Oil & Gas Authority

Technology Insights

April 2018

Contents

Front Cover: Source EC-OG:
The Subsea Power Hub (see section A3) is an example from a portfolio of developing and future technologies which together will make subsea systems more autonomous, capital efficient and supportive of field development opportunities.

All data are sourced from the OGA Stewardship Survey 2016 unless stated otherwise.

Executive summary

63 operators submitted their Technology Plans as part of the 2016 UK Continental Shelf (UKCS) Stewardship Survey, providing the Oil and Gas Authority (OGA) with a unique insight on companies' technology portfolios, as well as their strategies to access further required technologies.

There is a strong industry awareness of the importance of technology. Operators' plans contained, on aggregate, 324 technology items across the asset life-cycle.

Direct technology investment is concentrated with a small group of 'leading' operators (11% of respondents) accounting for 85% of the spend. An additional 18% of operators also partake in significant technology development and/or piloting and pursue a 'fast-follower' strategy. The remaining 71% are entirely reliant on the supply chain for technologies.

Findings include:

- Exploration and drilling stood out for having a portfolio of modern technologies available through the UK supply chain, with operators also engaged in further development
- Technologies to support late-life and decommissioning are receiving rapidly growing attention, in particular by larger operators
- Technology progress is slower in the area of subsea and surface facilities, despite the need for novel solutions to unlock the development of small pools and other marginal discoveries

The UKCS continues to be an innovative basin. There is a well-balanced technology portfolio across major disciplines and a growing focus on addressing operational cost pressures and future development of contingent resources.

Looking at individual operators' plans and how these relate to specific asset portfolios, it's clear there are technologies which could be adopted more widely. The OGA is continuing to support operators to share knowledge and experience in deploying these technologies to maximise economic recovery of UK petroleum (MER UK).

Innovation has a leading role to play in the UKCS; over 45% of the technologies described in operators' plans are at concept stage or under development. These emerging technologies may also help the UK supply chain to grow their global exports.

However, recent economic pressures have seen operator technology spend decline by 36% since 2014 and there is a risk technology development is delayed.

The OGA is continuing close collaborative work with the Technology Leadership Board (TLB), and the Oil and Gas Technology Centre (OGTC) to ensure the right technologies are prioritised and deployed swiftly in order to maximise recovery from the UKCS.

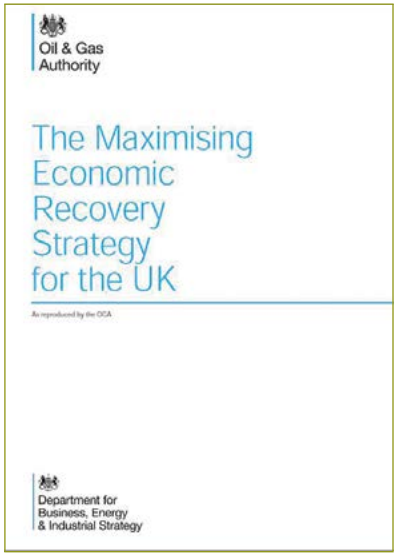
1. Introduction

Technology development has been crucial to oil and gas exploration and production over the past 50 years and has also helped the UK oil and gas supply chain grow to a position of global leadership. Continuous innovation has enabled access to increasingly complex hydrocarbon accumulations and has increased the volumes recovered from old and new fields.

Today, emerging and/or existing technology remains critical to deliver MER UK and the legally-binding MER UK Strategy requires licence holders to deploy optimal technologies.

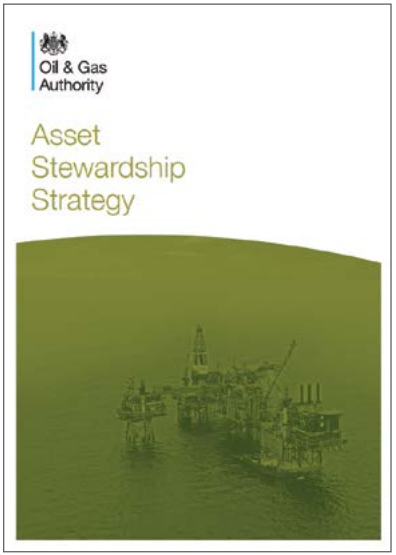
As part of the 10 Asset Stewardship Expectations, the OGA's Technology Expectation of industry stipulates that every UKCS operator should have a technology plan to assist in delivering its MER UK obligations, and should submit that plan as part of the annual UKCS Stewardship Survey.

The OGA supports operators to share their experience in deploying existing technologies and works with the TLB and the OGTC to promote collaboration on development and deployment.



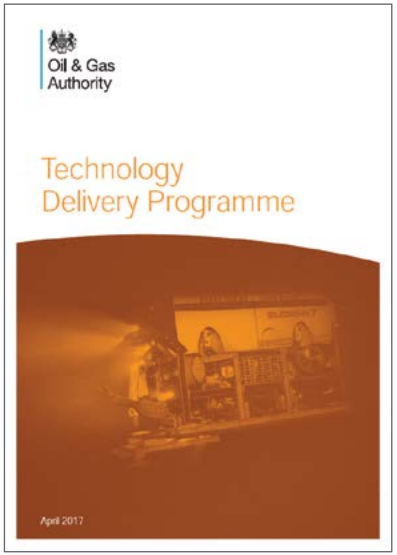
MER UK Supporting Obligations Technology

- Operators to deploy technologies (new and existing) to their optimum effect to achieve MER UK
- Operators to consider all potential benefits for the UK from the development of these technologies



Asset Stewardship Expectations SE08 Technology Stewardship

- Expect all UKCS licence operators to have technology plans, supporting MER UK
- Request licence operators to submit their plans as part of the Asset Stewardship Survey



Technology Delivery Programme OGA Role

- Work with operators to share best practices, and understand the use of new technologies
- Work with the TLB, OGTC and other technology organisations to accelerate technology initiatives through to deployment

2. UKCS Stewardship Survey

2.1 Technology findings (2016)

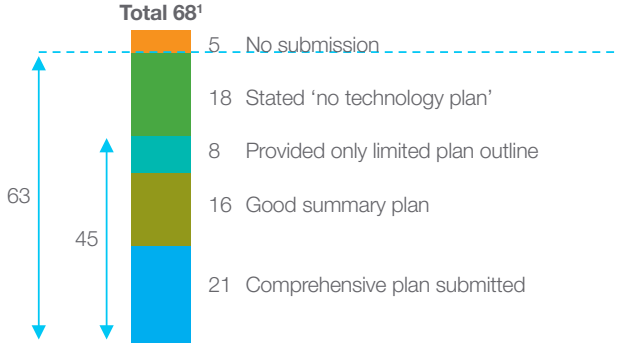
The OGA asked operators to provide information about the technology needs of their UKCS asset base and the plans to develop or source technologies to address these needs:

- 63 operators (93%) responded to the Survey
- 45 operators (66%) provided technology plans
- The majority of the plans submitted were complete and insightful

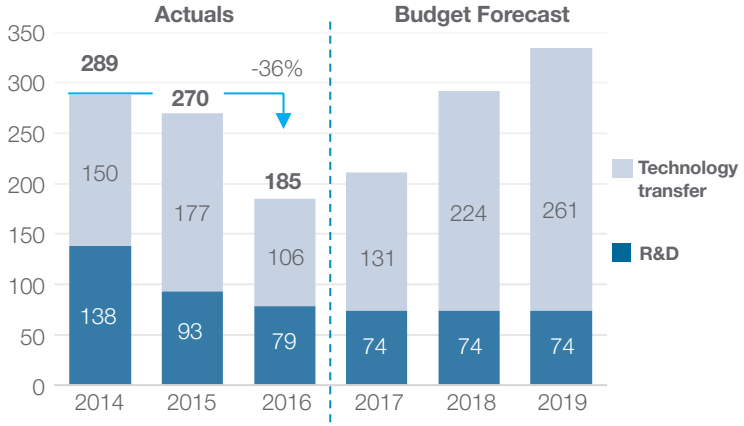
Operators were also asked to report their UKCS[2] technology spend and a three-year forward outlook.

Overall, in 2016 UKCS operators spent £185m on R&D and transferring new technologies to the field. This represented a sharp decline (minus 36%) in comparison to pre oil price downturn (2014).

Technology Plan Submissions



UKCS Operators' Technology Spend (£m)

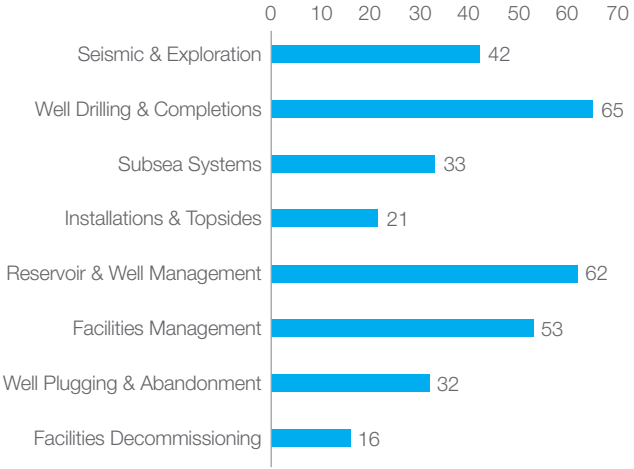


1.) Excl. onshore and midstream operators
2.) Total of direct spend by UKCS subsidiaries and corporate charges

2.2 Technology Plans

Operators cumulatively listed 324 technology solutions covering the entire asset lifecycle from exploration to decommissioning.

Number of Technologies in Operators' Plans (Total = 324)



Breaking down the content of the technology plans into disciplines, exploration and wells stood out for having a broad portfolio of modern technologies. These are provided both by the supply chain and through operator R&D.

Exploration has seen a constant stream of innovation and the latest advances in computing power and other digital technologies are accelerating that even further.

Improved acquisition techniques (e.g. 3D broadband), advanced inversion algorithms and further integration with petrophysical and subsurface modelling can all help find, and de-risk, smaller and more complex accumulations.

In **well drilling and completion**, technologies are being deployed to reduce well costs and increase reserves and productivity.

This includes being able to achieve more accurate well positioning; drilling through a complex overburden; improved completion equipment; and efficient stimulation techniques.

Technologies to support the management of **late-life and decommissioning** are receiving growing attention, in particular by larger operators.

This includes trials to adopt visual and other non-intrusive technologies, including robotics, for platform inspections and maintenance, as well as supply chain-led efforts to make subsea inspection and intervention equipment more capable and autonomous.

In **well plugging and abandonment** (P&A), operators are investing in the solutions to reduce the cost of P&A.

However, progress is slower on developing novel **facilities concepts** which could help unlock the development of small pools and other marginal discoveries.

In **subsea**, the focus is on technologies to reduce the cost of tie-back developments. This can be achieved through simpler design and installation, as well as autonomous technologies.

Novel, lower-cost concepts are also being considered for **surface facilities**. These include smaller, un-manned and re-deployable platforms, subsea storage, and efficient floating production and storage units.

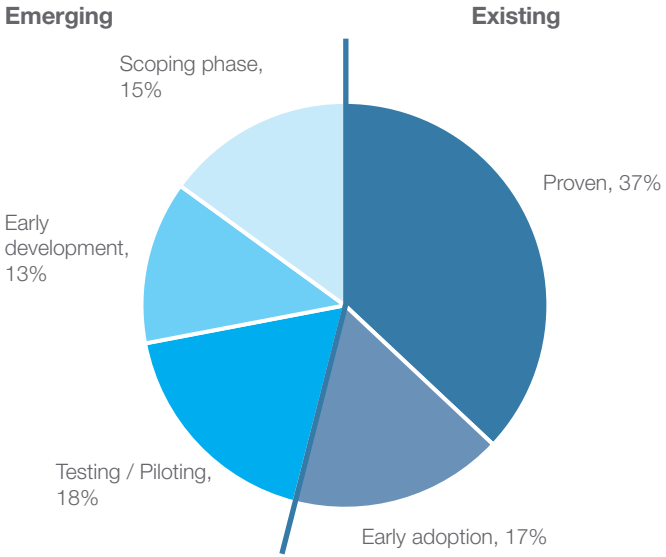
Bringing these new concepts to the field, however, requires considerable investment and potentially greater collaboration by operators.

Comparison of individual operators' plans shows there are a large number of existing technologies which could be more widely adopted. Better sharing of knowledge and experience will help scale up the use of these technologies to the wider benefit of the UKCS.

Over 45% of technologies described in operators' plans are currently under development.

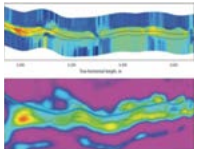
Piloting and early adoption of technologies often takes a long time, partly because of risk aversity and because of limited opportunities to test solutions in the field. Collaboration among operators and with the supply chain on piloting and de-risking of novel technologies is therefore vital to accelerate deployment.

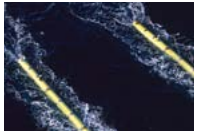
Operators' technology plans – technologies by maturity

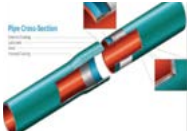


Existing technologies: highlights

Area	Examples of existing technologies
Seismic & exploration	- Improved survey acquisition (3D seismic broadband, OBNs, EM) - State of the art processing and interpretation – AVO, FWI, reprocessing, subsurface models - Time-lapsed seismic (4D) for reserve recovery optimisation
Well drilling & completions	- Geosteering: integration of different survey techniques (deep-resistivity and seismic) with real-time monitoring and decision making - Techniques for efficient/effective well delivery: extended reach drilling, multilaterals, smart mud, cuttings treatment, automation and efficient drilling operations - Stimulation: efficient multi-stage fracking, dissolvable plugs, optimised proppants, contingency options, slim-hole fracking
Subsea systems	- Efficient tie-backs, including design simplification, pipeline technologies, mechanical connectors, hot taps and advanced subsea equipment - Subsea inspection and repair, intelligent pigging, and advanced NDT tools
Installations & topsides	- Remote monitoring, wireless instrumentation - High accuracy multiphase metering
Facilities management	- Inspection in hard to reach areas: drones, ROVs, intelligent pigging, visual asset surveying and inspections - Digital offshore operations, data acquisition, predictive analytics, planning
Reservoir & well management	- Surveillance, real-time monitoring, fibre optic, telemetry - Water production mitigation and management, solids management, advanced screens, sand clean out, flow assurance chemical solutions - Intervention, coiled tubing tools, lightweight slickline, HPHT equipment
Well plugging & abandonment	- Rig-less access for well intervention and P&A - Upgraded milling tools
Facilities decommissioning	- Planning and preparation. supporting digital technologies, installation conditioning and removal, supporting digital technologies, flowline clean-up and sealing



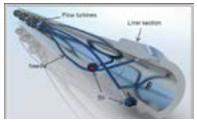


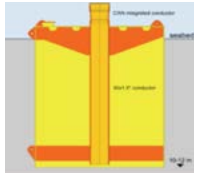


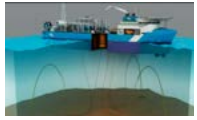
OBN - Ocean bottom node
EM – Electromagnetic
AVO - Amplitude variation with offset
FWI - Full waveform inversion
NDT - Non-destructive testing
ROV - Remotely operated underwater vehicle
HPHT – High pressure, high temperature

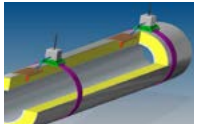
Emerging technologies: highlights

Area	Examples of new and emerging technologies
Seismic & exploration	- Advances in time-lapsed (4D) seismic and reservoir modelling, also using OBNs - Integrated geoscience modelling with latest processing techniques - Enhanced decision making and machine learning applied to exploration
Well drilling & completions	- Advanced drilling techniques such as automated managed-pressure drilling, designer muds, single trip steerable liner drilling, high angle side tracks, pre-set conductors - Accurate well placement and hazard avoidance, advanced geosteering, ultra-deep resistivity, next generation telemetry - Efficient reservoir stimulation techniques (acid fracking, jetting, propellant assisted perforating)
Subsea systems	- Efficient production and storage facilities (floating and/or subsea) - Tie backs: composite pipes, fully electrical controls, subsea power generation, UAVs - Stranded reservoirs: enabling technologies for small pool type development
Installations & topsides	- Produced water treatment technologies, local discharge, compact designs - Mini FPSO, novel FPSOs, NUIs
Facilities management	- Robotics and autonomous inspections, avoiding confined space entry - Corrosion and integrity inspections through insulation/cladding, corrosion under insulation
Reservoir & well management	- Well monitoring: acoustic sensing, HPHT sensors, fibre optic DAS/DTS - EOR (including low-cost polymer), low salinity, designer waters, combination EOR, continuous injection
Well plugging & abandonment	- Alternatives to casing section milling and cement barriers (thermite, plasma cutting, alloys) - Through-tubing primary cement integrity evaluation
Facilities decommissioning	- Monitoring: autonomous inspection vehicles









UAV - Unmanned aerial vehicle
FPSO - Floating production storage and offloading vessel
NUI Normally unmanned installation
DAS - Distributed acoustic sensing
DTS - Distributed temperature sensing
EOR – Enhanced oil recovery

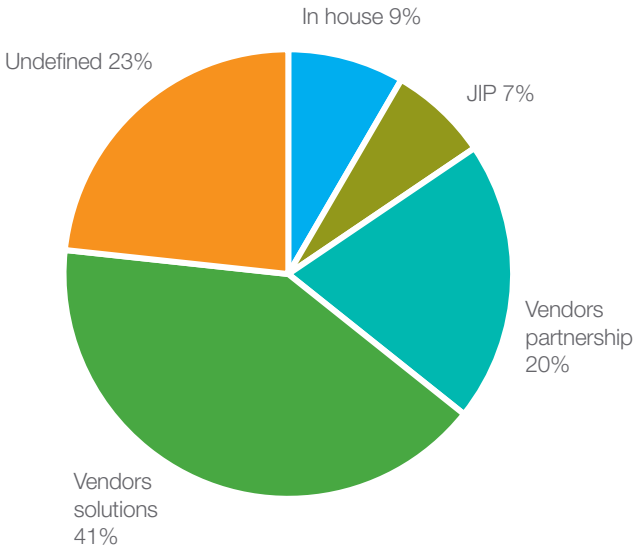
2.3 Technology spend and activity

The vast majority of technology spend (96%) and technology activities (76%) are concentrated with 18 operators (or 28% of the Survey respondents).

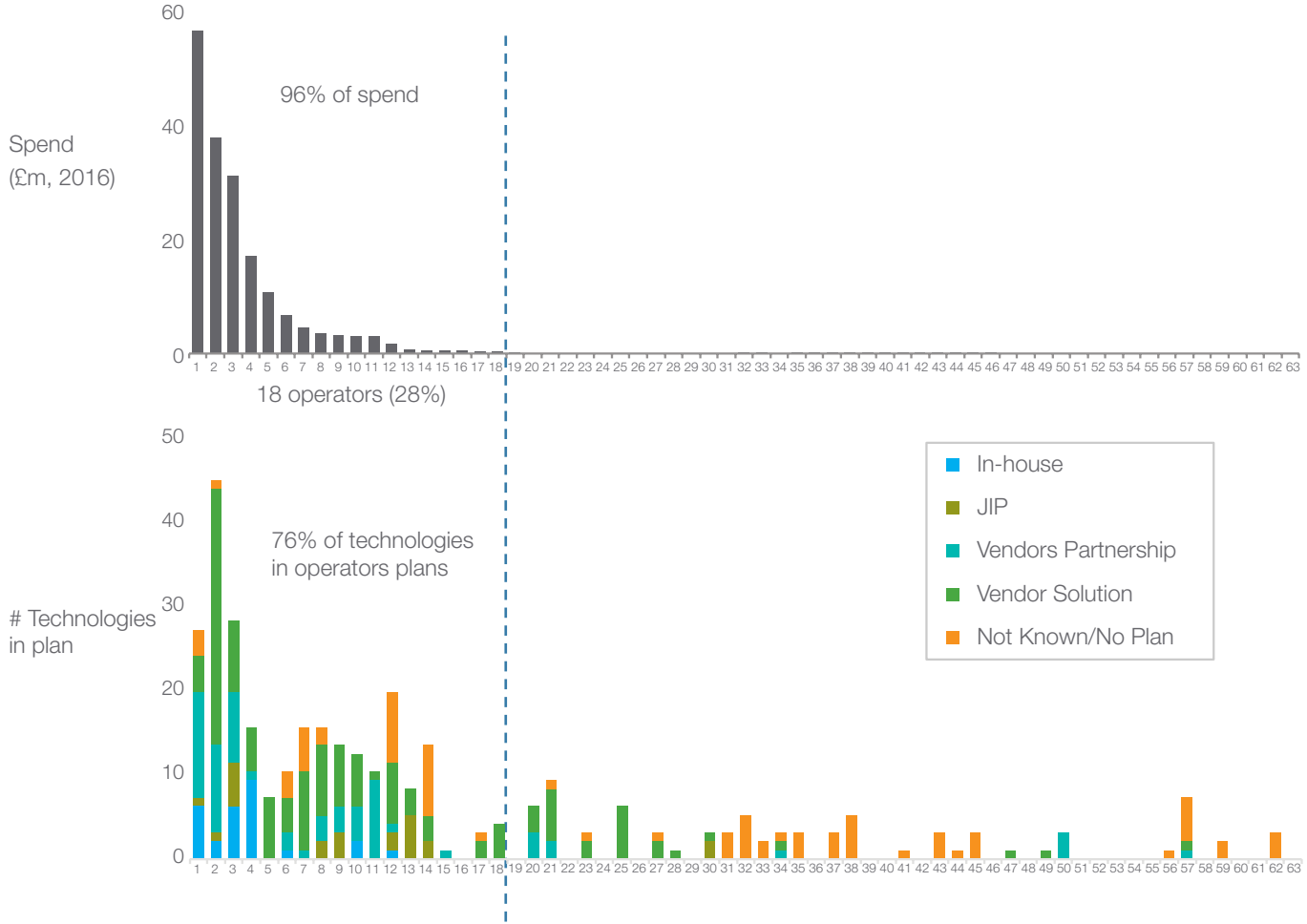
Operators within this group take a range of approaches to source technology. These are both internal and external to their own organisations.

In 16% of cases, technologies are delivered through operators' in-house and joint industry projects, while the majority of technologies (61%) are developed either in partnership with or through the supply chain. The remaining 23% do not have defined plans.

Technologies' delivery mode



Technology spend and activity by operator (anonymised)



Based on several factors, including technology spend, direct development activities and tolerance of technology risk, the OGA has classified UKCS operators into four groups:

Leader

- Comprehensive technology plans cover technology priorities of own asset base
- In-house R&D to seek competitive advantage through technology, complemented by JIPs and partnerships with vendors
- Lead pilots and “first deployments”

Fast Follower

- Good understanding of technology needs of own assets
- Technology spend focuses on JIPs and partnership with vendors to take advantage of latest industry practices
- Considers deployment of emerging technologies, accepting a level of risk

Informed Buyer

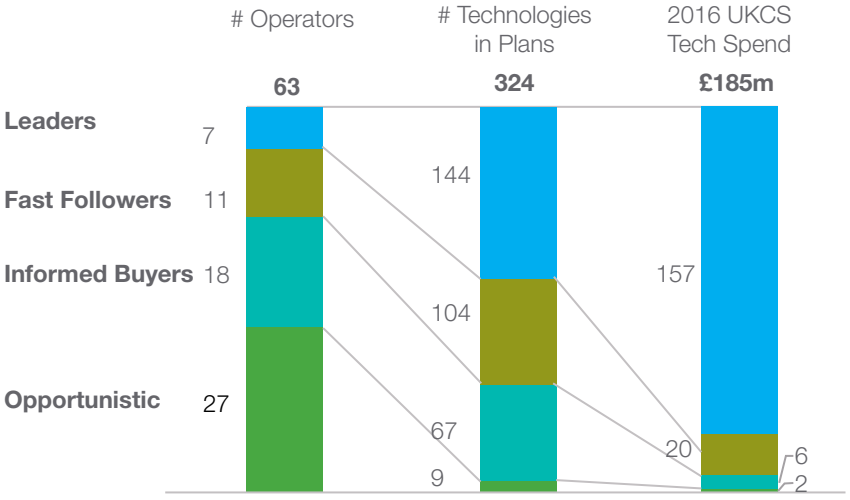
- Good understanding of technology needs of own assets
- No direct investment in technology
- Follows evolution of relevant technologies in the marketplace, and only consider the ones with sufficient maturity for deployment

Opportunistic

- Insufficient focus and/or organisational capabilities to interrogate the technology market
- Only considers mainstream technology solutions

Leaders and Fast Followers represent 28% of the respondents (18). These two categories accounted for over 76% of the technology solutions being deployed or under development, and 96% of technology spend.

The Leaders group, in addition, plays a critical role in progressing emerging technologies (early stages through to pilot).



Source: UKCS Stewardship Survey 2016

2.4 Industry benchmarks

Data from the ONS[1] show that UK-based extractive industries[2] (of which oil and gas represents 90% by GVA[3]) spend of just over 1% of their sales income on R&D (average 2014-2016). By comparison, this is significantly lower than other UK industrial manufacturing sectors, which range from just over 3% to 7%.

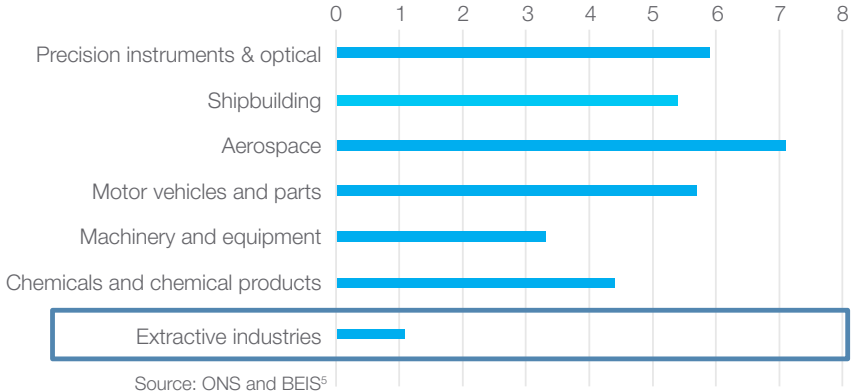
To illustrate how the UKCS compares on a global scale, the OGA has compared the total spend by operators on UKCS R&D with the total R&D on upstream technologies by individual oil and gas majors.

In addition, normalised by the annual hydrocarbon production, UKCS operators' R&D spend is at the low end of the range of the global majors.

While a comparison between different industries and global markets only presents limited insight, the findings nevertheless suggest that the UK oil and gas industry's current levels of investment in technology may not be sufficient to support the longer term Vision 2035 ambitions of MER UK and export growth[4].

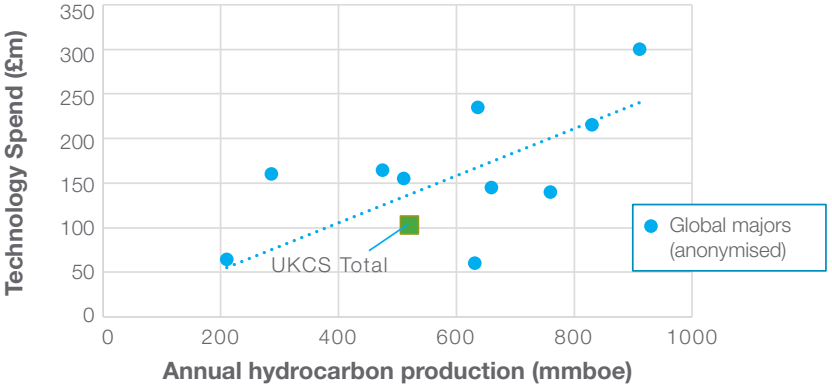
1. Office for National Statistics R&D Survey 2016
2. Extractive industries are comprised of: petroleum and natural gas extraction (operators and support services), mining and quarrying
3. Gross Value Added
4. https://www.ogauthority.co.uk/about-us/vision-2035/
5. This chart has resulted from a combination of data from different sources (ONS & BEIS)

Industry R&D spend as percentage of sales income - UK industrial manufacturing sectors (average 2014-2016)



Source: ONS and BEIS[5]

Operators R&D spend versus annual production (average 2014-2016)



Sources: UKCS Stewardship Survey (UKCS operators), OTM (global majors)

2.5 UKCS Technology landscape

Oil and gas operators
Develop and deploy technologies in support of their business objectives, balancing technology investment against expected returns and potential risks

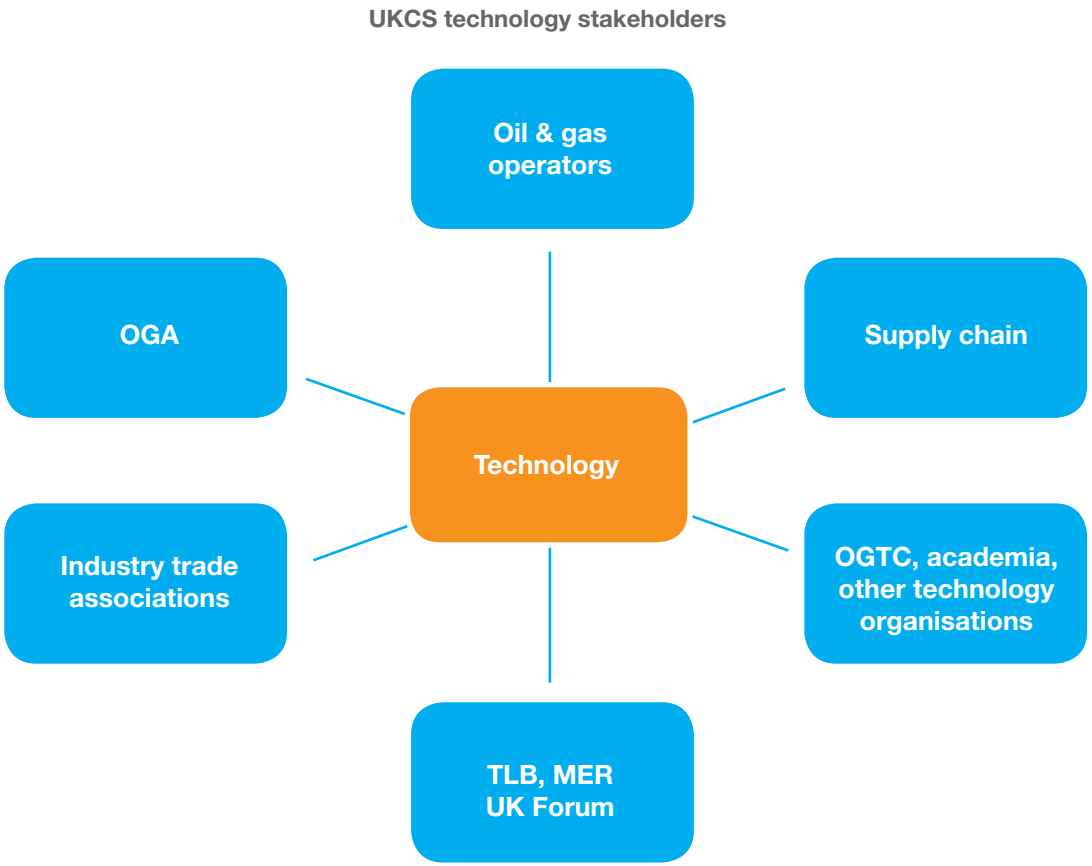
Supply chain
Provide innovation in response (and/or anticipation) to operators' needs both in the UKCS and global oil and gas markets

OGTC, academia, other technology organisations
Support and deliver technology research, development and piloting jointly with the oil and gas industry and provide links across other industries

TLB and the MER UK Forum
Define technology strategy at UKCS industry level, connecting technology opportunities with industry demand and MER UK priorities, across disciplines

Industry trade associations
Work with their members to share lessons learned and showcase best practice

OGA
Holds operators to account on their technology plans to ensure technology is used to achieve MER UK

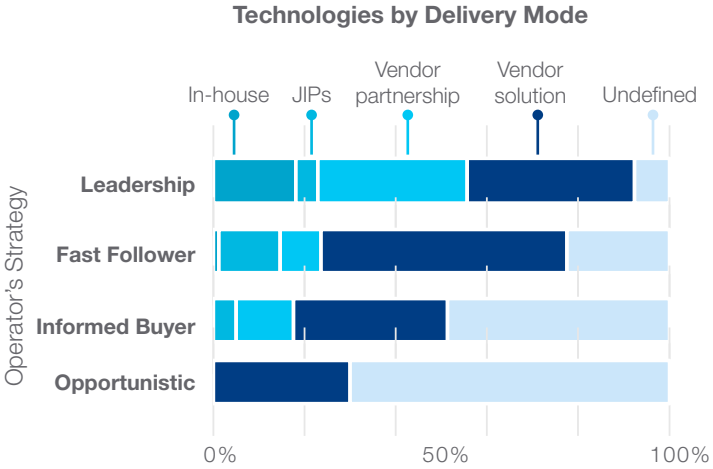

UKCS technology stakeholders
Oil & gas operators
OGA
Supply chain
Technology
Industry trade associations
OGTC, academia, other technology organisations
TLB, MER UK Forum

Oil and gas supply chain

The UK oil and gas supply chain has world leading capabilities and plays a central role in the development and field deployment of technologies for the UKCS.

Operators' technology plans show that the sourcing of existing technology from vendors accounts for 41% of the operators needs, with an additional 20% delivered through partnerships with vendors (see Section 2.3).

Leading operators develop technologies often in partnership with vendors. The other groups of operators are much more reliant on adopting existing vendors' solutions.



UK oil and gas supply chain capabilities[1]

Sector	Capabilities
Reservoirs	Seismic data acquisition and processing contractors Geoscience consultancies Data interpretation consultancies Seismic instrumentation
Wells	Well services contractors Drilling contractors Well engineering consultancies Drilling and well equipment design & manufacture Laboratory services
Marine & Subsea	Marine & subsea contractors Heavy lift/pipe lay contractors Floating production storage units Subsea manifold/riser design and manufacture Marine & subsea equipment Subsea inspection services
Facilities	Engineering, operation maintenance & decommissioning contractors Engineering consultants Structure & topsides design & fabrication Machinery, plant design & manufacture Engineering support contractors Specialist engineering services Specialist steels & tubulars Inspection services
Support & Services	Catering & facility management Sea & air transport Warehousing & logistics Communications Recruitment Training HSE services Energy consultancies IT hardware & software

1. EY Review of the UK Oilfield Services Industry, Jan 2018

3. Technology contribution to MER UK

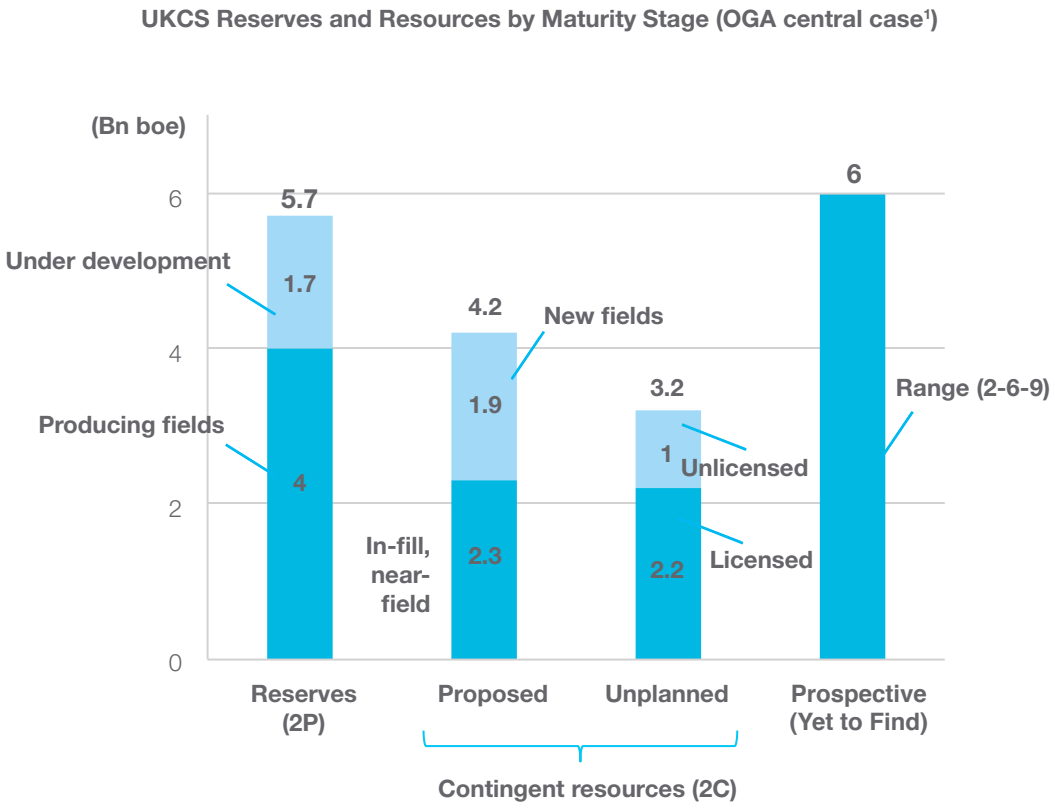
Existing and emerging technology can help realise a significant prize in terms of hydrocarbon resource recovery. The OGA estimates remaining recoverable hydrocarbon resources from the UKCS range between 10 and 20 bnboe[1]:

- Remaining 2P reserves estimated at 5.7 bnboe, a reserve-to-production ratio of circa 10 years (at current production rate)
- Contingent 2C resources (estimated at 7.4 bnboe) are also significant - much of these are in mature areas and more than half is under consideration for development
- Undiscovered (prospective) resources are estimated in a range from 2 to 9 bnboe (central case 6 bnboe)

In addition, technologies will be crucial to mitigate future risks to MER UK:

- Asset integrity issues, low production efficiency[2], and high opex[3] may contribute to premature decommissioning
- If contingent resources are not developed whilst existing infrastructure is still in place, some may be stranded
- Exploration results are challenged by low drilling activity, but work can be done to de-risk leads and high-grade prospects

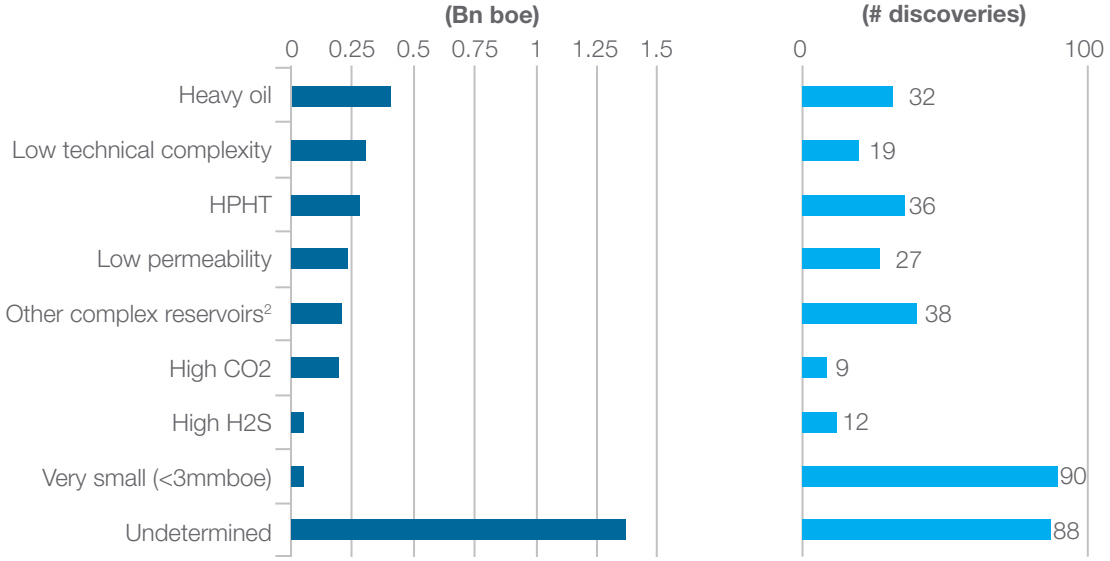
1) UK Oil and Gas Reserves and Resources - as at end 2016
2) UKCS Production Efficiency
3) Analysis of UKCS Operating Costs in 2016



bnboe - Billion barrels of oil equivalent

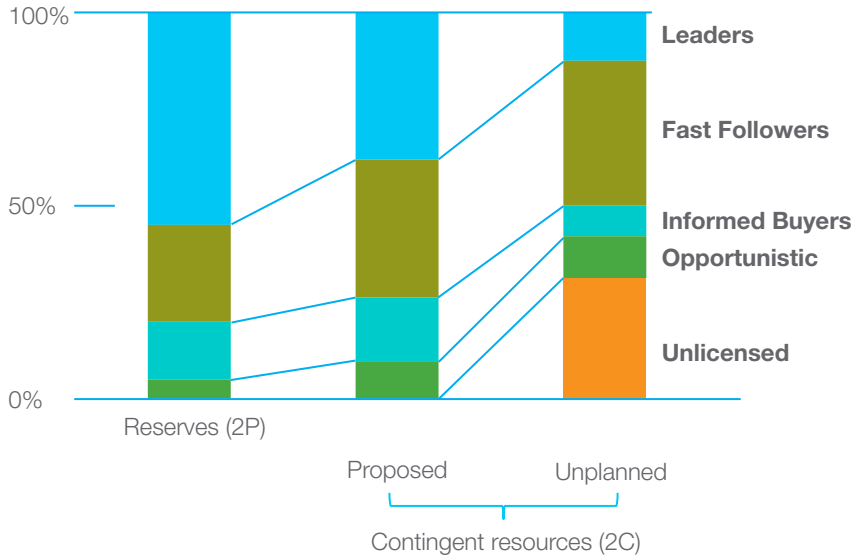
Small and/or complex oil and gas accumulations contain 3.2 bnboe of hydrocarbon resources which are technically recoverable, but some may not be currently economically viable. Use of Technology will be a key lever to help unlock these resources.

Unplanned contingent resources (3.2 bnboe) breakdown by primary technical complexity[1]



1) A number of discoveries have more than one challenge associated with them. For the purposes of this document, the OGA has allocated a single 'primary' challenge to each discovery
2) Classified according to the primary reason of reservoir complexity, based on 2016 PARS analysis

The majority of the unplanned contingent resources are licensed to operators which do not fall into the Leaders category. Therefore more collaboration is required between operators to test and de-risk these technologies. In addition, access to additional sources of funding (from the OGTC and, potentially, vendor financing) will be very important to accelerate deployment.



4. Conclusions and next steps

Responses to the technology section of the UKCS Stewardship Survey highlighted the strong industry awareness of technology to support operators' plans and deliver MER UK.

However, different disciplines are receiving different emphasis.

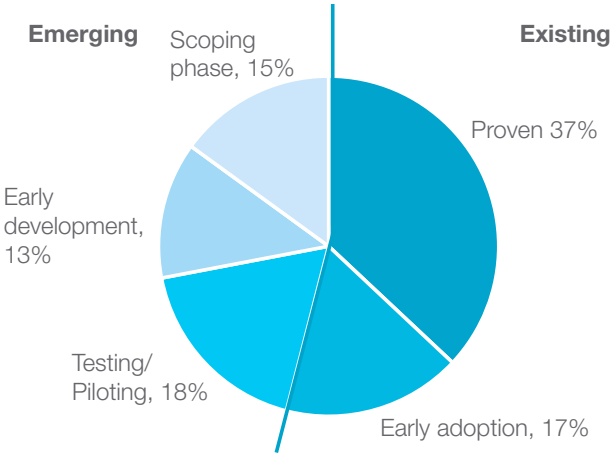
Technologies to support exploration, for example, are widely available through the innovative UK supply chain, and there is significant investment made by larger operators on novel technologies for asset inspection and maintenance.

Slower progress, instead, is being made in adopting technologies to make the development of marginal oil and gas resources more viable.

It is also clear that there is considerable potential for the wider adoption of existing technologies, while emerging technologies can provide strong export potential for the UK supply chain.

Over 45% of the technologies in the operators' plans are at concept stage or under development. However, only 28% of the UKCS operators invest directly in technology developments and R&D spend has declined, overall, by 36% since 2014. There is a risk that the full development cycles of novel technologies are delayed and recovery of UKCS hydrocarbons is not maximised.

Operators' Plans – Technologies by Maturity



The OGA is playing an increasingly active role in supporting operators to share knowledge and experience in deploying these technologies, in order to help lower the perceived technology risk, maximise uptake and achieve MER UK.

In Q2 2018, the OGA will hold a 'Tier Zero' review with the managing directors of 22 operators which will include a discussion on technology plans.

The OGA is working with individual operators through the asset stewardship programme (tiered reviews) to explore where technology solutions (existing or emerging) can assist operators and where lessons can be shared with industry.

Working with the TLB, the OGA is contributing to develop a shared technology strategy for the UKCS, supporting Vision 2035[1], and developing a forum of industry technology leaders to facilitate communication on technologies and sharing experience.

1) https://www.ogauthority.co.uk/about-us/vision-2035/

The OGTC is driving industry to accelerate priority technologies through the development and piloting phases. The OGA is continuing to work closely with the OGTC to identify and promote technology investment for MER UK, supporting specific OGTC projects as needed.

Technology Stewardship - 2018

- 2017 Stewardship Survey – submission amendments (end Q1)
- OGA Tier Zero review, with managing directors from the top 22 operators, including discussion of technology plans feedback (Q2)
- Update Technology Insights (Q3)
- Operator review meetings to address technology opportunities in their asset portfolios (ongoing 2018)
- Working with the TLB to support a shared UKCS technology strategy and a forum of industry technology leaders (ongoing 2018)
- Working with the OGTC to promote development and deployment of critical technologies for MER UK (ongoing 2018)

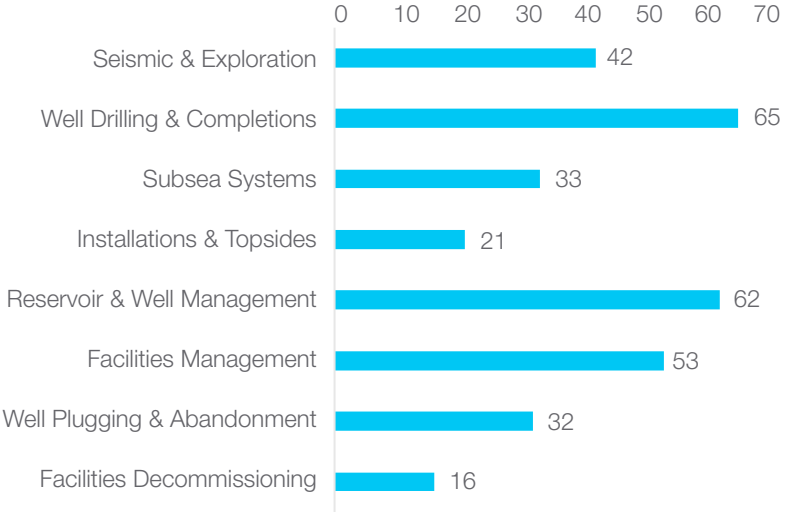
APPENDIX

A. Technology Plans details

Operators cumulatively listed 324 technology solutions covering the entire asset lifecycle from exploration to decommissioning.

In the following sections, the aggregated content of the operators' technology plans is broken down by the eight disciplines as described in this chart.

Operators' Plans – Technologies by discipline (total = 324)



A.1 Seismic and exploration

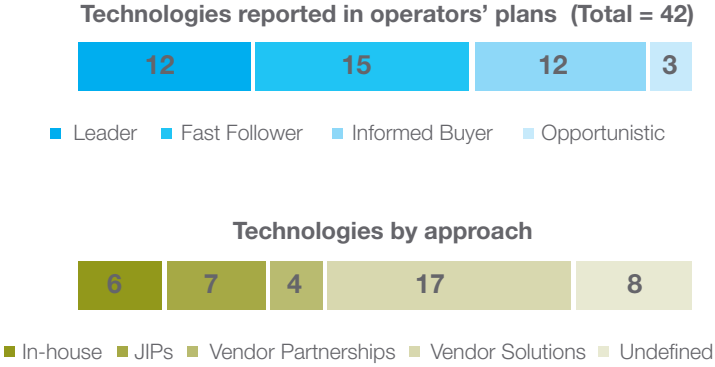
Technologies for seismic and exploration enjoy a broad interest across UKCS operators, with 21 companies citing 42 technologies in their plans.

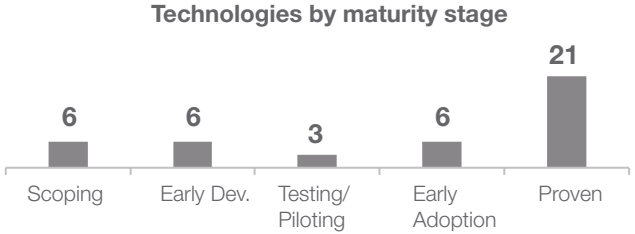
These fulfil a range of objectives, including:

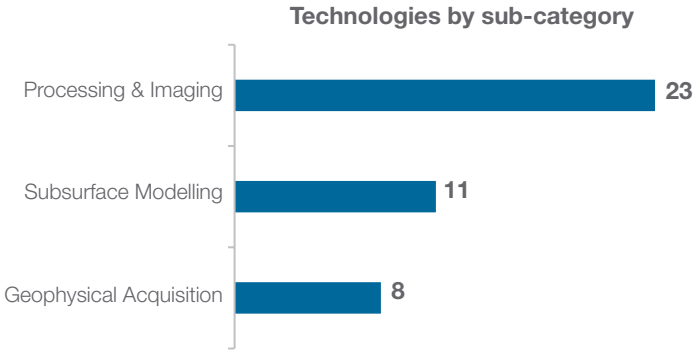
- Explore in frontier areas and deeper/ more complex prospects
- De-risk more complex discoveries for their cost effective development
- Extend/optimise hydrocarbon recovery from legacy fields

Leading operators are directly involved in the development of technologies for seismic and exploration, often considering this a source of competitive advantage. However the majority of the technologies in this area are provided directly by the innovative UK supply chain and/or through partnerships.

Technologies for exploration listed in the operators' plans are generally available or at a mature stage of development. However, there are also emerging technologies considered for survey acquisition, inversion and geoscience modelling.

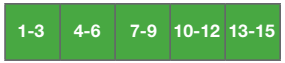

Technologies reported in operators' plans (Total = 42)
12
15
12
3
Leader
Fast Follower
Informed Buyer
Opportunistic
Technologies by approach
6
7
4
17
8
In-house
JIPs
Vendor Partnerships
Vendor Solutions
Undefined


Technologies by maturity stage
6
6
3
6
21
Scoping
Early Dev.
Testing/ Piloting
Early Adoption
Proven

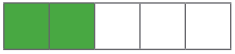

Technologies by sub-category
Processing & Imaging
23
Subsurface Modelling
11
Geophysical Acquisition
8

Seismic and exploration technologies: detail

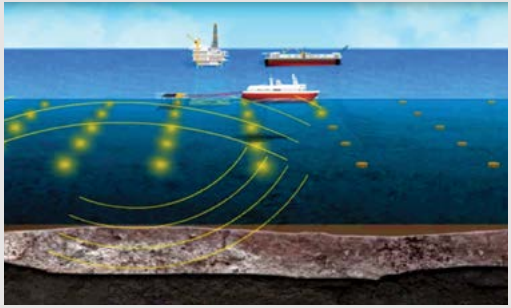
SEISMIC AND EXPLORATION		
Application	**Technologies**	**Frequency (0 to 15)**
Geophysical Acquisition	Operators have used the latest 3D broadband seismic technology provided by vendors in order to illuminate and derisk difficult prospects, and identify incremental opportunities around legacy fields. Additional acquisition technologies have proven useful in special cases: - Ocean Bottom Nodes (OBN) - Electromagnetic surveys - Look ahead vertical seismic profile There is an opportunity for operators to share experience about the above technologies, their applicability and benefits of different acquisition techniques as well as opportunities to collaborate with the supply chain on these.	
Processing & Interpretation	Latest processing technologies include: - Spectral amplitude variation with offset (AVO) - Prestack waveform inversion - Fullwave (FWI) - Mix discrete and continuous inversion - Hybrid techniques combining seismic with other geological information. In addition, operators are also reprocessing legacy seismic with modern techniques. There are high opportunities for sharing and further technology development.	



Frequency is defined as the number of operators plans where technologies are listed, and graphically reported by the sliding scale in the table. Each segment of the scale corresponds to up-to 3 operators

SEISMIC AND EXPLORATION		
Application	**Technologies**	**Frequency (0 to 15)**
Subsurface Modelling	There is ongoing utilisation by operators of: - Advanced depositional models to improve interpretation - Integrated geo-mechanical and fluid dynamic models - Advanced structural models (e.g. fault seal) In addition, emerging and specialised applications also include: - Turbidite modelling - Sand injectites - Data analytics and decision support software to improve interpretation and reduce cycle time. Significant scope to share lessons learnt.	
Time-lapsed seismic (4D)	Operators are increasingly using 4D seismic to maximise recovery from legacy fields. - Leveraging the most advanced 3D broadband and inversion techniques - Integrating reservoir modelling and seismic processing - Considering use of OBN (to be positioned near structures and for repeatability) There are both high sharing and development opportunities for these technologies (e.g. through JIPs and working with academia)	

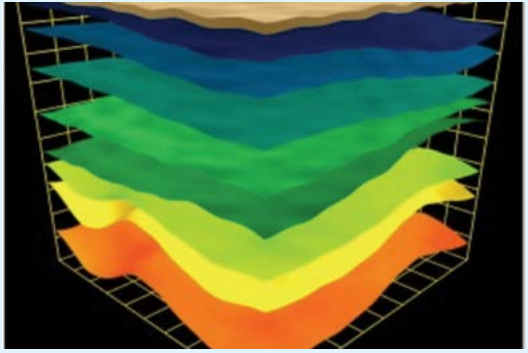
Existing technology: Ocean-bottom nodes



Picture courtesy of Chevron Corporation

Ocean bottom nodes were first deployed in the North Sea in the 1990s and now new technology enhancements are making them more capable and easier to deploy. By placing hundreds of these small units on developed fields or new discoveries, operators can obtain cleaner and clearer data and structural images, helping to better estimate a reservoir's potential and/or helping resolving more difficult targets (e.g. sub-basalt). OBNs can be deployed close to existing facilities including platforms and pipelines and have the ability to record data continuously over an extended time period.

Emerging technology: Advanced inversion techniques and 4D



Picture courtesy of ITF & Imperial College London

Following advances in algorithms and computing power, operators are now able to obtain significantly more value from their seismic survey recordings. In particular, when applied to time-lapse (4D) seismic surveys full-wave inversion (FWI) can help provide high definition subsurface images. As a result, operators are better able to identify smaller oil and gas targets and make significant development and production efficiencies.

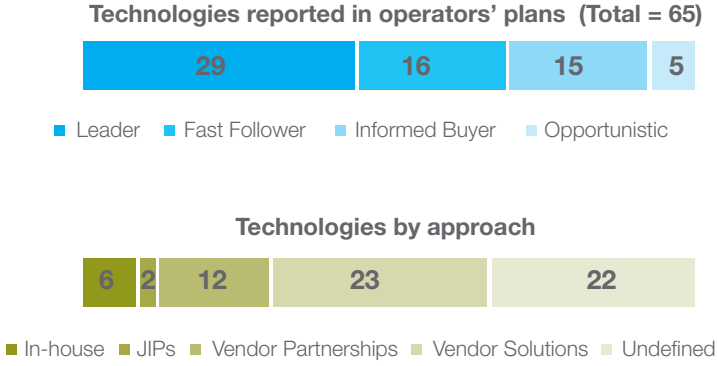
A.2 Well drilling and completions

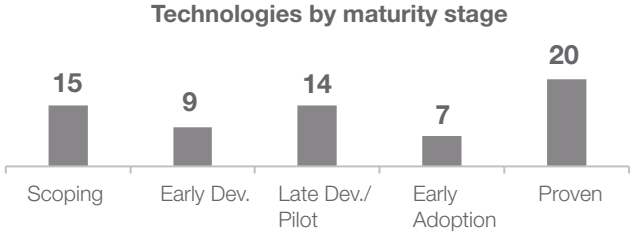
24 operators listed 65 well drilling and completions technologies in their plans. These were evenly distributed across all operators groups, reflecting a broad industry interest in reducing well costs and improving well value.

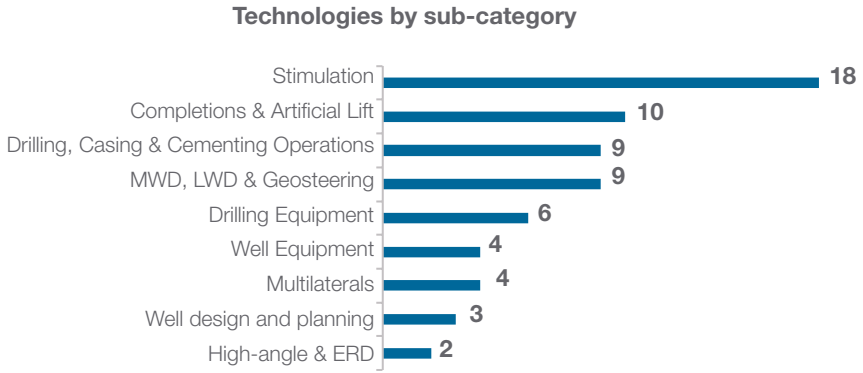
Operators aim to use these technologies in order to:

- Achieve cost efficiencies (e.g. through enhanced work practices, design simplification and alternative drilling strategies)
- Develop more complex fields (e.g. HPHT and tight reservoirs)
- Create more valuable wells (e.g. improve reserves per well and production rates)

A number of these technologies are provided by the established UK supply chain or being developed in partnership with operators.

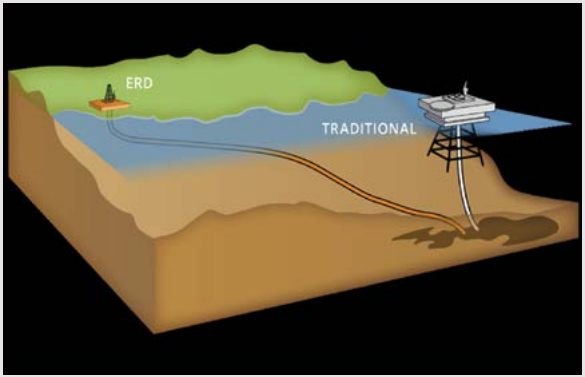

Technologies reported in operators' plans (Total = 65)
29
16
15
5
Leader
Fast Follower
Informed Buyer
Opportunistic
Technologies by approach
6
2
12
23
22
In-house
JIPs
Vendor Partnerships
Vendor Solutions
Undefined


Technologies by maturity stage
15
9
14
7
20
Scoping
Early Dev.
Late Dev./ Pilot
Early Adoption
Proven


Technologies by sub-category
Stimulation
18
Completions & Artificial Lift
10
Drilling, Casing & Cementing Operations
9
MWD, LWD & Geosteering
9
Drilling Equipment
6
Well Equipment
4
Multilaterals
4
Well design and planning
3
High-angle & ERD
2

Existing technologies include:

- Cost effective extended reach drilling providing access to potentially stranded reserves
- Multilateral completions providing cost and recovery benefits
- Geosteering for accurate well placement (e.g. in the development of thin reservoirs)
- Artificial lift solutions for demanding environments and improved reliability



Picture courtesy of Merlin ERD

Extended reach/high angle drilling is a successful and well established technology under used in the UKCS. It enables economic access to stranded reserves in mature fields and reduces overall development capex for new fields. Derisking these techniques through wider knowledge sharing and the use of good practices would increase deployment of this technology.

Emerging technologies aim at extending drilling capabilities, and/or reducing well costs:

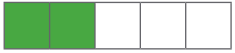
- Advanced and enhanced managed pressure drilling to reduce reservoir damage and drill tight-margin wells
- Thermal treatment of drilling cuttings allowing for local discharge
- Drill automation, sensors and data analytics to improve safety and efficiencies (e.g. to prevent stuck pipe)

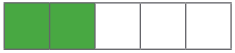
Picture courtesy of BP plc 2018

Increasing adoption of automated drilling processes have potential cost and safety benefits. Digital technologies which integrate data from a wide range of tools and processes have already introduced many efficiencies in oilfield operations and provided gains in both well drilling and completions as well as recovery and production. Looking ahead, data analytics combined with automated technologies that are currently under development, have the potential to deliver greater efficiency.

Well drilling and completions Existing technologies

WELL DRILLING AND COMPLETIONS - HIGH ANGLE, ERD, MULTILATERALS & OTHER EFFICIENT DESIGNS		
Application	**Technologies**	**Frequency (0 to 15)**
High angle and ERD and other designs	- ERD best practices - Vertical monobores	
Multilaterals	- State of the art multilateral designs and execution	

WELL DRILLING AND COMPLETIONS - MWD, LWD and GEOSTEERING		
Application	**Technologies**	**Frequency (0 to 15)**
Geosteering	- Deep resistivity tool, high end logging-while-drilling, real-time scanning	

WELL DRILLING AND COMPLETIONS - COMPLETIONS AND ARTIFICIAL LIFT		
Application	**Technologies**	**Frequency (0 to 15)**
Artificial lift	- Algorithm optimisation for control and monitoring of ESPs, increased reliability - Downhole jet pump for low flow and pressure wells - Gas lift modelling.	

Well drilling and completions Existing technologies

WELL DRILLING AND COMPLETIONS - STIMULATION		
Application	**Technologies**	**Frequency (0 to 15)**
Stimulation	- Optimised proppants - Improved drop ball sleeve system - Contingency technologies (milling, fishing) - Dissolvable casing plugs - Slimline drilling - Acid fracturing developments - Green frac fluids - Stimulation guns - Novel penetration technology	

Well drilling and completions New and emerging

WELL DRILLING AND COMPLETIONS - DRILLING EQUIPMENT AND OPERATIONS		
Application	**Technologies**	**Frequency (0 to 15)**
Rig and drilling equipment	- Wired drill pipe - Drill pipe tracking (RFID) - Surface BOP (Deepwater MODU)	
Mud, processing and treatment	- Thermal processing systems - Thermal handling of cuttings with a rotomill system	
Advanced drilling techniques and automation	- Automated managed pressure drilling - Riserless mud recovery - Designer muds - Bit collision detection - Automated drilling - Automated pressure and leak detection - Advanced model predictive tools updated in real-time - Algorithm development for enhanced autonomy - Simultaneous drilling operations	

Well drilling and completions New and emerging

WELL DRILLING AND COMPLETIONS - MWD, LWD and GEOSTEERING		
Application	**Technologies**	**Frequency (0 to 15)**
Advanced geosteering	- Looking ahead of the bit - Real time monitoring - Ultra deep resistivity - Next generation telemetry	

WELL DRILLING AND COMPLETIONS - COMPLETIONS AND ARTIFICIAL LIFT		
Application	**Technologies**	**Frequency (0 to 15)**
Specialised completions	- High horsepower, high temperature pumps - Coiled tubing ESP - Electric submersible twin screw pump - High temperature completion steam injection - High temperature steam injection safety valve	

A.3 Subsea systems

20 operators, primarily large and medium-size companies, listed 33 technologies for subsea systems.

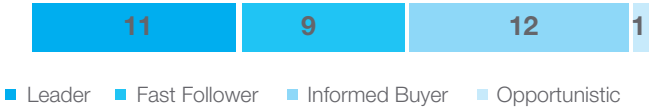
These aim at achieving:

- Cost efficiencies (Capex and Opex)
- Greater system capabilities to deal with the more complex requirements of future field developments

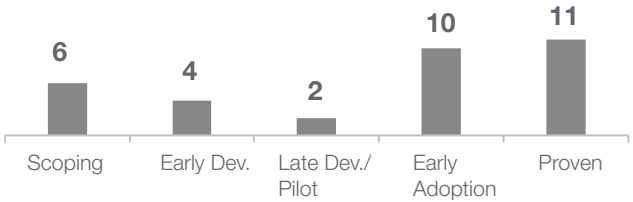
Operators can rely on an active and innovative UK supply chain developing and offering subsea solutions in this space, and the majority of technology projects have vendors' participation.

Operators' interest is concentrated on existing technologies (at early adoption of proven stages) and therefore able to be readily incorporated into projects, with fewer cases of emerging technologies, such as composite pipes and subsea storage.

Technologies reported in operators' plans (Total = 33)

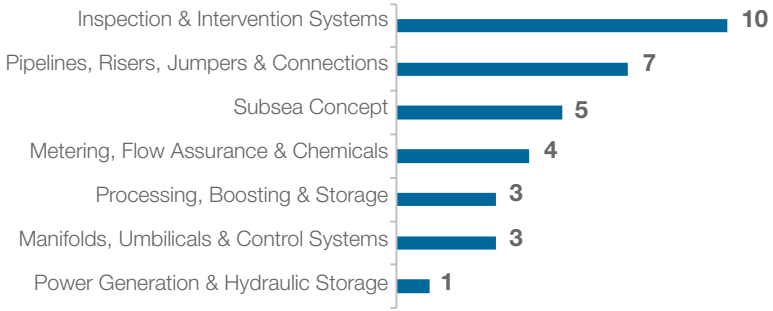


Technologies by maturity stage



Technologies by approach

Technologies by sub-category



Existing technologies include:

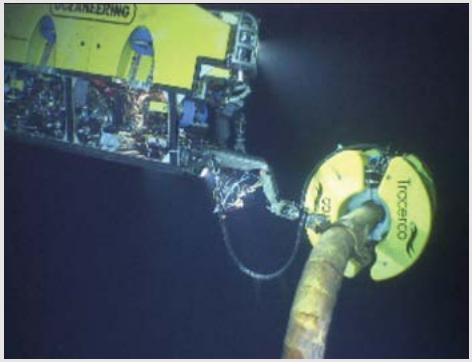
- Mechanically connected pipelines
- Intelligent pigging systems
- Use of RoV based tools such as CT scanners and automated weld inspections

Operators believe that emerging technologies have a role to play to improve overall development economics.

- Capex reduction - focus on lower cost subsea schemes for developments, e.g. efficient tie-backs, alternative pipelines, riser and umbilical systems, local power generation
- Opex reduction – advanced flow assurance modelling, riser and pipeline pigging, inspection, monitoring and cleaning, control system monitoring and repair
- Subsea storage (possibly combined with unmanned facilities)

Picture courtesy of EC-OG

Harnessing renewable energy subsea has the potential for a range of subsea applications, having low installation and maintenance costs. For example, local power for instrumentation, alternative power source during outages or maintenance programmes, during umbilical replacement and decommissioning. Furthermore, subsea infrastructure can be provided with localised power that could support cost effective developments and/or maintain existing facilities.

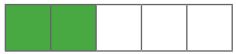


Picture courtesy of Tracerco

Cost effective and reliable pipeline and riser inspection has been a key challenge for operators. In response, a number of technologies and techniques have been developed and deployed, for example intelligent pigging, pulsed eddy current and magnetic eddy current tools. A recent development is a computed tomography (CT) scanner, a technology widely used in the medical sector, which can be used on subsea coated pipe. Its development is an example of co-operation between operators and the supply chain and it also demonstrates how a mature technology from one industrial sector can be developed for use in another.

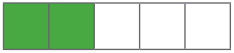
Subsea systems Existing technologies

SUBSEA SYSTEMS - FLOW ASSURANCE, INSPECTION AND INTERVENTION		
Application	**Technologies**	**Frequency (0 to 15)**
Flow assurance	- Proactive modelling and intelligent interventions (optimise well bean-ups and production chemical usage) - Drag reduction agents - Heated flowlines	
Riser and pipeline inspection	- Subsea computed tomography (CT) inspection scanner - intelligent inspection tools/pigging (tethered/untethered) - Magnetic eddy current, pulsed eddy current	

SUBSEA SYSTEMS - EFFICIENT CONCEPTS		
Application	**Technologies**	**Frequency (0 to 15)**
Efficient tie-back design	- Project execution models (simplified and fit for purpose) - Optimised design (design, manufacture and fabrication, installation and scheduling)	
Subsea boosting and processing	- Subsea multi-phase booster - Subsea cooling loop	

Subsea systems New and emerging

SUBSEA SYSTEMS - FLOW ASSURANCE, INSPECTION AND INTERVENTION		
Application	**Example Technologies**	**Frequency (0 to 15)**
Autonomous inspection & cleaning	- Underwater autonomous vehicles - ROV mounted time of flight inspection equipment	
Subsea control monitoring & repair	- Subsea umbilical monitoring and active healer - Subsea electrical testing - Diverless control line repair	
Flow assurance	- Frictionless pipe lining - Emerging chemical or mechanical technological options for heavy oil	

SUBSEA SYSTEMS - PIPELINES, MANIFOLDS, UMBILICALS AND CONTROL SYSTEMS		
Application	**Example Technologies**	**Frequency (0 to 15)**
Subsea controls	- Umbilical less solutions (all electric controls) - High integrity pressure protection system (HIPPS)	
Pipelines, risers and umbilicals	- Composite and spoolable pipe - Reusable pipes - Hybrid umbilical (steel and thermoplastic) - Deep/harsh water umbilicals	

SUBSEA SYSTEMS - EFFICIENT STANDALONE FACILITIES		
Application	**Example Technologies**	**Frequency (0 to 15)**
Facilities and utilities	- Subsea power hub (turbine/battery) - Thermal energy regeneration - Subsea oil storage tanks - Subsea production buoy - Subsea storage unit	

A.4 Installations and topsides

13 operators listed 21 technology opportunities within installations and topsides. Interest in the development and deployment of supporting technologies is primarily distributed among operators of medium size, reflecting the asset ownership profile.

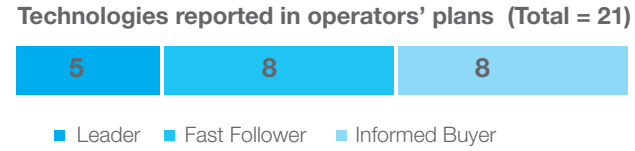
Operators see opportunities to leverage technology to make installations:

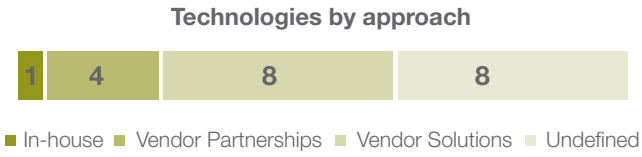
- More efficient (e.g. inspection and monitoring techniques, automation, improved reliability (e.g. turret systems) and use of unmanned facilities for Opex efficiency, use of innovative platforms and floating facilities to reduce Capex)
- Capable to deal with multiphase fluids (metering), oil in water measurement and produced water treatment

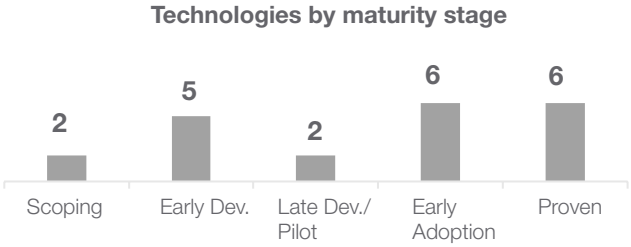
Operators can rely on an active and innovative supply chain developing and offering solutions in this space and the majority of technology projects have relied on vendors' participation.

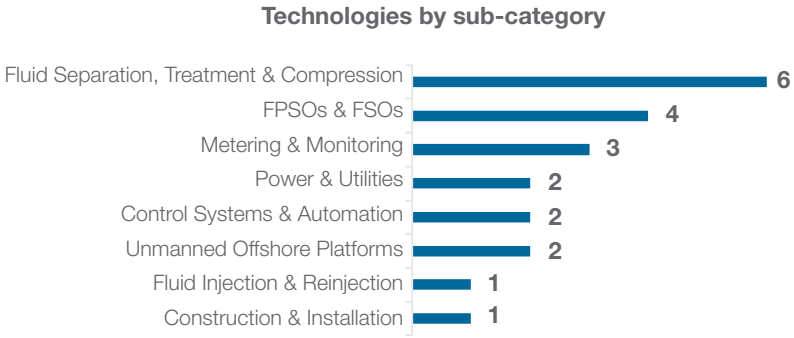
Operators' technology interest is more focused towards mature and late-stage development technologies, which are able to be incorporated into upcoming project opportunities.

There are emerging technologies (e.g. dynamically positioned FPSOs, small-scale unmanned platforms and alternative small-scale fluid separation and processing solutions) which may fit reasonably short deployment timelines.


Technologies reported in operators' plans (Total = 21)
5
8
8
Leader
Fast Follower
Informed Buyer


Technologies by approach
1
4
8
8
In-house
Vendor Partnerships
Vendor Solutions
Undefined


Technologies by maturity stage
2
5
2
6
6
Scoping
Early Dev.
Late Dev./ Pilot
Early Adoption
Proven


Technologies by sub-category
Fluid Separation, Treatment & Compression
6
FPSOs & FSOs
4
Metering & Monitoring
3
Power & Utilities
2
Control Systems & Automation
2
Unmanned Offshore Platforms
2
Fluid Injection & Reinjection
1
Construction & Installation
1

Existing technologies sourced from the supply chain include:

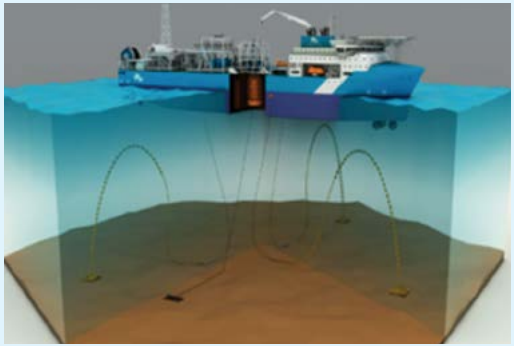
- Low cost platforms
- Normally unattended installations (NUIs)
- Multiphase metering (including ‘virtual’)
- Small scale produced water treatment technologies

There is interest in emerging technologies to improve development economics:

- Remote facilities monitoring and greater use of automation
- Innovative and efficient floating production systems
- Extended-life FPSO turret systems (to improve reliability and minimise downtime)
- Multiphase metering systems with improved accuracy
- Metering systems for heavy oil systems

Picture courtesy of EverSea NV (DEME-group)

Fixed platform costs can have a significant impact on development economics. The use of unmanned platforms can offer a low cost alternative coupled with reduced operating costs. This technology solution is supported by low cost water treatment technologies and efficient tieback solutions. A recent 4-slot reusable platform was installed in the Dutch sector of the North Sea as a low cost alternative to traditional platform solutions.



Picture courtesy of Amplus Energy

The industry has historically relied on subsea tiebacks and the use of moored floating facilities for field development solutions. Emerging technologies such as small scale dynamically positioned floating production units and unmanned production buoys could provide low cost alternatives. These technologies are not reliant on existing infrastructure and are well suited for redeployment and re-use applications including clustering. Potential to reduce initial investment capital coupled with reduced operating costs could be an important enabler for marginal and remote discoveries.

Installations & Topsides Existing technologies

INSTALLATIONS & TOPSIDES - EFFICIENT INSTALLATIONS		
Application	**Technologies**	**Frequency (0 to 15)**
Fixed Platforms	- Platform re-use - NUIs - Slim platforms - Redeployable platform	
FPSOs & FSOs	- Turret system capable of long service life (deepwater, harsh environment) - Qualification of polyester mooring lines	

INSTALLATIONS & TOPSIDES - FLUID SEPARATION AND TREATMENT		
Application	**Technologies**	**Frequency (0 to 15)**
Water separation efficiency and reliability	- Modified cyclone inlet separator - Simplified process for heavy oil	

INSTALLATIONS & TOPSIDES - METERING, MONITORING & CONTROL SYSTEMS		
Application	**Technologies**	**Frequency (0 to 15)**
Facilities monitoring and automation	- NUI wireless instrumentation - Automation and remote monitoring	
Metering	- High accuracy gas metering - Multiphase metering of heavy oil - Online oil in water measurement - Virtual metering - Guided wave	

Installations & Topsides Emerging technologies

INSTALLATIONS & TOPSIDES - EFFICIENT FLOATING INSTALLATIONS		
Application	**Technologies**	**Frequency (0 to 15)**
Innovative floaters	- Low cost simplified FPSOs - Dynamically positioned FPSOs - Mini-FPSO	

INSTALLATIONS & TOPSIDES - PROCESSING AND UTILITIES		
Application	**Technologies**	**Frequency (0 to 15)**
Water treatment & utilities	- Compact NUI deployable systems - Local discharge capability - Urea NOX reduction technology	

A.5 Reservoir and well management

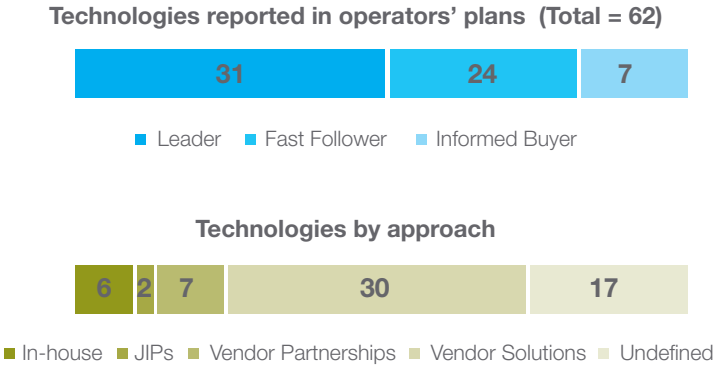
19 operators listed 62 technology opportunities within reservoir and well management. Interest in the development and deployment of supporting technologies is mainly focused on by large operators. Interest from medium sized operators is also strong. There was a lack of reported well management technologies.

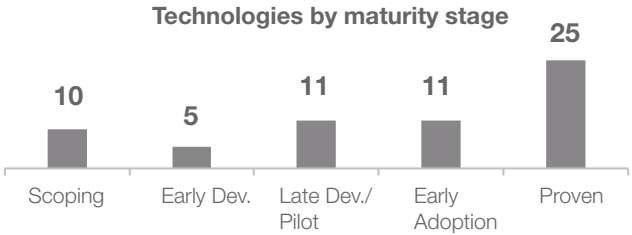
Operators use technologies to support their reservoir and well management objectives of:

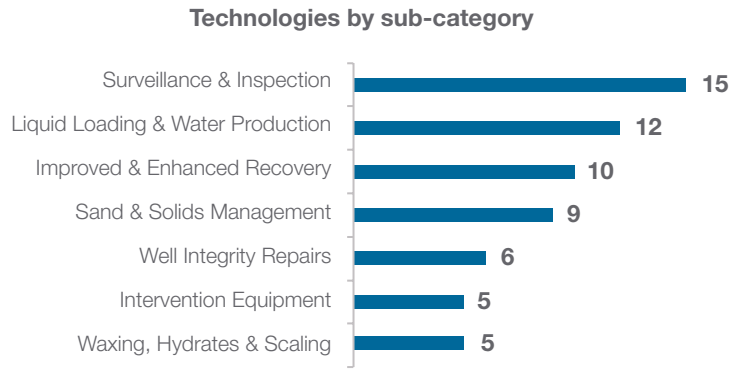
- Production optimisation (e.g. well performance monitoring, EOR)
- Support maintenance, integrity, safety and uptime goals (e.g. sand control, scale management, pressure integrity)

Operators have an established and engaged supply chain to work with for reservoir and well management technologies. This provides the majority of technology solutions, most of which are proven technologies.

In addition, there are some technologies that are at an early commercial stage with others undergoing scoping in-house by the operator (e.g. EOR and data analytics).


Technologies reported in operators' plans (Total = 62)
31
24
7
Leader
Fast Follower
Informed Buyer
Technologies by approach
6
2
7
30
17
In-house
JIPs
Vendor Partnerships
Vendor Solutions
Undefined


Technologies by maturity stage
10
5
11
11
25
Scoping
Early Dev.
Late Dev./ Pilot
Early Adoption
Proven


Technologies by sub-category
Surveillance & Inspection
15
Liquid Loading & Water Production
12
Improved & Enhanced Recovery
10
Sand & Solids Management
9
Well Integrity Repairs
6
Intervention Equipment
5
Waxing, Hydrates & Scaling
5

Existing technologies include:

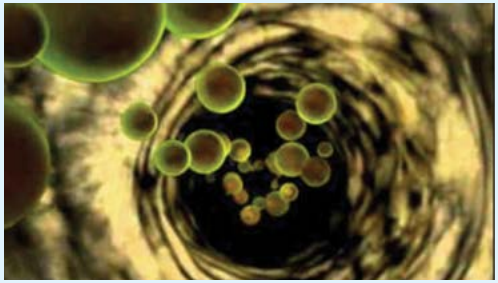
- Well monitoring to provide reservoir productivity increases
- Digital oilfield based technologies, capable of exploiting the large quantity of available data
- Produced water and sand controls to optimise production
- Well intervention tools and execution methodologies

Emerging technologies can contribute to further production optimisation and increase hydrocarbon recovery, including:

- Cost effective monitoring capabilities, exploiting new sensor technology and data analytics
- EOR development and investigation of further utilisation opportunities
- Improved sand control technology and alternative approaches
- Water production tracing and remediation using intelligent tracers and alternative shut off methods

Picture courtesy of Ziebel AS

Monitoring is an essential activity to ensure that wells are performing optimally, providing inflow profiling, breakthrough detection, hydraulic fracture monitoring and integrity verification. To support this need there are a number of enabling technologies that can help provide effective and real time well performance monitoring. Examples include the use of fibre optic, deployed by composite carbon rods or disposable one trip tools.



Picture courtesy of Baker Hughes GE

Enhanced Oil Recovery (EOR) can play a significant role in MER UK by increasing the recovery volumes, extending field life, helping stimulate field redevelopments and deferring decommissioning activities. A joint industry task group has compiled lessons learned from polymer EOR projects, benefiting future project development. Furthermore, the use of low salinity waterflood West of Shetland is the first instance of EOR deployment from the beginning of operations, whilst the use of miscible gas has proved useful for field regeneration elsewhere in the UKCS. Offshore EOR is more costly than conventional water flood schemes, but cost efficiencies and knowledge sharing have the potential to increase the uptake of EOR.

Reservoir and well management Existing technologies

RESERVOIR AND WELL MANAGEMENT - PRODUCTION MANAGEMENT		
Application	**Technologies**	**Frequency (0 to 15)**
Well Deliquification	- Velocity string - Foamer technologies	
Produced water treatment	- Membrane ultra filtration - Chemical solutions	
Sand control	- Oil based gravel packing - Sand clean out (CT tool) and repair - Chemical solutions - Screen modification	

RESERVOIR AND WELL MANAGEMENT - INTERVENTION EQUIPMENT AND EXECUTION		
Application	**Technologies**	**Frequency (0 to 15)**
Intervention methodologies and tools	- Coiled tubing - Lightweight slickline - HPHT equipment - Extend technical limits for LWIV (harsh/deep) for subsea well access	

RESERVOIR AND WELL MANAGEMENT - SURVELLIANCE AND INSPECTION		
Application	**Technologies**	**Frequency (0 to 15)**
Well & reservoir monitoring	- Fibre optics - Carbon fibre rods - Smart well - 'B' annulus for subsea - Digital oil field technologies & practices	

Reservoir and well management Emerging technologies

RESERVOIR AND WELL MANAGEMENT - IMPROVED AND ENHANCED RECOVERY		
Application	**Technologies**	**Frequency (0 to 15)**
EOR	- Low cost Polymer - Continuous injection - Low salinity & designer waters - Combination EOR	
Water Production Tracing	- Intelligent tracers - Gas tracers	
Water Production Remediation	- Gloop substances - Alloy plug	
Advanced Sand control	- HPHT ceramic screens - Multilateral gravel pack - Rattling screens - Bullhead	

RESERVOIR AND WELL MANAGEMENT - SURVELLIANCE AND INSPECTION		
Application	**Technologies**	**Frequency (0 to 15)**
Advanced well monitoring	- Acoustic sensing - HPHT sensors - Fibre optic DAS/DTS - Data analytics - Logging drones	

A.6 Facilities management

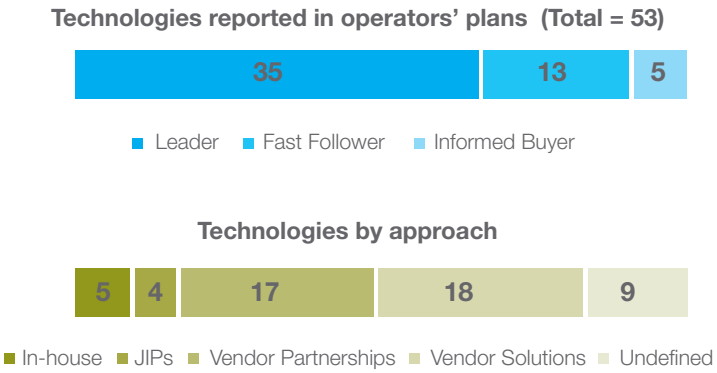
15 operators listed 53 technology opportunities within facilities management. This is a priority for larger companies, which operate the majority of UKCS legacy assets.

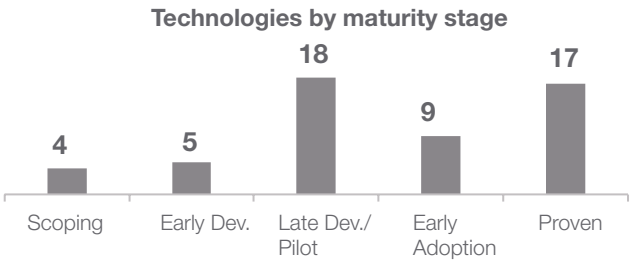
Objectives:

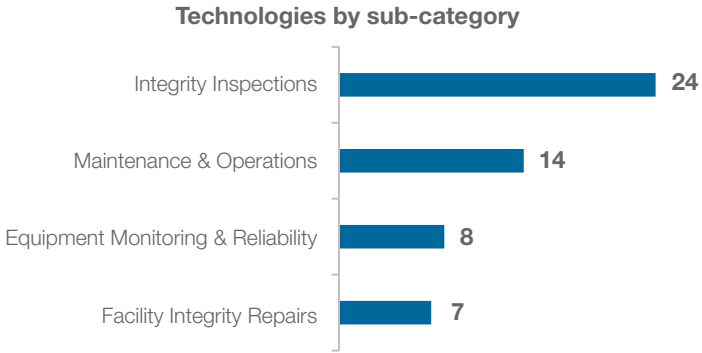
- Increase production efficiency by reducing the time for planned and unplanned inspections and maintenance
- Reduce Opex related to maintenance and operations
- Improve safety through better inspections techniques and reducing the need for exposure to hazards

While relying on an experienced supply chain for the deployment of inspection and maintenance technology, operator plans show that operators (larger ones in particular) are directly involved in R&D and/or piloting of technologies in this area.

Operators directly invest in technologies (e.g. for non-intrusive inspections and for the use of robotics/ autonomous systems) often collaborating with other operators and/or vendors in R&D and piloting.


Technologies reported in operators' plans (Total = 53)
35
13
5
Leader
Fast Follower
Informed Buyer
Technologies by approach
5
4
17
18
9
In-house
JIPs
Vendor Partnerships
Vendor Solutions
Undefined


Technologies by maturity stage
4
5
18
9
17
Scoping
Early Dev.
Late Dev./ Pilot
Early Adoption
Proven


Technologies by sub-category
Integrity Inspections
24
Maintenance & Operations
14
Equipment Monitoring & Reliability
8
Facility Integrity Repairs
7

Operators have been steadily upgrading technologies used in facilities management and introducing innovative techniques, sometimes imported from other industries.

Examples of existing technologies include:

- Digital operations, connecting offshore to shore and automation
- Wearable, wireless technologies supporting inspection, planning and maintenance operations
- Predictive maintenance systems
- Robotics for hard-to-reach area inspection

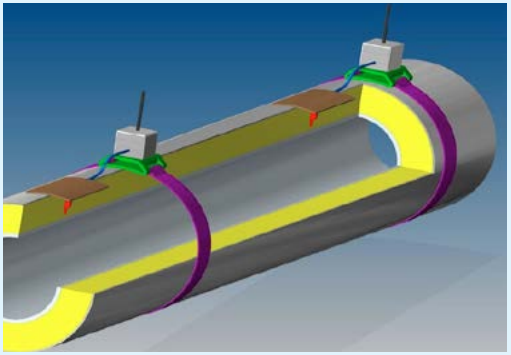
Operators are also pursuing novel technologies which may radically improve facilities management.

These include:

- Corrosion under insulation (CUI) - technologies to detect and monitor CUI using a combination of acoustics, electro-magnetic, visual imaging and x-ray techniques
- Vessel and tank unmanned inspection - technologies and supporting sensors to provide inspection services in confined and dangerous space without requirement for manned entry
- Advanced robotic and autonomous inspection - research and develop the next generation of systems that are able to inspect and monitor assets in increasingly challenging areas above and below the waterline.

Picture courtesy of Sky-Futures Ltd

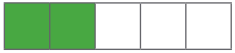
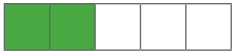
The use of drones is increasingly becoming established in the offshore environment. These systems are developing to be more capable, having increasing flight duration and wider payload options. They are being utilised in more challenging conditions providing operators with faster response times to their survey needs and thereby supporting quicker and more knowledgeable decision making.

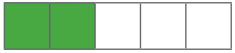


Picture courtesy of 3-Sci

A number of corrosion detection and monitoring technologies are currently under development and trial, including ultrasonic, time of flight diffraction, digital x-ray and real time radiography. The exploitation of these technologies will be further enabled by the advances in robotic and autonomous systems. New technologies will provide operators with more reliable and immediate knowledge about their assets conditions and allow for pre-emptive remediation. As a result significant safety and cost benefits will be delivered.

Reservoir and well management Existing technologies

FACILITIES MANAGEMENT - INTEGRITY INSPECTION AND REPAIRS		
Application	**Technologies**	**Frequency (0 to 15)**
Hard to reach areas inspection and surveying	- Drones. Inspection of hard-to-reach areas, e.g. unmanned satellites, flare tips, etc. - Use of NDT technologies - Small bore pipe inspection - Thermal imaging cameras for leak detection - Digital surveying utilising visualisation and imaging techniques, laser scanning	
Corrosion prevention and monitoring	- Impressed current Cathodic Protection - Real time corrosion monitoring - Time of Flight Diffraction" (TOFD) ultrasonic, digital DR X-Ray radiography and real time radiography - Corrosion inhibitor effectiveness and monitoring systems - Scavenger optimisation - Pipeline corrosion monitoring system	
Composite repair and verification	- JIPs - Vendors solutions	

FACILITIES MANAGEMENT - OPERATIONS AND MAINTENANCE		
Application	**Technologies**	**Frequency (0 to 15)**
Digital operations	- Virtual control rooms and virtual coordination - Mobile field computing/tablets - 4G wireless and wearable technology - Remote witnessing - Walk to work	

Reservoir and well management Emerging technologies

FACILITIES MANAGEMENT - INTEGRITY INSPECTION AND REPAIRS		
Application	**Technologies**	**Frequency (0 to 15)**
Robotic and autonomous inspection	- Modular ROVs/AUVs - Live offshore drone inspection - Robotic arms - Beyond visual sight drones for inspection and monitoring NUI and remote assets	
Tank and internal vessel inspection without entry	- Phased array ultrasonic, automated scanning systems, “Time of Flight Diffraction” (TOFD) and laser scanning	
Advanced corrosion prevention and monitoring	- Internal, external and corrosion under insulation technologies. e.g. Pulsed eddy current, scanning radiography and long range UT techniques, atomic magnetometers	

FACILITIES MANAGEMENT - EQUIPMENT MONITORING AND RELIABILITY		
Application	**Technologies**	**Frequency (0 to 15)**
Predictive maintenance	- High-end advanced fault analytics algorithms leveraging operational data for equipment failure prediction. (inc. rotating equipment)	

FACILITIES MANAGEMENT - OPERATIONS AND MAINTENANCE		
Application	**Technologies**	**Frequency (0 to 15)**
Cleaning and preparation	- Dry ice blasting (no requirement for encapsulation or grit blasting) - Mechanical and chemical equipment cleaning methodologies (e.g. heat exchangers)	

A.7 Well plugging and abandonment

12 operators listed 32 technology opportunities within plugging and abandonment (P&A). Interest in P&A is more concentrated with large and medium size operators, who hold the greatest share of well stock to be abandoned.

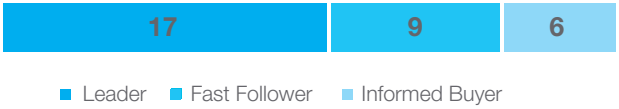
These companies saw clear opportunities through technology to:

- Support planning optimisation
- Make the process of well abandonment more cost effective (e.g. well inspection and confirmation of cement condition, casing removal, barrier placement)
- Introduce alternative approaches to P&A (e.g. the use of Light Well Intervention Vessel (LWIVs), barrier technologies)

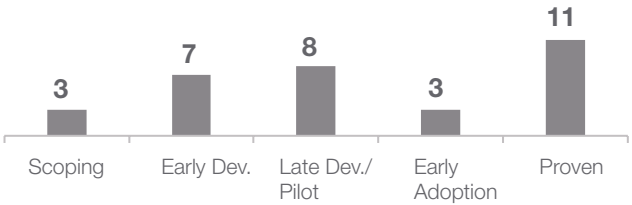
Operators have worked closely with the supply chain and rely on its support in developing and offering solutions for P&A applications. The majority of technology projects have relied on vendors' participation and joint industry projects have supported technology development.

Operators have a large share of technologies under development compared with other segments. This reflects the growing interest in the benefits of technology in this area and its contribution to lower the overall UKCS P&A cost estimate.

Technologies reported in operators' plans (Total = 32)

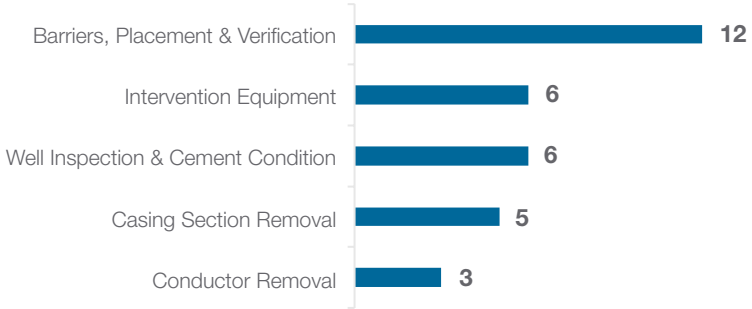


Technologies by maturity stage



Technologies by approach

Technologies by sub-category



Existing technologies include:

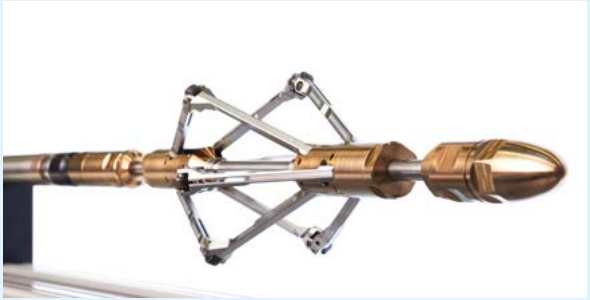
- Improved section milling process
- Vessel motion and stabilisation monitoring to support operational optimisation
- Tool development for perforate and cement in a single operation providing cost and operational efficiencies

Emerging technologies aim to change the traditional approach to well P&A and significantly reduce costs. These include:

- Alternative materials to cement in creating effective barriers and seals
- Alternative technologies for casing removal without cutting or milling. There are a number of technologies under development by the supply chain and in collaboration with operators.
- Logging through multiple strings to determine the quality of the cement bond.

Picture courtesy of Interwell AS

Sealing the reservoir/restoring the caprock is a fundamentally and costly part of well P&A. Technologies to reduce costs without any reduction in the effectiveness of the barrier will help achieve the goal of a 35% cost reduction in decommissioning. There are a small number of potential alternative barrier materials under development. For example an open collaboration group has been established to share laboratory testing and field trial data for a thermite based technology. If successful, the further development of this technology would provide a step-change in the approach to permanent well abandonment, delivering cost and performance efficiencies.



Picture courtesy of Darkvision Technologies Inc.

The ability to determine the quality of the cement seal between the casing and the caprock has continued to prove challenging. This information potentially eliminates the need to remove casing and set additional barriers. New technologies and techniques are currently under development drawing on medical and analytical techniques as well as enhancing existing ultrasonic methods to new levels of capability.

Well plugging and abandonment Existing technologies

WELL P&A - ENHANCED P&A		
Application	**Technologies**	**Frequency (0 to 15)**
Section milling	- Upgraded section milling - Zonal isolation (alternative to casing removal using section milling)	
Conductor removal	- Hydraulic workover mast - Vessel motion & stability monitoring	
P&A intervention equipment	- Enabling LWIV technologies for subsea wells riserless well abandonment - Tubing agitator - Casing centralisers	

WELL P&A -BARRIERS, PLACEMENT AND VERIFICATION		
Application	**Technologies**	**Frequency (0 to 15)**
Cement plug setting	- Perforate, Wash & Cement	

Well plugging and abandonment Emerging technologies

WELL P&A - BARRIERS, PLACEMENT AND VERIFICATION		
Application	**Technologies**	**Frequency (0 to 15)**
Through tubing cement evaluation	- Ultrasonic multi-annuli logging - X-ray radiography tool - Particulate cement additives - Enhanced wireline log interpretation	
Alternative barriers to cement	- Bismuth - Resin - Thermite plugs - Scale formation - Swelling clays	

WELL P&A - CASING SECTION AND CONDUCTOR REMOVAL		
Application	**Technologies**	**Frequency (0 to 15)**
Non-milling casing cutting, removal	A step-change to deliver tubing/casing removal - Laser - Plasma - Rocket propellant - Water abrasion.	

A.8 Facilities decommissioning

7 operators listed 16 technologies in the area of facilities decommissioning.

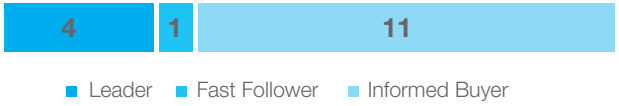
These technologies aim to:

- Improve efficiencies in decommissioning survey, planning and management
- Reduce the cost of facilities conditioning and removal (e.g. cleaning, preparation, cutting and lifting surface and subsurface facilities)

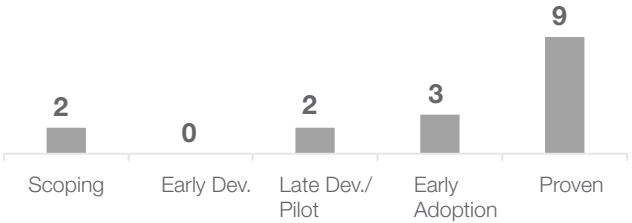
Vendor solutions have been stated as the main source of technologies to support facilities decommissioning. Additional technologies have been supported thorough close working between operators and the supply chain.

Most of these technologies are proven tools and systems, with additional capabilities resulting from further developments of existing technologies.

Technologies reported in operators' plans (Total = 16)

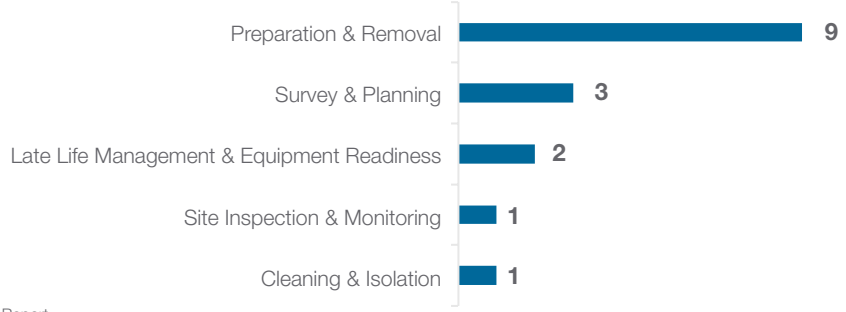


Technologies by maturity stage



Technologies by approach

Technologies by sub-category



1) UKCS Decommissioning – 2017 Cost Estimate Report

Existing technologies include:

- Topsides removal – using single lift capabilities
- Zone rated tablets - supporting inspection, planning and decommissioning operations
- Flowline sealing – hot tapping, flushing and sealing with expanding cement.

Emerging technologies have the potential of delivering further cost efficiencies:

- Novel subsea infrastructure removal – utilising innovative methods and process with supporting parallel tool development
- Autonomous subsea infrastructure monitoring – reducing the cost of environmental monitoring through increasingly autonomous and capable systems

Picture courtesy of OGA

As specific facilities and infrastructure decommissioning needs are identified, modified and bespoke tools can be developed and deployed for cutting and removal processes. These tools will improve overall efficiencies and provide significant cost savings. For example, the cutting and handling of subsea flowline bundles has resulted in specific tools being developed, providing operators with additional and proven options for future projects. As facilities decommissioning matures these tools and processes should become standardised.

Picture courtesy of Shell

Single lift of platform topsides is now a proven practice. To date, the world's heaviest offshore lift occurred in the UKCS. A twin hulled vessel using eight horizontal lifting beams completed the lift of the Brent Delta topsides weighing 24,200t in 2017. There are differing removal options and the key to efficient low cost removal is being able to identify the optimum method for each individual asset.

Facilities decommissioning Existing technologies

FACILITIES DECOMMISSIONING		
Application	**Technologies**	**Frequency (0 to 15)**
Planning and preparation	- Barcode technology - Zone rated tablets - 3D modelling - Digital surveying	
Topsides removal	- Single-lift vessel	
Subsea infrastructure conditioning or removal	- Hydraulic grapple technologies - Jet-cutting - Subsea concrete crushing - Upscaling of diamond wire - Hydraulic shears - Hot tapping and injection of expanding cement to seal	

Facilities decommissioning New and emerging

FACILITIES DECOMMISSIONING		
Application	**Technologies**	**Frequency (0 to 15)**
Novel subsea infrastructure removal	- Hydraulic lifting tools - Neutrally buoyant lift and tow system - Reverse riser reel - In-situ disposal	
Subsea infrastructure monitoring	- AUVs	

Oil & Gas Authority

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