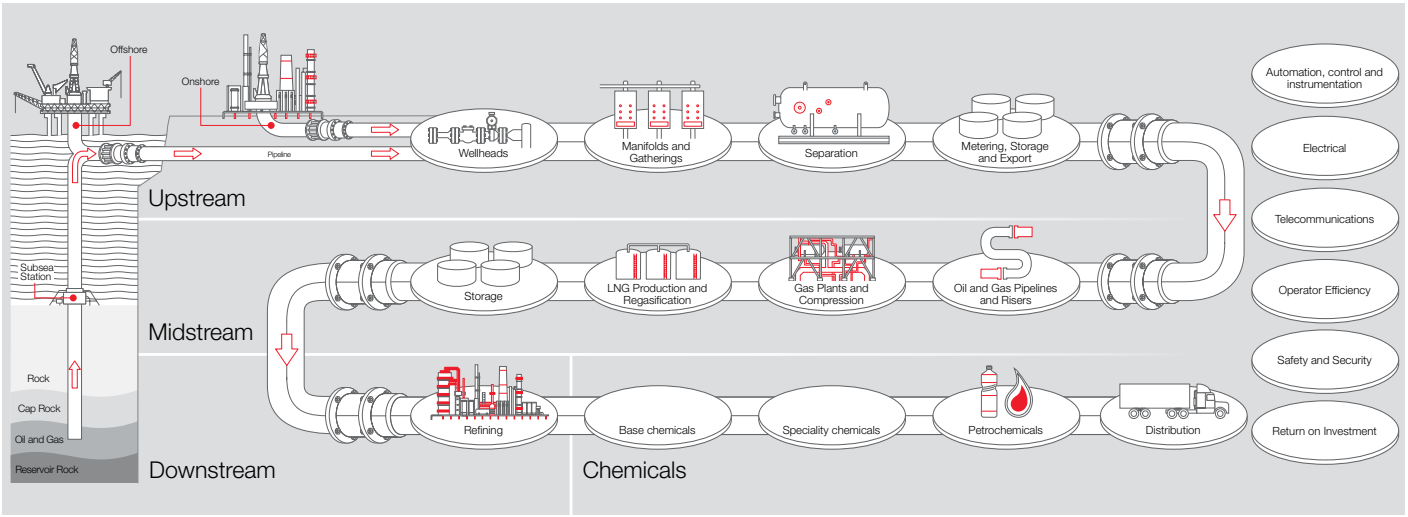


ABB offers a digital solution for every aspect of the hydrocarbon value chain.

- Power and automation for the world's largest chemical cellulose plant – Sappi Saiccor
- Automation and instrumentation for the world's largest chemical complex ever built in a single phase with over 50 production lines – Dow and Saudi Aramco Sadara project

With an installed base of more than 70 million connected devices and more than 70,000 digital control systems across a range of industries, and its deep understanding of the OGC industry in particular, ABB makes it possible to understand and optimize industrial processes like never before.

ABB is an expert in developing and enhancing process control systems, communications solutions, sensors and software for the industrial IoT, helping OGC companies to exploit fully the promise of the fourth industrial revolution.
Only when things, services and people are in sync will real change occur – all three matter and ABB has a proven track record of bringing these elements together seamlessly.

ABB's proven approach and technological capabilities help OGC customers analyze data more intelligently, optimize their operations, boost productivity and enhance profitability while reducing risks to schedule and safety across their entire operations.

And, knowing just how critical it is for the right people to have the right information at the right time, ABB has gone a step further for customers by partnering with Microsoft to develop one of the world's largest industrial cloud platforms. This partnership will give customers new insights to empower faster, more astute decision making.

Collaborative operations: A proven four-angled approach to cut costs, reduce schedules and minimize risk through properly integrated digitalization

ABB's collaborative operations approach addresses the need to use big data and data analytics to realize the potential of the industrial internet of things. We consolidate data to manageable levels whereby people can take decisions, helping to improve coordination between functional silos by providing greater visibility and real-time system integration.

Collaborative operations is made up of four key elements:

- **Intelligent engineering:** An integrated approach which covers the processes, tools and standards that take project execution from a traditional multi-vendor approach to one which streamlines the equipment to reduce human error, risks, labor and CAPEX costs. It also provides single-source accountability for extra peace of mind and shortens completion time. This project delivery model goes beyond traditional approaches to deliver extra value in large projects.

- **Intelligent infrastructure:** Having an intelligent infrastructure which seamlessly integrates process control, safety, power, automation, telecoms and electrification systems into one collaborative system is the backbone of many operations. By optimizing how machines, applications and people communicate ABB, when used a single-source supplier, has proven that companies can significantly reduce CAPEX and OPEX expenditures while simultaneously improving production.

- **Intelligent applications:** Are software and system components that help improve efficiencies and optimize performance across the enterprise. They ensure the intelligent infrastructure reaches its full potential to deliver sustainable profitability. To that end ABB offers a suite of applications designed to enhance day-to-day equipment efficiency, promote safe and secure

production and make it easy to access expert guidance whenever and wherever required.

- **Intelligent services:** Minimize downtime and improve employee effectiveness through a combination of human intervention and technological solutions which enable companies to move from costly reactive or unnecessary time-based maintenance to planned and predictive interventions based on actual equipment needs to ensure a cost-efficient and extended equipment lifecycle.

The first two elements provide the foundation on which performance improvement and cost containment rely while the other elements ensure that initial engineering and infrastructure investments continue.

Our approach is scalable such that companies can join in where it makes sense –though full benefits will only accrue to those opting for the totally integrated solution.

Greenfield

From a greenfield point of view, companies benefit from combining intelligent engineering with intelligent infrastructure, the first two elements of ABB's collaborative operations framework. The former simplifies and accelerates project execution while the latter helps to further reduce initial CAPEX expenditures by streamlining the equipment required and reducing required footprints and delivers ongoing OPEX savings once the project has been delivered. We call this **Intelligent Projects** and the approach can cut costs 20-30% and shorten schedule completion by a quarter.

This is achieved using engineering in the cloud, standardized processes, automated data management, smart I/O systems and soft marshalling to decouple the hardware and software engineering activities in greenfield projects.

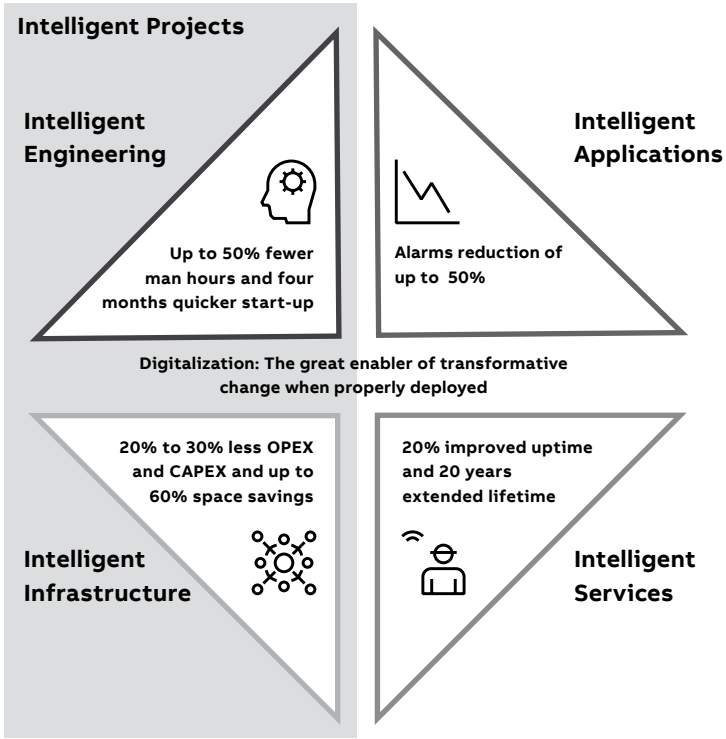
For example, standardized hardware designs and smart I/O products significantly reduce the need for upfront planning. Virtualization, emulation and simulation are technologies that can be used to enable application software testing to be conducted in a cloud environment without requiring the hardware. This allows hardware to be shipped to site much sooner leading to an earlier completion of installation and field loop verification.

This approach eliminates the need for project-specific junction boxes, armoured multi-core field cables and marshalling cabinets. Standard junction boxes containing smart configurable I/O become smart junction boxes. These can be procured from stock and installed in any convenient location. Field devices are simply cabled to the nearest smart junction box. The I/O loops are quickly and efficiently tested and verified by taking advantage of digital communication technologies such as HART. All this is achieved in parallel with the software engineering in the cloud. When the application software is downloaded into the hardware the I/O system is soft marshalled and connected to the application software using a simple signal names (tag) matching process.

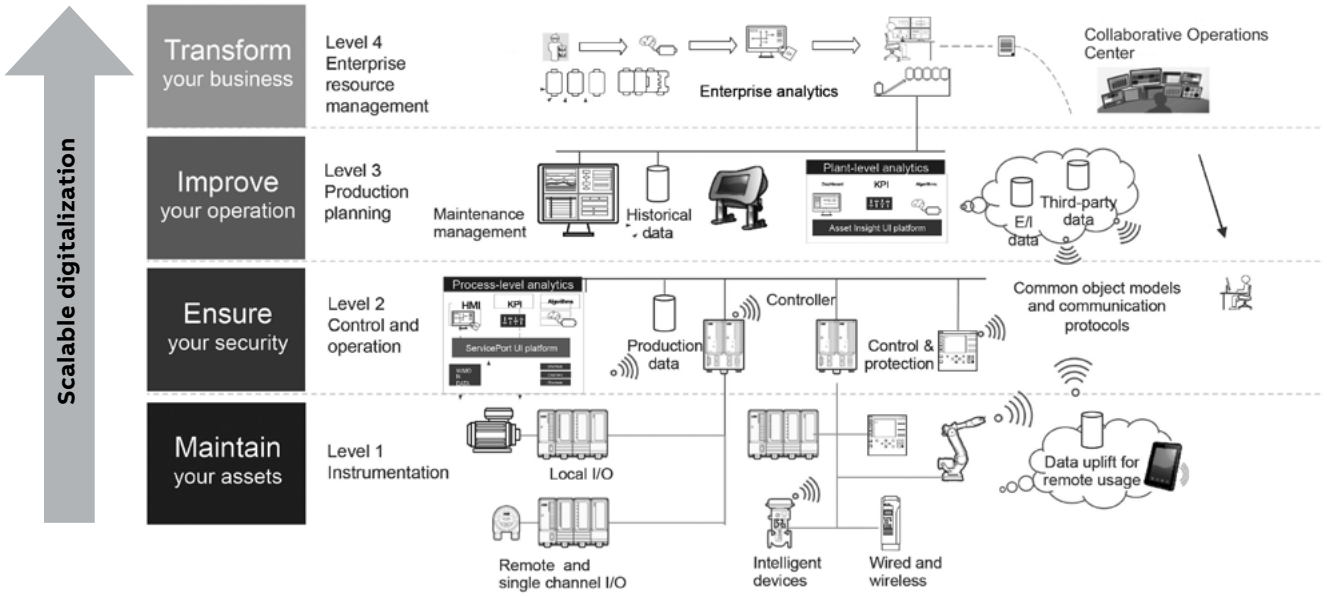
Cloud computing thus paves the way for "virtual commissioning" using process models which can be used to significantly boost the value of functional testing by providing a more realistic feedback. This approach results in far fewer changes and modifications being required on-site during commissioning.

ABB's cloud computing approach is further used to make designs, workflows, methodologies, support tools and lessons learned accessible to all project execution groups. This automated data management facilitates a common approach to automation engineering even when multiple EPC contractors across different countries are involved.

ABB's workflow manager tool, for example, ensures that the right people in the engineering process are quickly informed of any changes and assists in quicker turnaround times for determining the impact that the change requests have on cost and schedule.



Collaborative operations: A four angled approach.



ABB's scalable model of digitalization.

Brownfield

For existing operations, companies may prefer to start their digitalization journey at an asset level which is fine so long as they do so with the end goal of enterprise-wide digitalization in mind. If they do not take such a long- term view they risk continuing to develop islands of intelligence of an insufficient scale to deliver significant value and they will increasingly find themselves at a disadvantage to OGC players who create a larger digital ecosystem.

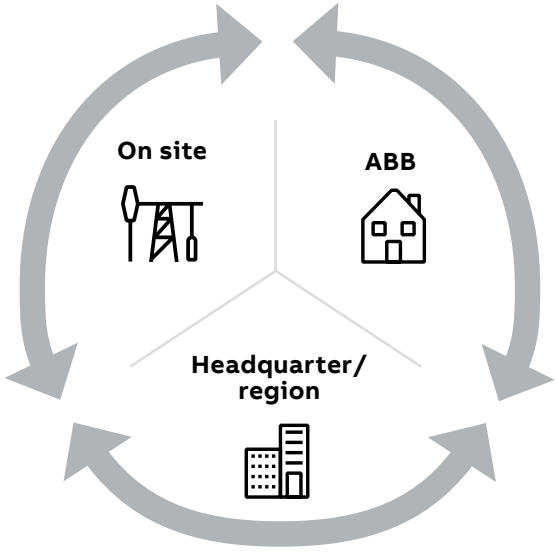
Ultimately they should be striving to close the communication loop more fully by having onsite operators liaise more closely with headquarter locations and suppliers such as ABB who can work remotely or in close proximity with local employees to make operations and services more efficiently.

In fact, at various ABB OGC collaborative operations centers located throughout the world we have created digital hubs that allow IT and OT experts to work very closely together to solve customer issues in real-time. These centers gather data drawn from assets across the customer's production sites and translate this into intelligence, before transferring it back to each plant's operations center on-site and to management at headquarters.

Using the ABB Ability cloud, based on Microsoft's Azure, data from instrumentation, switchgear, motors, drives and other smart sensors, for example are channeled through analytics which undertake condition monitoring, remote diagnostics, performance monitoring, cybersecurity and condition-based maintenance. Depending on customer requirements, a full suite of experts can man the center 24/7 meaning that project teams to address crisis situations can be quickly assembled. There are even high security Armor rooms for working directly on customers' own networks meaning that issues can be addressed particularly quickly and effectively.

Collaborative Operations: In Summary

ABB's Collaborative Operations approach is a way of properly harnessing digitalization to increase the speed and quality of decision-making along the full hydrocarbon chain, changing how people interact with others in their organizations, fast-tracking innovation and creating new business models. This can be at an asset level or enterprise-wide, onsite or remotely, with as much expert guidance as required, up to and including the real-time assistance from ABB at a distance.



Closing the communication loop: Fully collaborative operations.

ABB's extensive cross-industry experience with digitalization underpins its ability to deliver effective solutions for oil, gas and chemicals customers at whatever level is required.

ABB Ability cloud platform and services:
Remote monitoring solutions

Range of cloud-based services and advanced analytics

ABB Ability plant and enterprise solutions:
Power generation solutions, network management systems, substations

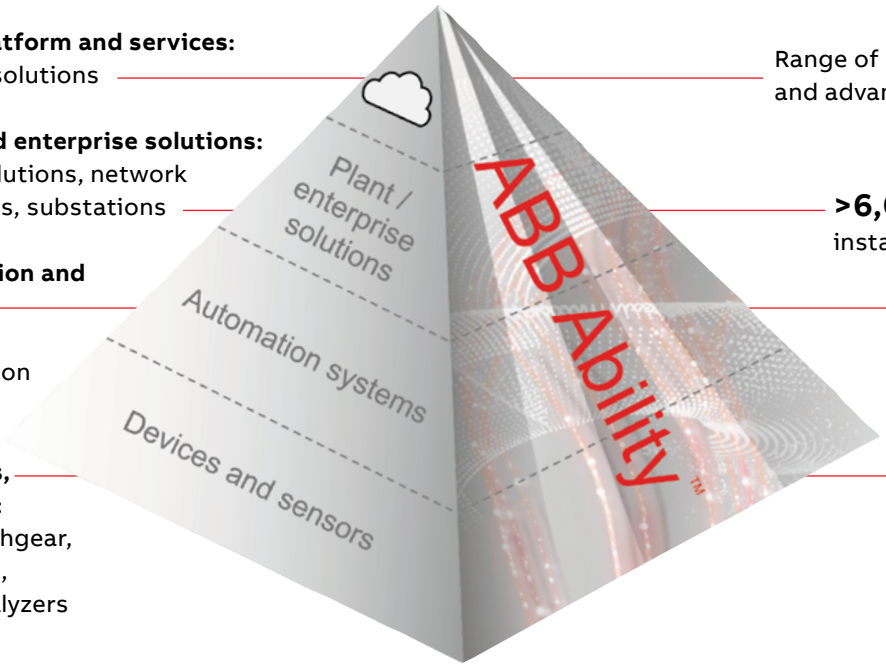
>6,000 solutions installed

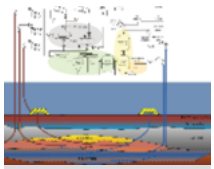
ABB Ability automation and control systems:
DCS systems: 800xA, Symphony+, substation automation systems

>70,000 systems intalled

ABB Ability products, devices and sensors:
Motors, drives, switchgear, transformers, robots, instrumentation, analyzers

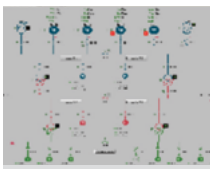
>70,000,000 digitally-enabled devices connected



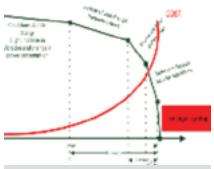


Smart Wells Flow Assurance and Production Optimization

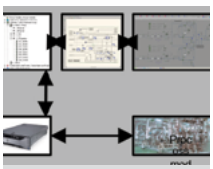
Plant Performance Solutions and Services



Power Management and Electrification



Asset Management and Conditioning Monitoring



Digital Projects and Engineering

Insight Safety and Alarm Management Applications

Collaborative Operation Centers

ABB Ability, IT Topology & Infrastructure, Cyber Security

ABB's OGC digitalization roadmap: Solution areas from devices to advanced analytics.

6.0 Optimizing the hydrocarbon chain in practice

Elements of what have been described so far in this white paper are already happening and the trend is set to accelerate.

Upstream: Off and Onshore – Norske Shell

Challenges solved
Full deployment of ABB's collaborative operations approach has doubled the lifetime of aging topside and subsea assets at Norske Shell while delivering 99 percent uptime, ensuring high levels of safety and managing energy consumption more effectively.

How
ABB was involved on this project from back when it was a greenfield site and part of Norske Hydro. And, under various changes in ownership, has continued to provide fully integrated solutions across the various sites. As such it is a good example for what a highly digital, enterprise-wide approach can deliver when there is a close, long-term relationship between the supplier and operator.

ABB has helped shell extend the operating life of Draugen and Ormen Lange by an additional 20 years, far beyond the usual lifetime of automation hardware and software.

- As part of its intelligent engineering offering, ABB developed an evolution program to prolong the life cycle of Shell's safety and automation systems by plotting an upgrade or replacement path for each item of hardware and software over the coming years, as well as the scheduled shutdown when the work is to take place.
- This minimizes risk and expenditure for Shell while safeguarding the high availability rate those assets have so far attained.

Shell is using digitalization to extract more output from these aging subsea and topside production assets through the combined use of ABB's engineering know-how, integrated power, automation, safety infrastructure and applications, bolstered by extended service packages.

- The data that ABB collects from the safety and automation systems at Draugen and Ormen Lange is continuously analyzed by S hell and ABB to find new ways to increase productivity. Several of these opportunities have led to increases in production. For example:
  - An automatic choke control solution developed by ABB has reduced the start-up time of Ormen Lange's 16 wells from 9 hours to 2 in low pressure wells and from 15 to 20 hours to only 2 for high pressure wells.
    – Previously, the wells had been started up slowly at a preset speed to prevent gravel and sand collapsing into the wells and destroying them.
    – Now, the automatic choke control solution monitors and manages critical well variables

in real-time enabling the ramp-up speed to be adjusted according to actual process dynamics.

- Also, by more accurately measuring the concentration of mono-ethylene glycol (MEG) needed to be pumped from onshore tanks into subsea wellheads to prevent water in the gas from crystallizing and blocking pipelines, and adjusting pump speed according to real-time conditions, ABB has helped Shell to reduce costs and increase output by:
  - Shutting down one of its three regeneration trains (the tanks at Nyhamna hold more MEG than the world produces in a single year).
  - Cutting energy consumption due to the dynamic speed control of the onshore pumps responsible for pushing the MEG through the pipelines to the well.
  - Shipping more gas since less space is taken up by the MEG in the pipelines.

Draugen has more than doubled its recoverable reserves and now has a recovery factor of around 70 percent, one of the highest in Norway.

Shell has reduced the need to deploy its own employees and expertise by leveraging digital solutions from ABB to optimize labor requirements.

- On the service side, thousands of hours of work are performed each year by authorized ABB personnel from several remote monitoring and operations rooms at ABB locations in Norway. Remote access to Shell's safety and automation systems enables ABB to safely implement changes, troubleshoot, provide support and carry out health checks.
- Two 800xA simulators at each site replicating the safety and automation systems are used for operator training, engineering and testing.

With single-source system accountability and the technological portfolio to break down disjointed information silos, ABB has helped Norske Shell leverage collaboration throughout the supply chain and optimize its highly complex operations by making it simpler to oversee.

- Multiple systems are tied to a single interface: Integrated automation, electrification, safety and information management systems. For example:
  - ABB has seamlessly integrated Norske Shell's process control and process safety systems into a 'single yet separate' entity which would more traditionally have been supplied by independent systems from two different vendors. In ABB's solution both systems use the same control architecture and human machine interface, share the same controllers and field equipment, and use the same software tools, yet their functionality remains separate, simplifying operations for Shell.

- ABB has been tasked with being the single point of contact for automation system service at the two sites, regardless of vendor or task. Every time a graphic is altered or a configuration changed or an incident occurs, it is logged in a database in accordance with strictly defined procedures. Each change has to be approved, first by the ABB technical account manager (TAM) and then by Shell. There are three ABB TAMs, each of whom has a deep and extensive knowledge of the safety and automation systems and the applications at the two sites.
  - The outcome of these procedures is not only an exceptional process safety record but also a vast bank of information about the performance, status and history of thousands of objects in the sites' safety and automation systems which can then be analyzed to improve operations further.

ABB technology helps Norske Shell cope better with energy volatility

- Gas compressors at its Nyhamna processing plant runs using ABB's variable speed drives to reduce energy consumption and carbon dioxide emissions significantly.

"Ever since the start-up phase in 2007, uptime at Ormen Lange has been more than 99 percent for most months of the year. Such high availability is unusual for a plant as large and complex as this. We've invested significant resources in continuously fine-tuning the plant, which has benefitted us enormously. Our experience from Ormen Lange tells us that it pays to invest in optimization."

Reidar Haugsgjerd, Process Control Engineer, Norske Shell

Background

Norske Shell operates two oil and gas fields on the Norwegian Continental Shelf and a large onshore plant at Nyhamna.

- Draugen: Shell's northernmost oilfield, located 150 km off the Norwegian coast at a depth of 250m.
- Ormen Lange: Norway's second largest gas field situated 125 km off the coast at 3000 m below the sea surface and supplying up to 20 percent of the UK's natural gas requirements.
- Nyhamna: Gas from Ormen Lange is transported through two pipelines to Nyhamna, Norway where it is dried and compressed before being moved through the second longest subsea pipeline in the world, the Langeled pipeline (1200 km), to the east coast of England.

Upstream offshore – Goliat FPSO

Challenges solved
A big FPSO project was brought in with minimized risk and initial reduced capital outlay and streamlined, ongoing operational costs by deploying a full range of intelligent applications and services to optimize production and profitability.

How
ABB's intelligent projects approach, combining intelligent engineering and intelligent infrastructure, delivered Goliat with:
– 50 percent less commissioning and 30 percent less engineering costs
– Reduced system complexity and footprint
  – 60 percent less PDCS/PMS system size reduction
  – 30 percent less system/FTC cabinet reduction
– Less risk due to ABB's having single-source system accountability meaning the project came online with fewer problems due to unexpected integration problems caused by different supplier technology

Operations continue to be optimized by deploying ABB's analytics portfolio, whose digital insights in a range of areas help improve safety, improve efficiency, increase uptime and lower maintenance expenses:
– SafetyInsight™: Minimizes lost production time by enabling faster startup following an unplanned shutdown and saves significant time and effort by automatically capturing actual SIF performance data for comparing against SIF design assumptions, as required by IEC 61511
– AlarmInsight™: Provides scalable software applications that enable operators to effectively respond to process disturbances in high-intensity situations by helping document, rationalize and maintain appropriate alarm levels and allowing operators to focus on the alarms that truly require attention
– OperationInsight™: An electronic log of activities in the control room including two modules, shift report and block log, which serve to improve safety and integrity by acting as the critical point for information transfer
– Web portal for asset condition and performance monitoring: Gathers operational data into a single web-based tool to enable collaboration across locations, disciplines and organizations and gives operators access to essential tools in one place, regardless of their location by providing process and condition data from System 800xA directly into Goliat's dashboard.

Other technology used to improve performance includes:

- ABB Process Power Manager: Reduces downtime by automating reactions based on priority or criticality and helps ensure faster recovery of power and production after a failure
- Compressor optimization solutions: Calculates best operating point of a group of parallel compressors and reduces fuel/power consumption and carbon emissions without reducing throughput while protecting gas compressors driven by ABB medium voltage drives from grid disturbances to achieve continuous operation and providing advanced diagnostics on the health status of electrical motor drivetrain
- WiMon wireless condition monitoring system: System which collects vibration and temperature data to assess machinery condition parameters, providing information to schedule maintenance only when needed - instead of on a routine schedule – for a more efficient approach to condition-based maintenance of motors and other rotating machinery.

Background
The Goliat FPSO consists of a processing plant, oil storage capacity and accommodation facility located in the Barents Sea within the Artic Circle – the first ever project there.

Upstream and Midstream – Queensland Gas Company (QGC)

Challenges solved
Integration of automation, electrification and telecommunications makes it possible for a skeleton crew to oversee a complex operation consisting of a 540 km pipeline and over 6000 wells spread over 3500 km^2 in Australia.

How
ABB's System 800xA enables the integration of the entire plant meaning that fewer than four people using a single operator interface are required to manage an operation the size of a country like Ireland since the real-time analytics can be viewed from anywhere.

- A 24-hour control room in Chinchilla lets QGC operators monitor and regulate the operations of wells, processing facilities and the pipeline
- The information is shared with the monitoring center in Brisbane which also oversees the operations in Gladstone where the two train liquifaction plants are located.

The fact that the automation, electrification and telecommunications systems are fully integrated helps QGC:

- Minimize operational costs, including travel, and allows real-time decisions to be made to optimize production parameters and respond quickly to alarms
- Maintain reliable and stable energy supply through load shedding, load sharing, generator control and synchronization
- Ensure the physical safety of personnel and sites via a full range of CCTV, intruder detection and hotline services enabled by a highly resilient fiber optic infrastructure
- Protect assets from deliberate or accidental cybersecurity incidents through a secure system architecture with advanced user control, host-based firewalls, continuous security patches and a secure-by-design philosophy.

Background
This is the world's first project to turn coal seam gas into liquified natural gas (LNG). There are two train liquefaction plants producing up to 8.5 million tonnes of liquefied natural gas per year.

It is estimated that 250 trillion cubic feet of gas reserves are estimated to lie beneath Queensland and New South Wales -enough to power a city of one million people for 5,000 years.

Coal seam gas produces up to 70 percent fewer greenhouse gas emissions than coal and 20 percent fewer carbon dioxide emissions than oil when burned to create the same amount of electricity.

The project, which started construction in 2010, started producing LNG in 2013 and continues development today. ABB has worked over 750,000 hours, or the equivalent of 400 man-years, without any lost-time incidents. Over 2500 wells of the 6000 expected during the project's lifetime are already operational.

Midstream - Trans-anatolian natural gas pipeline (TANAP)

Challenges solved

SCADA, telecommunications, pipeline monitoring and security systems will deliver enhanced security and optimize communication across 1850 km of the TANAP pipeline and 20 districts which, without proper integration, could evolve into disjointed information silos.

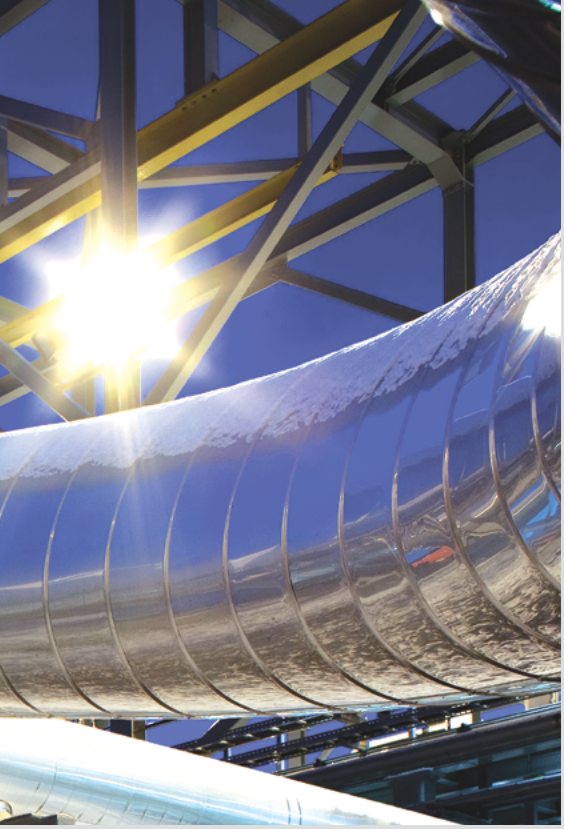
How

Integrated pipeline-wide communication is being facilitated by ABB's sophisticated point of control (PoC) technology available via ABB's System 800xA control system

- The TANAP system will be fully automated with main and back-up control centres to meet the requirements of gas transmissions and associated environmental and safety considerations.
- PoC allows the transfer of authority to operate parts of the pipeline to be passed between central and local HMIs, while automatically maintaining the integrity of the system. Using PoC, engineers will thus be able to quickly and safely transfer control from the central control room to local operational staff on request. The central control room will retain view-only access until the control is transferred back.

Sophisticated leak detection and pipeline monitoring systems will ensure more product reaches intended destinations safely and cost-effectively

- Leak detection will be carried out directly using distributed acoustic sensing (DAS), which relies on the fact that sound waves hitting a cable cause minute changes in the optical properties of the fibre contained within it, as do changes in temperature.
  - Laser pulses sent down a cable will report these changes using a technique known as coherent optical time domain reflectometry (COTDR), and algorithms on the servers can interpret the data, pinpoint where the leak has occurred and verify it using other data, such as the pressure wave that usually accompanies a break in the line.
- Intruders will be detected in the same way as leaks, with laser pulses. All the pipeline's stations, manned and unmanned, will be surrounded by fences, and all the fence lines and surrounding areas will be fitted with a fibre optic cable that are automatically monitored 24 hours a day.
  - If any suspicious activity is detected, the system can attempt to verify it using CCTV. If the system thinks it 'sees' something untoward, it can sound the alarm, present the operator with the evidence and even suggest what standard operating procedures the operator should follow next.
- For extra security, the data collected will be shared via ABB's System 800xA through firewalled connections, but separate from it, with its own dedicated servers.
  - Indeed cybersecurity is such an important issue ABB uses a defence-in-depth approach that involves multiple layers of security controls placed throughout the system. Cybersecurity is a critical factor in all phases of the system lifecycle and it is an integral part of the SCADA and telecoms solution. ABB addresses it at each stage of the project – from design and development to operations and maintenance.



Background
The TANAP pipeline is the largest section of the $45 billion 3,500 km Southern Gas Corridor, which will transport gas from the Shah Deniz 2 field in the Caspian Sea through Azerbaijan, Georgia, Turkey, Greece and Albania, to join the European network in Italy.

- TANAP is a company formed for the execution of the project, with SOCAR of Azerbaijan, BOTAS of Turkey and BP as shareholders.
- The $11 billion TANAP pipeline will interconnect with the South Caucasus Pipeline (SCPx) at Turkey's border with Georgia and the Trans Adriatic Pipeline (TAP) at its border with Greece.
- The project consists of a 56" and 48" diameter onshore pipeline system of 1,814 km in length with a 21 km offshore section beneath the Marmara Sea comprised of two parallel 36" diameter pipelines.

Downstream – Wacker Chemie

Challenges solved
Advanced services improved the efficiency of aging assets while delivering 20 percent operational cost savings (OPEX).

How
Using ServicePort technology, remotely and on-site, to analyse Wacker's complete automation system and control loops, ABB service engineers were able to:

- Implement minor process changes which helped operators run the more closely to their specification limits, boosting output and energy efficiency without reducing product quality
- Optimize control loops to eliminate weak points and bottlenecks, thereby extending the durability of components and helping the plant run as effectively today as it did on its first day over 30 years ago

Control loops are usually only adjusted during the planning and engineering stages, and their performance is not called into question once a plant is operations. Changes to the production process do not automatically result in control loops being updated, and the effects of aging and wear-and-tear remain unacknowledged.

- By automatically and continuously monitoring all performance parameters, ServicePort notifies operators early of looming faults so the right countermeasures can be taken quickly
- Save 35 days of analysis time, facilitating faster corrective action with less downtime risk and 20 percent OPEX savings

Background
In Burghausen, Germany Wacker Chemie AG operates a ketene cracking plant in which liquid acetic acid is evaporated and fed into cracking furnaces in a gaseous state. Special catalysts are then used for separating the gas into ketene and water. Ketene is used as the raw material for producing isopropenyl acetate and acetylacetone.

The ketene plant uses ABB's Freelance process control system with DigiVis taking care of the operation and observation functions. The required automation tasks are performed by five redundant type AC 800F controllers or rack-based process stations. The part of the plant inspected comprised a total of 139 control loops, including 109 loops that were studied in more detail.

7.0 Conclusion

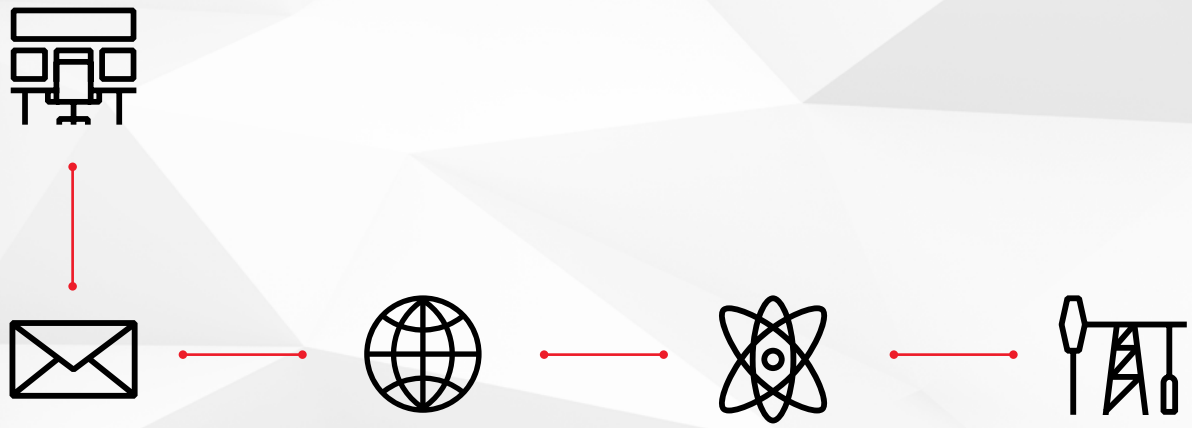
The oil, gas and chemicals industry is in the middle of an existential crisis.

During other similarly uncertain times, companies were able to increase productivity in ways which were disruptive at the time. For example, companies improved operations by using automation to scale up output at a reduced cost with greater quality. In the information era, further productivity improvements were achieved through process integration, centralizing things where it made sense.

The current digital era is about turning the data made possible through the information era into action, increasing both the speed and quality of decision-making. It requires greater collaboration within companies and across the wider supply chain.
As discussed in this paper, companies need to react to the 'new normal' of low oil prices and adapt their business models yet again.

Fortunately, the technological solutions available today are sufficiently robust and cost-effective that, harnessed effectively, they offer companies the tools they need to thrive in these challenging conditions.

The question, however, is how willing are companies to change the way they operate and embrace digitalization at an enterprise level?



8.0 Contacts

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ABB Oil, Gas and Chemicals
www.abb.com/oilandgas