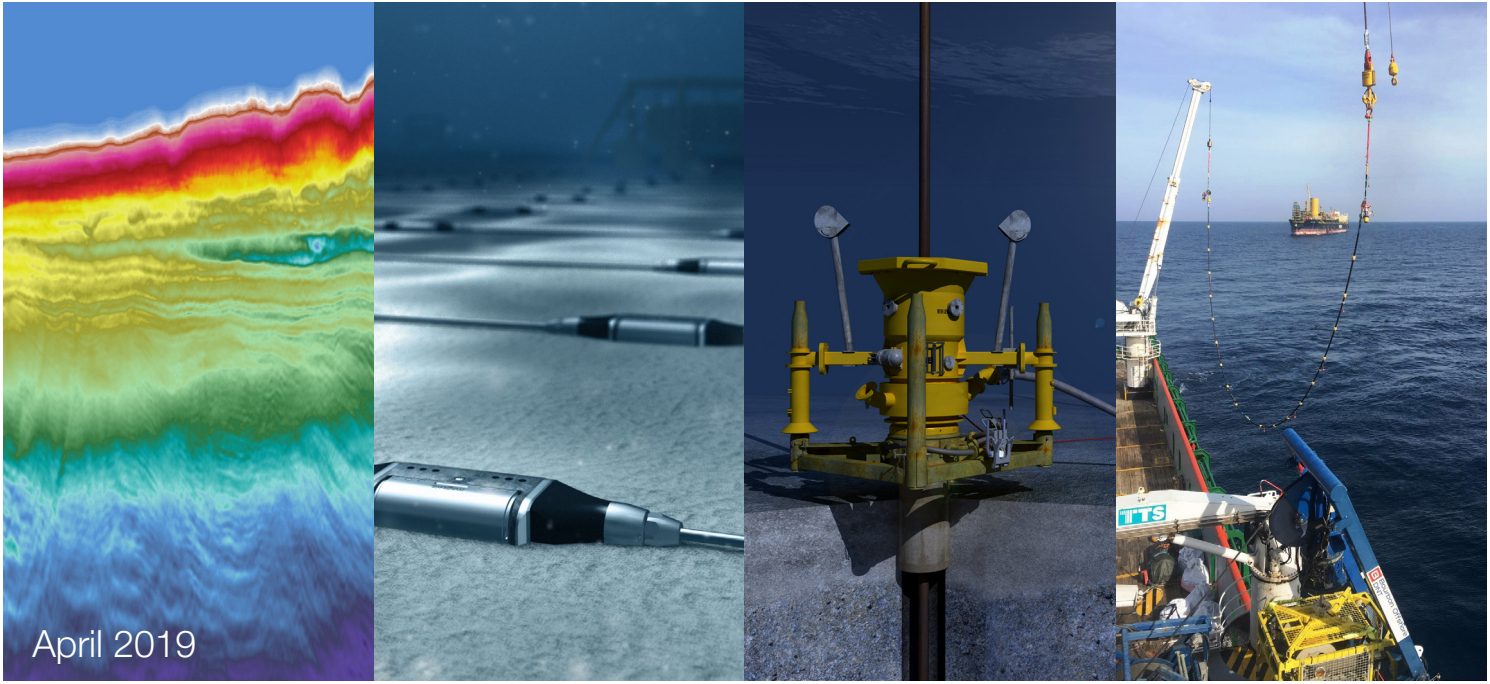
Oil & Gas Authority

UKCS Technology Insights



April 2019

Unless identified elsewhere, all data is from the OGA UKSS 2017 and 2018

Cover photos:

High frequency FWI image – courtesy of DownUnder Geosolutions using Capreolus 3D data from TGS

Ocean bottom nodes – courtesy of Magseis Fairfield

Riserless mud recovery – courtesy of Enhanced Drilling

Carbon composite pipe – courtesy of Magma Global

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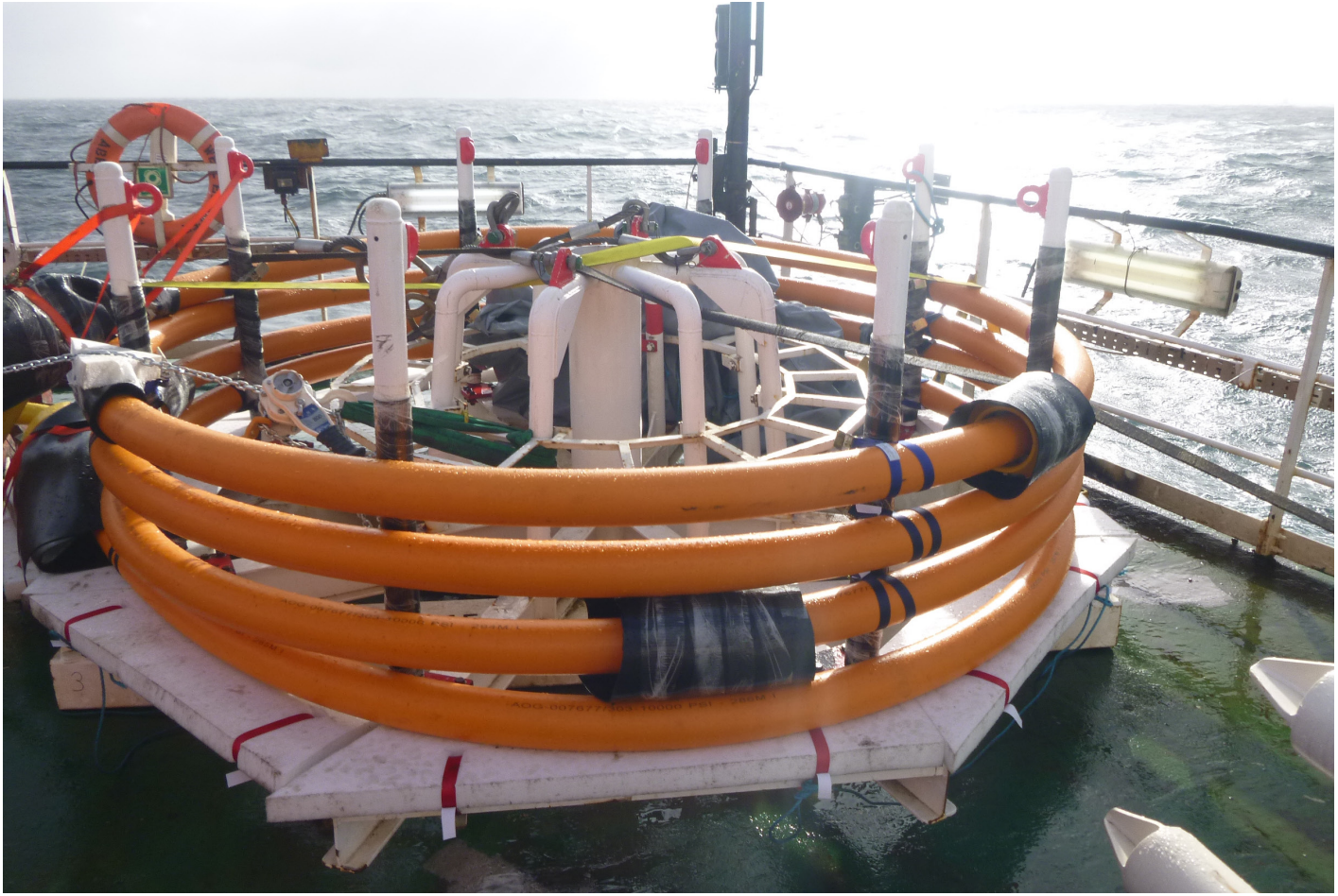


Image courtesy of Airbourne Oil & Gas

Foreword

I am pleased to see constant progress in the way our industry is maturing and deploying new technologies for the UK Continental Shelf (UKCS). This important effort is being supported by the coordinated work of the Oil and Gas Authority (OGA), the Technology Leadership Board (TLB) and the Oil & Gas Technology Centre (OGTC).

This year's Technology Insights summarises the rich content of UKCS operators' technology plans, submitted through the OGA annual Stewardship Survey in 2018. This gives the industry a very useful tool to share experience on available technologies to maximise economic recovery (MER UK) from the UKCS, and to collaborate on the development of new ones.

2018 was also a year of definition for the TLB. We engaged with industry through the MER UK Taskforces to identify challenges and value opportunities which technology can unlock to achieve MER UK objectives in the next five years. This has been done. We are in the process of appointing sponsors for each of the key opportunities, and working with the OGTC to define development plans for technologies which shall require new projects and investment.

2019 is a year of delivery and uptake of technology across industry. The TLB shall support collaborative working between OGTC, MER UK Taskforces and industry sponsors. A small technical team will be established to measure progress on all key objectives. Ultimately, these objectives will be followed up and monitored through the OGA stewardship to further encourage uptake and share best practice.

There are huge prizes in reserves growth, production value and, most importantly, safe asset operation and life extension from the use of current and new technologies.

We shall also implement an extensive industry and public communication plan to further promote engagement, awareness and uptake of technology to sustain the UKCS.

I am really looking forward to continuing our work through the TLB to support the cross-industry uptake and realisation of the potential of technology for MER UK.

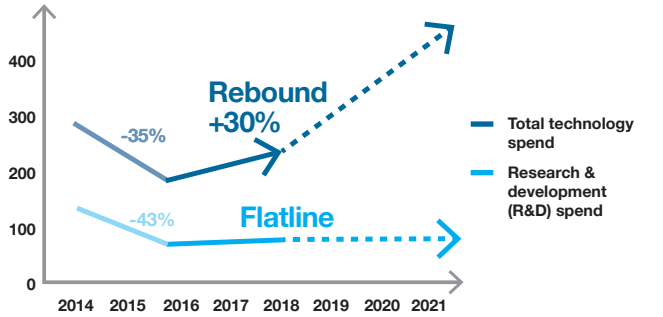
Bill Dunnett
Chairman, UKCS Technology Leadership Board

Executive summary

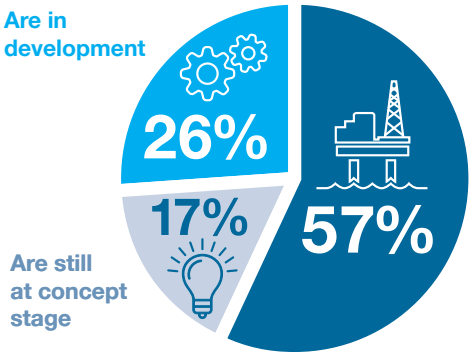
This report provides a unique insight into companies' technology portfolios, including strategies to access further required technologies to maximise economic recovery. This study is based on the technology plans which operators submit to the OGA.

In 2018 UKCS operators spent £241m on developing and deploying technologies, an increase of 30% since 2016, but still below the pre-industry downturn levels of 2014. The OGTC is adding financial resources and capabilities, including driving more industry match-funding.

UKCS operators' technology spend per annum

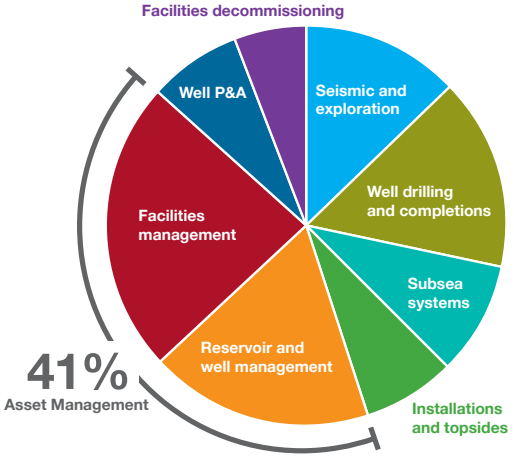


Technology stages



Innovation is very important to the future of the UK Continental Shelf (UKCS). 57% of technologies in operators' plans leverage existing solutions, whilst 26% of technologies are still under development with a further 17% of opportunities at an initial concept stage.

UKCS Technology mix (operators' plans)



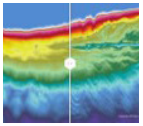
Operators' plans cover the full asset lifecycle, with an emphasis on asset management.

Based on operators' experience, the OGA has identified a shortlist of 30+ existing technologies which are critical for the UKCS.

Technology Stewardship Expectations

Expectation driven by

Available operators' experience	Proven value added	Large scope for wider UKCS deployment


Seismic & exploration


Well drilling & completions


Subsea systems


Installations & topsides


Reservoir & well management


Facilities management


Well plugging & abandonment


Facilities decommissioning

The OGA continues to engage with operators to ensure that, where feasible, these technologies are deployed.

Operators' technology plans

Good compliance with the Technology Stewardship Expectation (introduced in 2016)

- 74 operators have formulated technology plans for their UKCS assets and have submitted these to the OGA

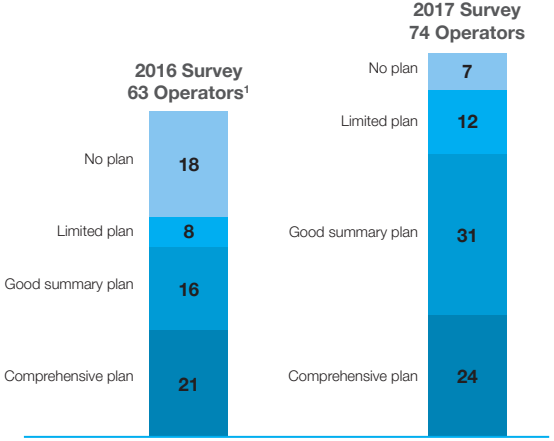
These plans show:

- A rich basket of existing technologies, deployment of which should be more widespread
- Common UKCS needs addressed through new technology, with opportunity to share development and piloting

Operators reported that the technology plan submissions have also proved beneficial internally

- A more systematic engagement of the different asset teams on technology objectives, priorities and deployment experience

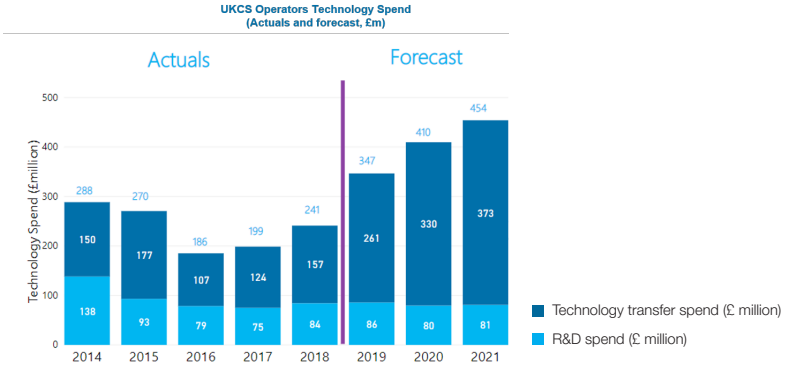
Operators' survey submissions



Source: OGA 2016 and 2017 UKCS Stewardship Survey
Note 1: out of 68 eligible, 5 did not submit

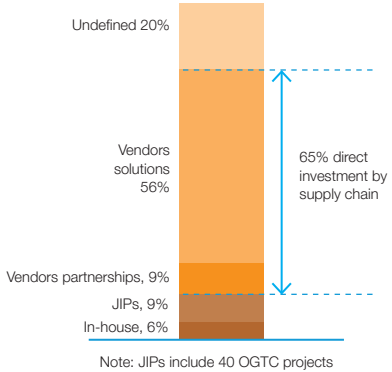
- 2017 survey 100% response rate
- Significant improvement to previous year
- 74% of submissions were of particular high quality
- Evidence new entrants embracing technology

Technology delivery



- Operators' technology spend is increasing and forecast to continue
- Over ten years, with £180m funding from the Aberdeen City Region Deal, the OGTC will co-invest with matched funding from industry
- To date the OGTC has directly invested £38m, and co-invested £95m with industry
- The supply chain contribution is considerable, with 65% of technology delivery coming from direct investment by the supply chain

Technology delivery



Note: JIPs include 40 OGTC projects

- The supply chain is fundamental to the supply of technology solutions
- Vendor-operator partnerships and joint industry partnerships play an important role
- The OGTC has approved more than 165 projects since October 2016 and has 68 trials in planning or completed

Technology maturity

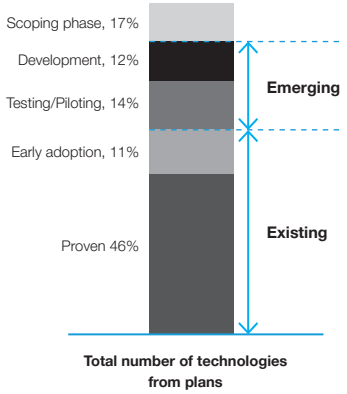
Analysis of the technology plans show:

- Predominant focus on technologies ready to deploy with 57% of total entries at the ‘existing’ stage
- Importance of innovation; emerging technologies represent a healthy 26% of the plans
- A ‘gap’ of 17% of asset needs are to be addressed by technologies still in ‘scoping phase’

Critical factors for delivery:

- Operators sharing their experience in the deployment of recent technologies
- Collaboration in development and piloting of new technologies, reducing cycle-time and risks
- Proactive engagement with the supply chain, as most technologies are developed and deployed by vendors

Technology maturity



- 57% technologies ‘existing’, however usage not widespread
- 26% technologies under development

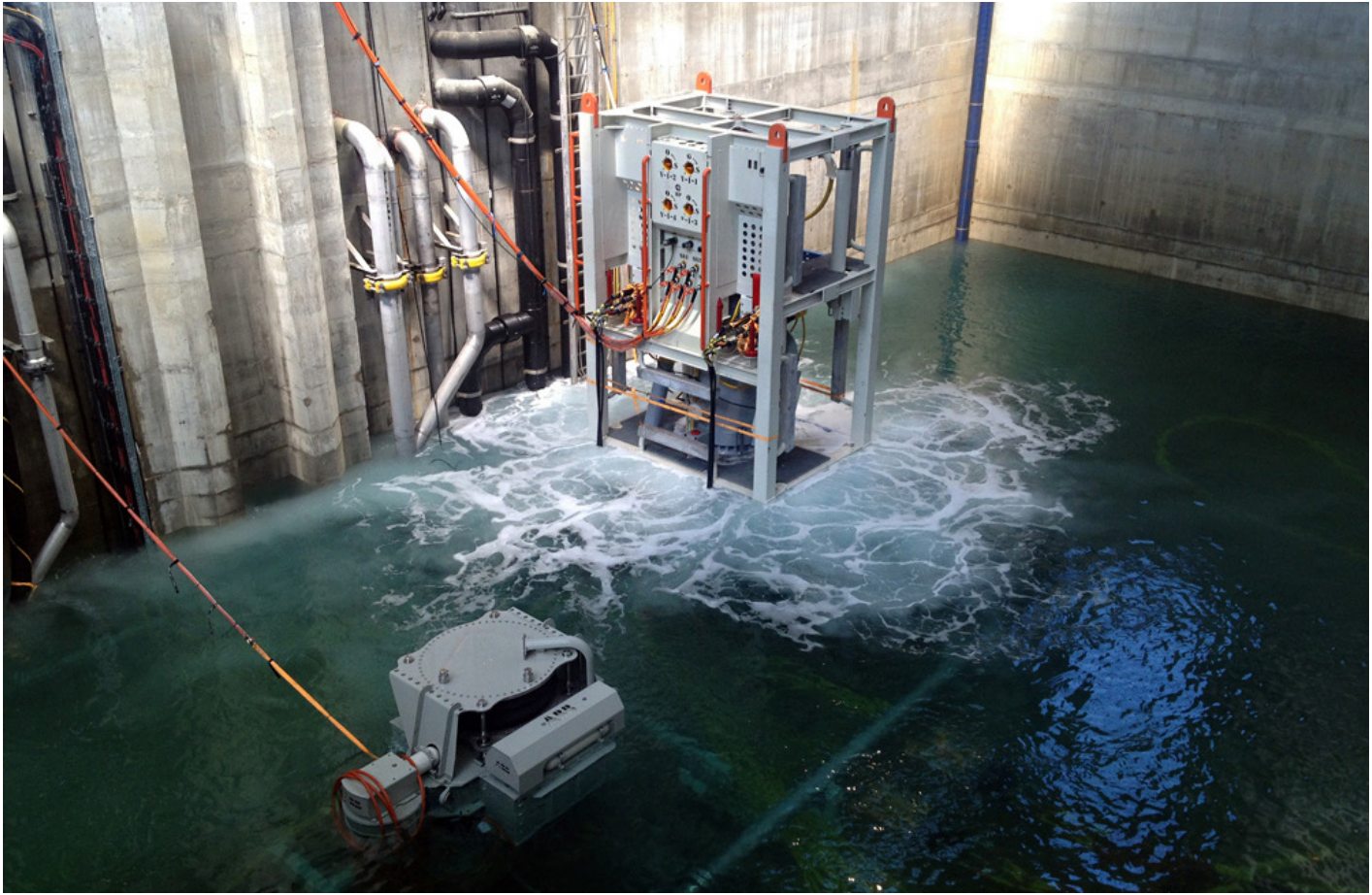
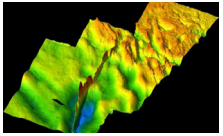


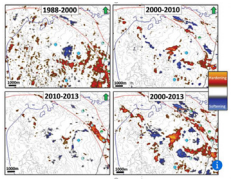
Image courtesy of Equinor ASA

Existing technologies for MER UK

Seismic and exploration

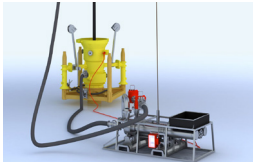
- 3D broadband
- Wide and multi-azimuth
- Ocean-bottom acquisition
- Latest inversion techniques
- Time-lapse (4D) seismic





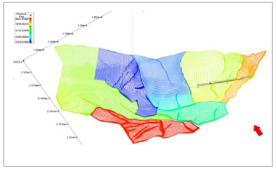
Drilling and completions

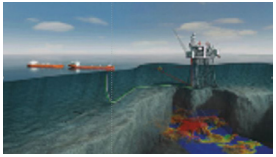
- Modelling and simulation
- Reduced casing string designs and slim-hole
- Measurement while drilling (MWD) and geo-steering
- Technologies for efficient operations and non-productive time (NPT) reduction



Reservoir and well management

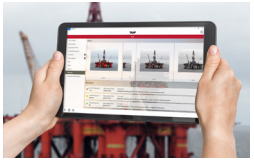
- Data analytics for reservoir management
- Monitoring, tracers, optical fibre
- Artificial lift (e.g. long life electric submersible pumps (ESP), and ESP management)
- Flow assurance (e.g. wax and scale treatments)





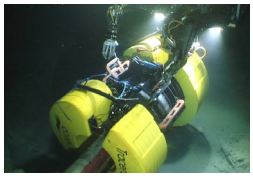
Facilities management

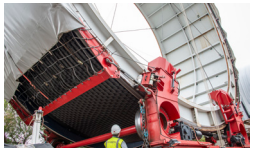
- Offshore wireless data devices
- Asset digitalisation and integration with the shore
- Hard-to-reach inspection
- Non-intrusive inspections (NII)
- Predictive maintenance



Subsea systems

- Mechanically connected pipes
- Spoolable pipelines
- Subsea boosting
- Multiphase flowmeters
- Smart and remote inspections



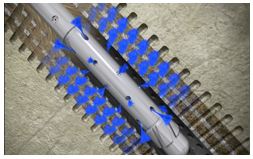


Installations and topsides

- Low-cost, reusable normally unmanned installations (NUI)
- Remote monitoring and automation
- Compact/modular processing equipment (e.g. oil, gas, water)

Well plugging and abandonment

- Well data management and campaign planning
- Cement-bond logging
- Thru-tubing barrier placing
- Efficient section milling



Facilities decommissioning

- Digital and remote surveying
- Technologies for efficient ‘light-house’ operations
- Cutting and removal technologies
- Bundle sealing and cutting

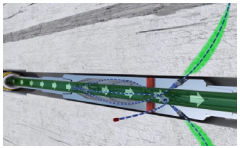
Emerging technologies – MER UK priorities

Seismic and exploration

- Low-cost ocean bottom nodes (OBN), permanent and sea-bottom sources
- Artificial intelligence (AI) for (real-time) processing
- Advanced interpretation integrating rock-physics and multiple surveys

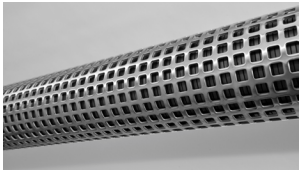
Drilling and completions

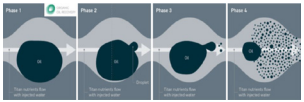
- Drilling automation
- Multilateral well design
- Smart completions
- Alternative reservoir stimulation technologies



Reservoir and well management

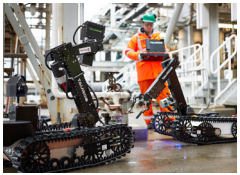
- Permanent wireless sensors
- Sand controls (e.g. ceramic screens)
- Flow assurance solutions (e.g. localised heat)
- Alternative enhanced oil recovery (EOR) (e.g. microbial, foam)





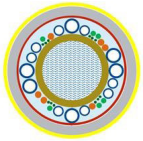
Facilities management

- Autonomous robotic inspections
- Hard-to-reach area inspections (e.g. under insulations and trunnions)
- Corrosion detection and prevention (e.g. self-healing coatings)
- Health and usage monitoring systems (HUMS)



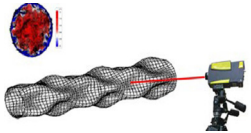
Subsea systems

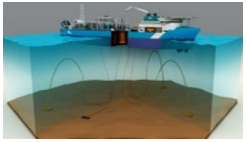
- All-electric subsea controls
- Local chemical injection
- Local power generation/storage
- Umbilical-less systems
- Subsea processing and storage
- Un-manned loading buoys
- Reusable, standardised, tie-back bundle



Installations and topsides

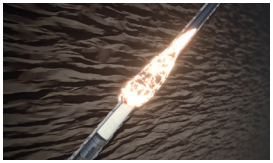
- Versatile floating units
- Unmanned loading buoys
- Advanced (e.g. self-calibrating, non-intrusive) multiphase meters
- Heavy oil equipment
- Nano filtration, membrane technologies





Well plugging and abandonment

- Bond-logging through multiple casing strings
- Alternative casing removal techniques (e.g. laser, plasma)
- Alternative barriers (e.g. thermite, bismuth, and natural barriers)



Facilities decommissioning

- Alternative cutting technologies (e.g. laser, corrosive fluids)
- Subsea removals
- Efficient site monitoring (e.g. autonomous underwater vehicles (AUV), passive sensors)

OGA's technology stewardship

Industry engagement

- Operators' technology plan submission (annual UKCS Stewardship Survey)
  - priorities matching needs of operators' portfolios
  - covering asset lifecycle

- Summary of findings
  - annual publication
  - on-line knowledge
  - existing technologies
  - emerging technologies (under development)

- Constant dialogue with technology managers (UKCS Technology Network)

Stewardship Expectation

- Deployment of key existing technologies expected
- Operators to demonstrate use of technologies matching their assets' types and maturities:
  - by asset
  - by future project

- Constant stream of innovation is vital for MER UK
- Industry priorities defined from plans and work with the TLB

technology leadership board

- OGA works with the OGTC and industry to deliver innovation

The Oil & Gas Technology Centre
Your Innovation Partner

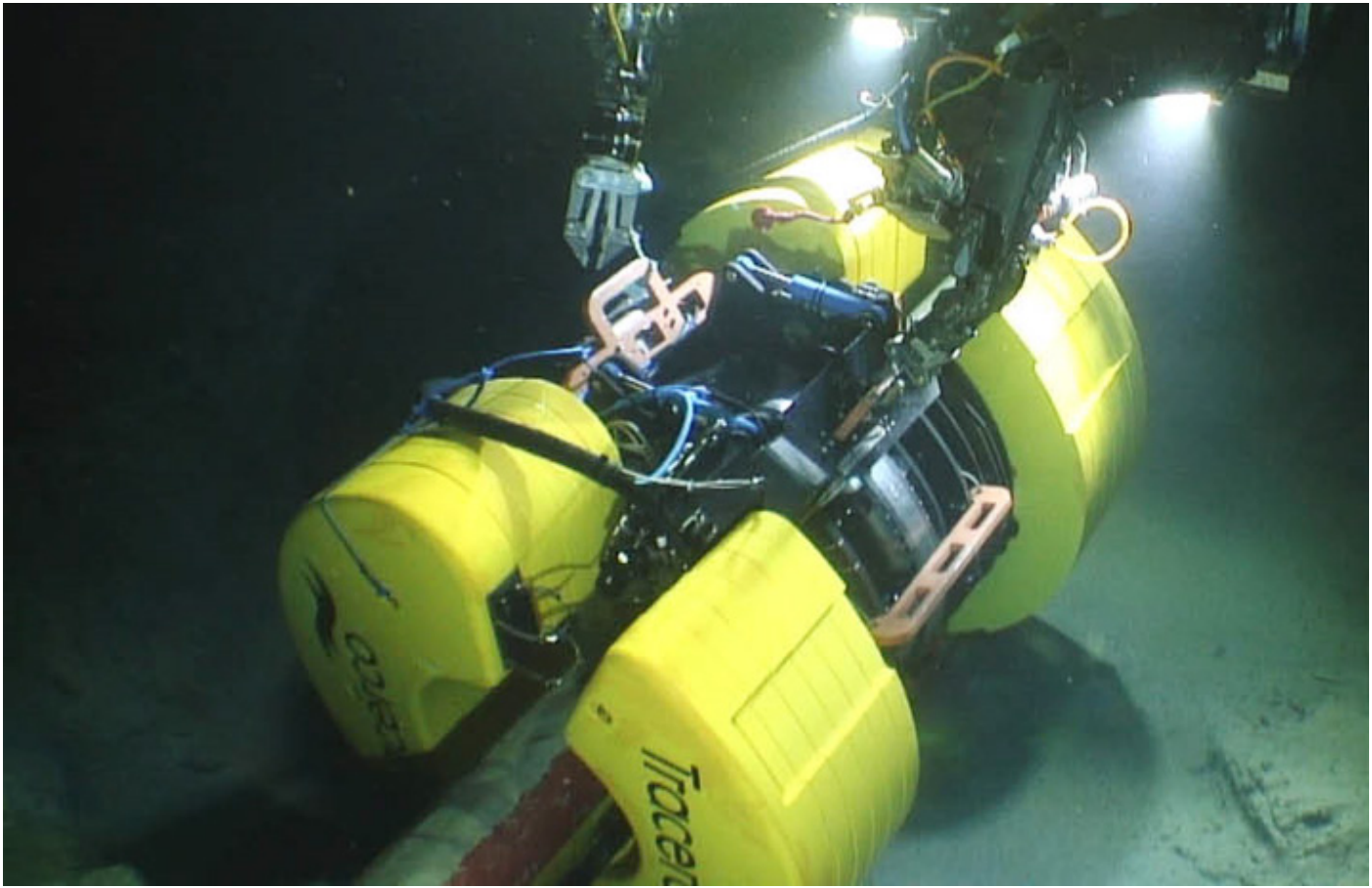
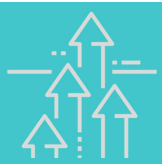


Image courtesy of Tracerco Ltd

The Oil & Gas Technology Centre

Technology innovation



Driving

Technology roadmaps tied to MER UK and Vision 2035 adding £1 trillion to the UK economy

Connecting

Industry, governments, regulators and academia to drive technology investment and deployment

Delivering

Projects that move the dial on key challenges and opportunities across the North Sea and beyond

The Oil & Gas Technology Centre's goals are to help maximise economic recovery from the UK Continental Shelf, anchor the supply chain and create a culture of innovation.

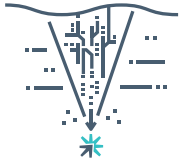
OGTC technology roadmaps

Driving change and unlocking £10 billion of value for the UK

Digital Transformation

10% increase in production efficiency

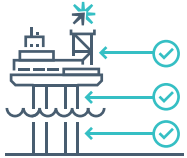
- Digitally enabled supply chain
- Digital and data architecture
- Smart facilities
- Digitally enabled worker
- Production optimisation



Subsurface

MER UK up to 20bn bbls

- Discover more
- Develop more
- Recover more



Decommissioning

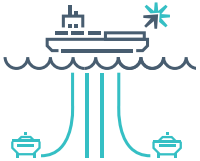
35% cost reduction

- Late life management
- Post cessation of production (CoP) operating expediture (OPEX) reduction
- Innovative removal
- Optimise abandonment

Wells

50% lower well construction costs

- Optimise design
- Flawless delivery
- Maximise production
- Optimise abandonment



Marginal Developments

50% under development

- Tieback of the Future
- Facility of the Future
- Integrated energy

Asset Integrity

50% cost reduction

- Risk based inspection and data analytics
- Detection and condition based monitoring
- Enhanced inspection techniques
- Repair and mitigation solutions

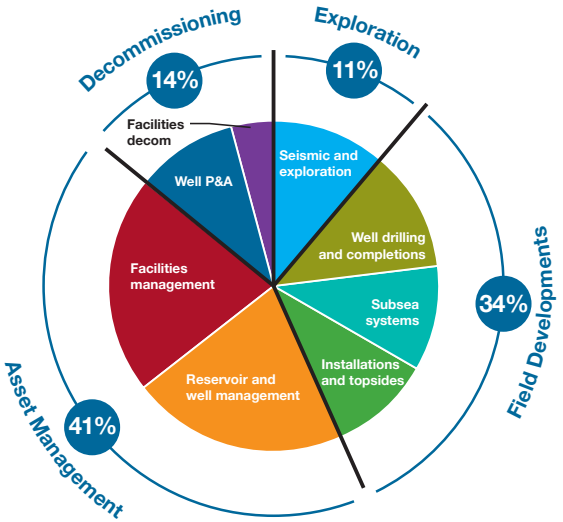
Image courtesy of Ecosse IP

Technology plan feedback

Technology domains

1. Seismic and exploration
2. Well drilling and completions
3. Subsea systems
4. Installations and topsides
5. Reservoir and well management
6. Facilities management
7. Well plug and abandonment
8. Facilities decommissioning

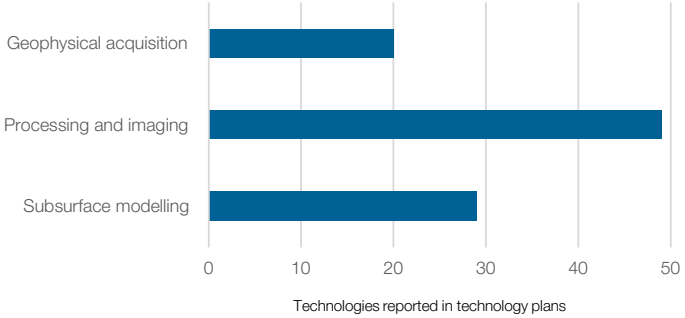
Technology plans' contents by domain



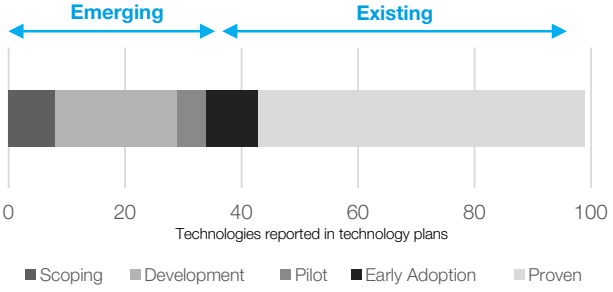
- 41% technology applications are concerned with (mature) asset management
- Decommissioning is an area of growing interest

1. Seismic and exploration

Technology categories



Technology maturity



Industry insights

- Combining high-resolution 3D broadband and the latest inversion techniques enables to better illuminate and de-risk UKCS targets (e.g. Pre-Zechstein, and injectites)
- OBNs are useful for sub-basalt imaging and near-infrastructure shoots (e.g. 4D), however this technology is still expensive
- Majority of these technologies are provided by the supply chain and the primary drive should be to ensure a more widespread usage of what is available
- Key areas of technology developments aim at reducing the cost and footprint of survey equipment (low cost, and permanent ocean bottom acquisition)
- In addition, artificial intelligence (AI) promises to deliver significant reduction in seismic analysis cycle-time (e.g. potentially allowing real-time, simultaneous modelling)
- Combination of different types of surveys to improve subsurface imaging is not widespread on the UKCS, and this may be an opportunity further enabled by AI

1.1 Operators' technology map

Operator	Geophysical acquisition	Processing and imaging	Subsurface modelling
Alpha Petroleum			
Apache North Sea			
Ardent Oil			
Azinor Petroleum			
BP Exploration			
Bridge Petroleum			
Burgate E&P			
Cairn Energy			
Chevron Corporation			
Chrysaor			
Cluff Natural Resources			
CNOOC			
Comtrack Ventures			
ConocoPhillips			
Corallian Energy			
Dana Petroleum			
Decipher Energy			
Draupner Energy			
EnQuest			
Equinor			
ExxonMobil			
Hurricane Energy			
Independent Oil & Gas			

Operator	Geophysical acquisition	Processing and imaging	Subsurface modelling
Ithaca Energy			
JTXG			
Marathon Oil UK			
National Iranian Oil			
Neptune Energy			
NSNR			
Parkmead Group			
Pharis Energy			
Premier Oil			
Reach Oil & Gas			
Repsol Sinopec			
Shell UK			
Siccar Point Energy			
Sumitomo			
TAQA Europa			
Total Upstream UK			
Whalsay Energy			

Number of UKCS technology priorities reported by operators in their plans

0 1-3 4-8 9-13 14-17

1.2 Existing technologies

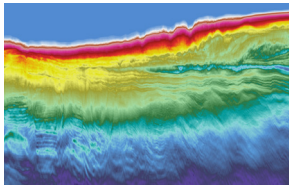
Seismic and exploration

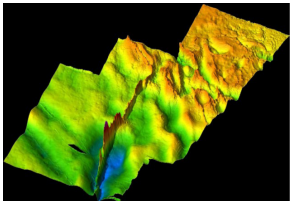
Areas	Technologies
Geophysical acquisition	• 3D broadband, e.g. Geostreamer, Isometrix, Broadseis, P-Cable (Azinor, Marathon, Chrysaor, Equinor) • Multi-azimuth and multi-source (CDG, BP) • Ocean bottom nodes (Equinor, CNOOC, Chevron, Corallian, Dana) • Electro-magnetic survey (Bridge Petroleum)
Imaging and Processing	• 3D seismic reprocessing (Cairn, Corallian, Repsol Sinopec, ExxonMobil, Hurricane, Shell) • Pre-stack inversion to discriminate lithology and fluid and improve imaging of injectites (Apache) • Migration algorithms: Least square (Apache), Generalised radon transform (Zennor) • Advanced amplitude variation with offset (AVO) and full-waveform inversion (FWI) (Apache, Equinor, BP, CNOOC)
4D	• Steerable streamers and repeatability criteria for high-quality 4D (Apache) • Deep-tow high-res 4D acquisition and processing (BP) • 4D acquisition using ocean bottom cables (Premier) • 4D processing (Dana, CNOOC, Repsol Sinopec, TAQA Total)
Logging	• Formation pressure log (Total) • Isotopic analyser of mud gases for overburden characterisation (Total)

Exemplars

Combining 3D broadband and latest inversion technology

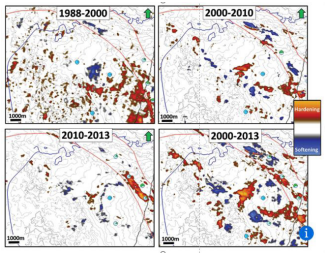
- 3D broadband, multi-azimuth and multi-source to increase definition and reach
- Integrated geoscience-processing techniques for greater accuracy and contrast
  - velocity modelling
  - combined with gravity data (e.g. sub-salt)
  - targeted multiple attenuation
  - AVO
  - FWI and high frequency FWI
- Critical to illuminate difficult UKCS targets (e.g. Pre-Zechstein, sub-salt, and injectites)





4D seismic

- 4D provides key benefits
  - improve reservoir management
  - optimise infill drilling
  - maximise recovery
- Use of 4D seismic has helped extend the field life of Apache's Forties field, identifying remaining oil targets and improving reservoir management
- Shell has successfully utilised 4D to derisk infill drilling in the Gannet cluster



1.3 Emerging technologies

Seismic and exploration

Technologies	Value
Surveys	• Low-cost ocean bottom nodes and robotics for installation (CNOOC) • Permanent and semi-permanent OBNs for reservoir area surveys (CNOOC) and ocean bottom sources (Total) • High-density and ultra high-density OBNs (BP) • Vertical seismic profiling, using distributed acoustic sensing (DAS) fibre in logging tools or embedded in wells (Total) • Combined use of Electromagnetic (EM) and high-resolution gravity data (experience from other basins, e.g. Norway) • Geochemical surveys using AUVs
Imaging and processing	• Deep-learning artificial intelligence for fast pre-stack 3D volume interpretation (Neptune) • Machine learning applied to well and seismic data (OGTC) • Joint facies and impedance inversion (Tullow, Sumitomo) • Discrete fracture network modelling (Hurricane)
Subsurface modelling	• Sand injectite modelling (JXTG Holdings, Equinor, TAQA) • Modelling of tight reservoirs (IOG, CNOOC) • Integration of deep-resistivity data sets into reservoir modelling (EnQuest)

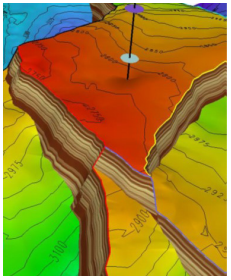
Exemplars

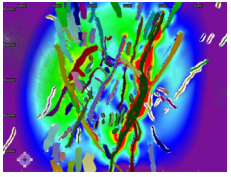
Ocean bottom acquisition

- The use of ocean bottom cables or nodes provides:
  - enhanced detail and data quality
  - broader bandwidth acquisition/ full-azimuth
- Total used OBNs on Alwyn North resulting in the sanction of the field life extension drilling programme
- BP is using them at Clair Ridge for its baseline survey

- A reduction in the cost of ocean bottom seismic, and the use of AI to process seismic data efficiently have the potential to unlock significant new opportunities in new exploration and old asset life extensions

Structural modelling

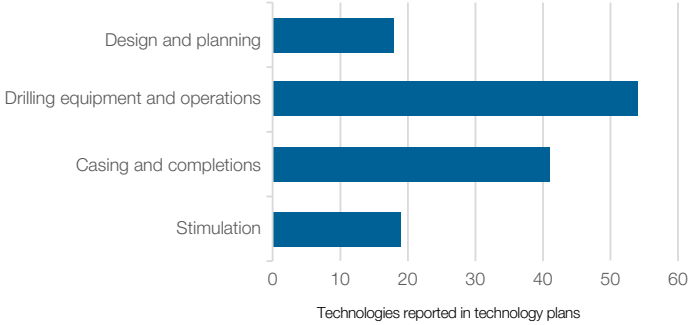




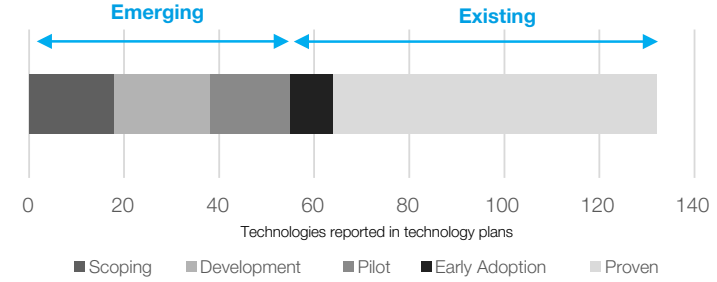
- Structural validation can result in better understanding of gross rock volume (GRV)
- Many cases where traps are potentially larger than previously thought
- Fracture modelling can result in better placed wells and higher well productivity
- UK is home to a number of global leading subsurface consultancies

2. Well drilling and completions

Sub-domains



Maturity



Industry insights

- Delivering more value from their wells is a key objective for operators
- Advances in geosteering, casing, completions and stimulation are helping to reduce risk
- Technology can deliver wells that are longer, multi-lateral, better targeted, at higher pressures and temperatures
- Many of these technologies are readily available from the supply chain but there is the opportunity for wider operator utilisation
- Further knowledge and technology developments have widened the opportunity for operators to utilise managed pressure drilling, extended reach drilling (ERD) and slim-hole drilling techniques
- Technology can contribute to a reduction in NPT, for example better understanding and management of borehole stability

2.1 Operators' technology map

Well drilling and completions

Operator	Design & planning	Drilling equipment and operations	Casing completions	Stimulation
Alpha Petroleum				
Apache North Sea				
BP Exploration				
Burgate E&P				
Cairn Energy				
Chevron Corporation				
Chrysaor				
CNOOC				
CNR				
ConocoPhillips				
Corallian Energy				
Dana Petroleum				
Decipher Energy				
Draupner Energy				
EnQuest				
Equinor				
Hansa Hydrocarbons				
Hurricane Energy				
I3 Energy				
Independent Oil & Gas				
INEOS				
Ithaca Energy				

Operator	Design & planning	Drilling equipment and operations	Casing completions	Stimulation
Marathon Oil UK				
National Iranian Oil				
OK Energy				
Parkmead Group				
Perenco				
Pharis Energy				
Premier Oil				
Repsol Sinopec				
Serica Energy				
Shell UK				
Siccar Point Energy				
Spirit Energy				
TAQA Europa				
Third Energy Offshore				
Total Upstream UK				
Whalsay Energy				

Number of UKCS technology priorities reported by operators in their plans

0 1-3 4-8 9-13 14-17

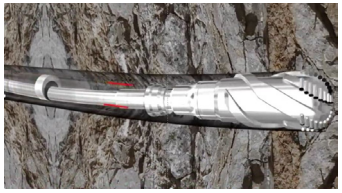
2.2 Existing technologies

Well drilling and completions

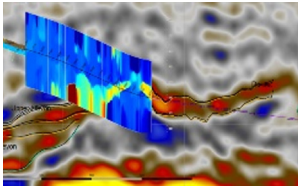
Areas	Technologies
Design and planning	• Advanced modelling/simulation for well planning (BP) using FullStream and PreDIX (Chrysaor) • Execution efficiency platform for decision making (ConocoPhillips) • ERD (Cairn, Burgate, Chrysaor, Corallian, Marathon) working to extend its range (Total, ConocoPhillips) • Slim-hole wells (TAQA, Chrysaor, Shell) • Reduced casing string design (Whalsay Energy)
Drilling equipment and operations	• Remotely operated pipe handling, drilling monitoring and automation (Equinor, BP, EnQuest) • Real time pressure prediction (Equinor, BP, EnQuest) and managed pressure drilling (ConocoPhillips, TAQA) • 'Rigid-lock' well head system to overcome structural challenges (Dana) • Offshore treatment of mud and drill cuttings (Equinor, EnQuest, Dana) • Drilling fluids optimisation (CNR). Designer muds for well interventions (EnQuest) • Riser-less mud recovery (EnQuest) • Experience with advanced drilling bits and tools (Apache, Chevron) • Thin reservoir contact maximisation (BP, Premier, ConocoPhillips, Decipher, Hurricane) • MWD, logging while drilling (LWD), 'ahead of the bit' reservoir imaging using ultra-deep resistivity (EnQuest, Marathon, Whalsay Energy, RepsolSinopec)
Casing and completions	• High torque tubing and casing (Apache) • High pressure, high temperature (HPHT) ceramic sand screens (Shell) • Hydraulic submersible pumps (HSP) for heavy oil, ESP late life upgrades, reliability and high water cut (Apache, EnQuest) • Simultaneous water/gas lift (SWAGL) design (Equinor) • Downhole diluent injection (Equinor) • Multi-laterals (Ithaca, CNR, Whalsay Energy, Premier)
Stimulation	• Cost effective, optimised multi-stage hydraulic fracking (Spirit Energy, INEOS, ConocoPhillips) • Dissolvable plugs for multistage fracking in long-reach wells and chalk formations (ConocoPhillips)

Exemplars

Geosteering



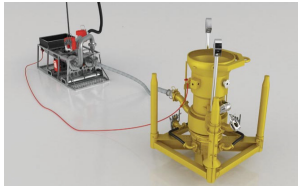
- Geosteering technologies allow operators to optimise targeting and landing of their wellbores (e.g. in thin reservoir developments)



- Premier and Equinor have had success deploying steerable drilling systems during new and asset life extension field developments
- EnQuest successfully used advanced reservoir imaging while drilling to interpret reservoir up to 100ft from wellbore
  - reduced well placement uncertainty
  - increased confidence for side tracks
  - improved reserve estimates and geological models

Technologies for efficient drilling operations

- EnQuest deployed four key technologies to de-risk the Kracken development:



  - a riser less mud recovery system which provided a build capability in unconsolidated sand
  - offshore thermal cuttings processing resulted in logistical efficiencies due to not waiting on weather
  - an innovative reversible oil based mud for water injection reducing equipment levels
  - real time pressure prediction was used to optimise drilling performance and increasing assurance

2.3 Emerging technologies

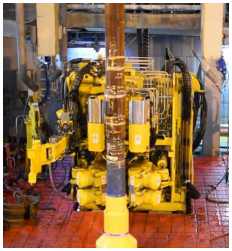
Well drilling and completions

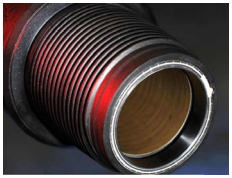
Areas	Technologies
Drilling equipment, operations and data gathering	• Automated drilling control systems (Equinor) • Wired drill pipe for high speed telemetry (Equinor) • Nuclear magnetic resonance (NMR) tools to define viscosity and permeability (Whalsay Energy) • Designer muds for ERD (Serica) • Surface blowout preventer (BOP) for deep water mobile offshore drilling units (MODU) (Chevron) • Coiled tubing drilling (Spirit Energy, Premier, Total) • Self healing cement (Bridge)
Casing and completions	• Suction pile conductor for unconsolidated seabeds (Siccar Point, CNOOC, ConocoPhillips, Total) • Stabbed-in cementing system for subsea (Chevron) • Well life cementing for ultra high pressure, high temperature (UHPHT) (Total) • Steam injection – High temperature (HT) completion components (Pharis) • Multi lateral gravel pack solutions (Whalsay Energy) • Subsea well head solids removal (Spirit Energy) • High frequency (HF) localised electric heating for flow assurance (Tullow) • Alternative retrofit pumps for wells end of life recovery (Apache)
Stimulation	• Stimulation techniques alternative to hydraulic fracking BlueSpark, Fishbone, Perf guns (IOG, CNOOC, Repsol Sinopec, Total, Shell) • Dissolving perforating guns (no need to be retrieved) (Shell) • Stimulation opportunity for infill wells (BP) • Cost-efficient fracking/re-fracking of non productive wells (Perenco)

Exemplars

Automation

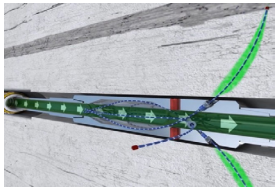
- Advances in analytics, sensors and control systems allows for greater automation of drilling processes
- Equinor deployed wired drill pipe to help unlock the complex Mariner development.
- High speed telemetry has enabled greater use of analytics thereby improving drilling mechanics, hydraulics control, and petrophysical understanding





Stimulation

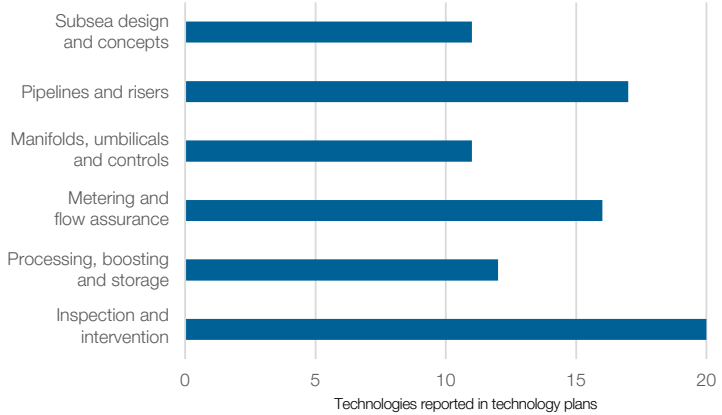
- Alternative technologies to hydraulic fracturing (e.g. pulsed stimulation and needle lateral systems) could improve recovery and operational efficiencies



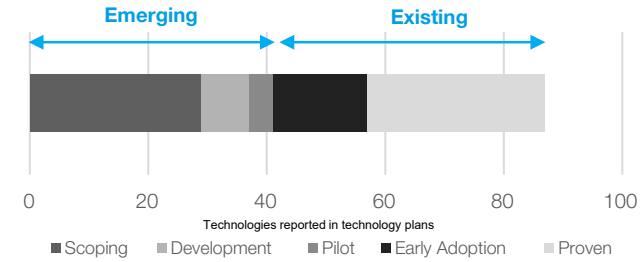
- Equinor and AkerBP have invested in an unconventional needle jetting stimulation technology
  - utilising erosion and chemical dissolution, formation penetration is made by an array of laterals
  - provides bespoke and specialised stimulation solutions

3. Subsea systems

Technology categories



Technology maturity



Industry insights

- Advances in subsea inspection and monitoring technologies and improved corrosion resistant materials are helping to maintain and extend the life of vital subsea infrastructure
- Novel pipeline materials, alternative jointing technology and innovations in flow assurance can support efficient tie-backs and low cost marginal developments
- The majority of technologies are developed by vendors, or in partnership with vendors and should be considered for wider utilisation and concept select
- Technology development is critical for operators to maximise on current developments and future opportunities. Many will have harsh and challenging conditions (e.g. deep water, HPHT, H_2S)
- Future cost and operational benefits will be delivered by emerging technology developments (e.g. electric subsea systems, local hydraulic and/or chemical storage and local power supply and generation)

3.1 Operators' technology map

Subsea systems

Operator	Subsea design and concepts	Pipelines and risers	Manifolds, umbilicals and controls	Metering and flow assurance	Processing, boosting and storage	Inspection and Intervention
Alpha Petroleum UK Holdings						
Anasuria Operating						
Apache North Sea						
BP Exploration						
Cairn Energy						
Chrysaor						
CNOOC						
ConocoPhillips						
Corallian Energy						
Dana Petroleum						
Draupner Energy						
EOG Resources Inc						
Hansa Hydrocarbons						
I3 Energy						
Independent Oil & Gas						
INEOS Industries						
Ithaca Energy						
Marathon Oil UK						
National Iranian Oil						
OK Energy						
Perenco						

Operator	Subsea design and concepts	Pipelines and risers	Manifolds, umbilicals and controls	Metering and flow assurance	Processing, boosting and storage	Inspection and Intervention
Premier Oil						
Repsol Sinopec						
Serica Energy						
Shell UK						
Siccar Point Energy						
Spirit Energy						
Sumitomo						
TAQA Europa						
Total Upstream UK						
Wintershall						

Number of UKCS technology priorities reported by operators in their plans

0 1-3 4-8 9-13 14-17

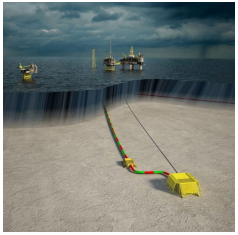
3.2 Existing technologies

Subsea systems

Areas	Technologies
Low cost subsea options	• Mechanically connected pipe systems (Perenco, Wintershall) • Low cost pipelines (Premier, Wintershall) • Low cost subsea tiebacks and platforms for small discoveries (5+ operators) • Long/deep water subsea tiebacks (Siccar Point) • Standardisation and optimised design of subsea systems (Total) • Subsea hot tap technology (NSMP) • Thermoplastic composite pipe (TCP) flowlines and jumpers (Anasuria, Dana) • Low cost subsea concepts (5+ operators)
Subsea boosting	• Small scale compression and local power generation (Total) • Increased oil recovery through subsea separation and pumping • Subsea pumping systems (5+ operators)
Flow assurance and metering	• Multiphase subsea flowmeter (Alpha, Marathon)
Subsea inspection and maintenance	• Efficient subsea inspections and monitoring systems (5+ operators) • Intelligent pigging systems (5+ operators) • Pipeline wax removal (Total, EOG Resources) • AUVs for subsea inspection and monitoring (Shell, Repsol Sinopec) • Marinising more inspection and detection tools (Total, Repsol Sinopec)

Exemplars

Low cost subsea options



- Chevron, Equinor, Shell, Total and Apache have experience of long subsea tiebacks (up to 190km) including deep water applications
- Lower cost pipelines (mechanically connected pipe and composite pipe) could provide CAPEX efficiencies, enabling marginal discoveries and remote fields
- Grouted tee and mechanical hot taps have been used extensively in the Gulf of Mexico but not in the UKCS

Multiphase flowmeters

- Subsea MPFMs are in use by a large number of operators worldwide e.g. BP, Shell, Petronas, ExxonMobil and Equinor
- Individual metering subsea has the potential to identify underperforming wells and improve production optimisation

Multiphase boosting/pumping

- Shell, Equinor, Total, Chevron and ExxonMobil have experience of multiphase boosting and pumping systems
- Subsea multiphase boosting provides increased recovery, topsides simplification and long tie-back applications

3.3 Emerging technologies

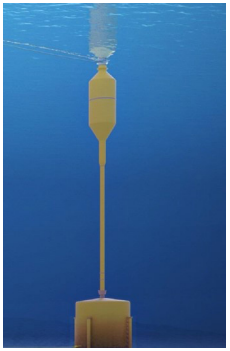
Subsea systems

Areas	Technologies
Low cost subsea options	• Lighter over-trawlable systems or remove need for (Total) • Small scale unmanned solutions for deep-water applications (Siccar Point) • Deepwater subsea tieback technologies for West of Shetland (WoS) (Siccar Point) • Long subsea tieback technologies (Siccar Point, BP)
'Local' subsea systems	• All electric subsea control systems (Total) • Alternative local energy systems (Shell, Total) • Subsea storage of chemicals and hydraulics (Shell, Total)
HPHT	• Subsea HPHT and UHPHT (Total) • All electric trees for small stranded UHPHT applications (Total) • HT reservoirs WoS (Total) • Technologies for small HPHT reservoirs (Total)
Flow assurance and metering	• Advanced flow assurance and simulation technologies (Total, Wintershall) • Subsea multiphase flowmeters without need for intervention (Alpha) • Pipeline drag reducers (multiple Operators) • Alternatives to intelligent pigging (pulsed eddy current technology) • HF localised electric heating for flow assurance (Tullow)
Subsea separation processing and boosting	• Multiphase subsea pumping systems (multiple operators) • Multiphase boosting, pumping and metering systems (5+ operators) • Subsea processing (5+ operators) • Small scale compression and local power systems (Total, Premier)

Exemplars

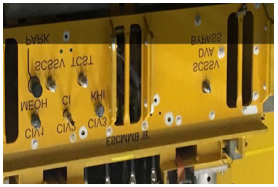
Low cost subsea options

- The OGTC ‘Tie Back of the Future’ initiative aims to unlock the large volume of marginal discoveries through:
  - rapid tie backs
  - 50% cost reduction
  - no marginal development stranded due to associated technology gap



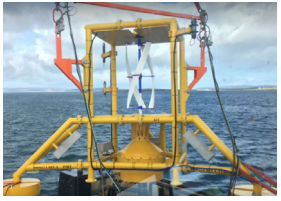
All electric subsea systems

- Total has piloted the use of an all electric subsea XTree and well, electric downhole safety valve (eDHSV) following a ten year R&D programme
- Results in simplified umbilical, enabling longer tie-backs



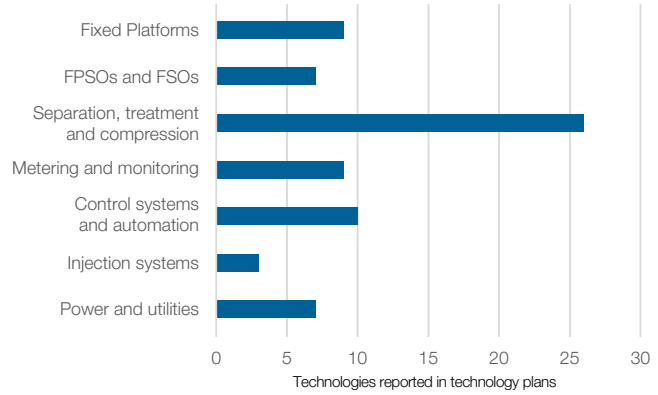
Alternative local power and storage systems

- The OGTC has supported the wet trail of a subsea power hub. This provides local power from seabed currents and local subsea power storage
- Developing local hydraulic and chemical storage systems is a step towards minimising or eliminating umbilical systems that could be an enabler for longer tiebacks

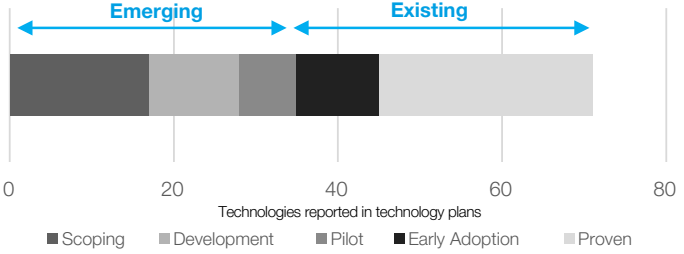


4. Installations and topsides

Technology categories



Technology maturity



Industry insights

- Technologies that support standardisation and enable lighter, smaller processing, treatment and compression systems are important for retrofit and future marginal developments
- Increasing levels of automation can unlock lower cost platform solutions and reduce OPEX on existing assets
- Accurate and reliable metering is required to address ongoing monitoring and optimisation challenges
- New membrane technologies alongside plant modifications and enhanced procedures are being used to improve and manage water treatment
- The majority of technologies are developed by vendors and are available ‘off the shelf’ or ready to be deployed
- There are a number of capable technologies under development to support field development (particularly compact floating facilities, unmanned production buoys and non-intrusive flow measurement)

4.1 Operators' technology map

Installations and topsides

Operator	Fixed platforms	FPSOs and FSOs	Separation, treatment and compresssion	Metering and monitoring	Control systems and automation	Injection systems	Power and utilities
Apache North Sea			■	■	■		
Bridge Petroleum							■
Cairn Energy		■					
CATS Management					■		
Centrica Storage			■				■
Chevron Corporation		■					
Chrysaor			■				■
CNOOC			■				■
Corallian Energy							■
Equinor	■		■	■			■
Hansa Hydrocarbons	■						
Independent Oil & Gas	■						
INEOS			■				
National Iranian Oil		■					
OK Energy	■						
Oranje-Nassau Energie			■				
Parkmead Group	■	■					
Perenco	■		■				
Pharis Energy			■			■	
Premier Oil	■				■		
Sumitomo		■					
Total Upstream UK	■		■		■		
Whalsay Energy		■	■			■	

Number of UKCS technology priorities reported by operators in their plans

0 1-3 4-8 9-13 14-17

4.1 Existing technologies

Installations and topsides

Areas	Technologies
Fluids treatment and processing	• Small scale separation process for out of specification water (Spirit Energy) • Efficient gas/oil separation prior to transporting oil in pipelines (Total) • Simplified separation and dehydration scheme on Bentley (Whalsay Energy) • Separation technology for high water cut application (Perenco) • Multiphase booster compressor for gas and liquids to minimise system complexity (ONE) • Naphthenate control using wash tanks (Pharis) • Produced water treatment and handling (Alpha Petroleum, INEOS, Chrysaor) and using silicon carbide membrane (Shell) online analyser (Equinor) • H_2S treatment technologies (Parkmead, CNOOC)
Control and automation	• Full remote control and automation capability via satellite on Solan field (Premier) • Platform automation, remote monitoring and control (Apache, Total, Spirit Energy)
Flow measurement and metering	• Virtual metering (Apache) • Upgrade of existing meters to ultrasonic meters (Dana) • Enhanced water treatment using centrifuge technology (Perenco)
NUI technology	• Low cost NUI facility in Southern North Sea (SNS) (IOG) • Automation and remote monitoring to enable conversion of existing facilities towards NUI status in SNS (Premier) • Suction pile mono pod NUI application (Repsol Sinopec) • Cost effective NUI operations (Apache)

Exemplars

Compact water treatment

- Alpha Petroleum's SNS Kilmar platform utilised a compact water treatment package following greater than expected water production
- Lack of deck space, platform weight and crane lifting restriction required a novel solution
- The technology demonstrated that compact low cost water treatment solutions can be installed on unmanned platforms

Low cost platforms

- Efficient NUI concept used by ONE in Dutch Sector of SNS
- Modular re-usable system provides low cost platform option for water depths up to 55m
- Platform generates local power through platform mounted wind turbines and solar panels demonstrating a novel approach that could be used for UK SNS gas fields

Facilities upgrades

- Existing facilities are often challenged by limitations on deck space and weight to accommodate upgrades
- Repsol Sinopec used a suction pile monopod as a low cost alternative to an adjacent standalone platform
- This technology offers opportunities for efficient upgrade for other UKCS platforms

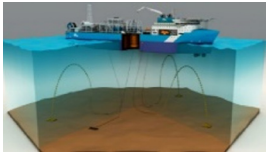
4.2 Emerging technologies

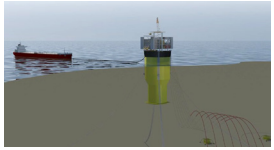
Installations and Topsides

Areas	Technologies
Heavy oil	• Offshore steam to improve recovery of heavy oil discoveries (Pharis) • High temperature safety valve, flow control devices and non condensable solvent injection with steam (Pharis) • Compact processing technologies for heavy oil streams (Equinor)
Metering	• Non intrusive flow measurement devices (CNOOC) • Accurate multiphase heavy oil metering (Equinor) • High accuracy gas metering (Spirit Energy) • Testing of new topsides and downhole metering concepts (Equinor)
Flow assurance	• Naphthenate control using wash tanks (Total, Pharis) • Inlet and outlet gas quality specification through use of advanced algorithms (CATS management) • Reduce topsides back pressures (Total), CAPEX-efficient and power-efficient solutions (SNS operators)
Facilities	• Unmanned developments for small fields (Parkmead) • Mini floating production storage and offloading (FPSO) solutions (Sumitomo) • Enhanced turret systems and polyester mooring lines (Chevron) • Low cost HPHT wellhead platforms (Total) • Low cost subsea systems and platforms for shallow water (Premier, OK Energy) • Reusable suction pile jackets (OK Energy)
Processing	• Gas to liquids technologies (Spirit Energy) • Technology for extracting energy from waste water (Centrica Storage) • Inefficient condensate recovery through continuous separation and automation (Spirit Energy) • New membrane technologies (Equinor, Wintershall)

Exemplars

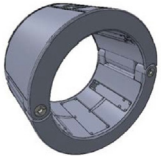
Novel floating facilities



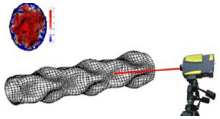


- Range of novel floating concepts are being progressed
- OGTC ‘Facility of the future’ initiative is underway to explore how to push the boundary of unmanned facilities (e.g. unmanned production buoys)
- Such novel concepts could potentially enable marginal discovery development through cluster type developments

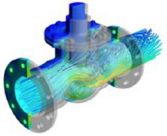
Metering



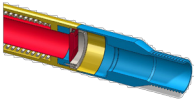
- Non-intrusive flowmeter using piezo-electric transducers. Trialled onshore with view to offshore field trial
- Non-intrusive multiphase flow measurement device using laser technology and machine learning. OGTC supported project undergoing calibration trials to ready system for commercial deployment



Heavy oil



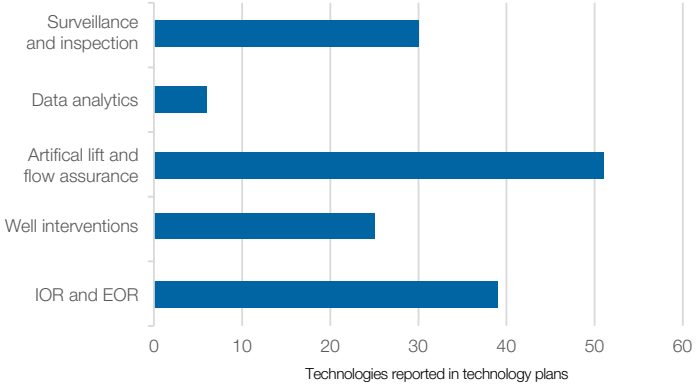
- Key technologies are being developed by industry to address operators’ heavy oil technology needs
- High temperature downhole safety valve to enable offshore steam flooding project being supported by OGTC



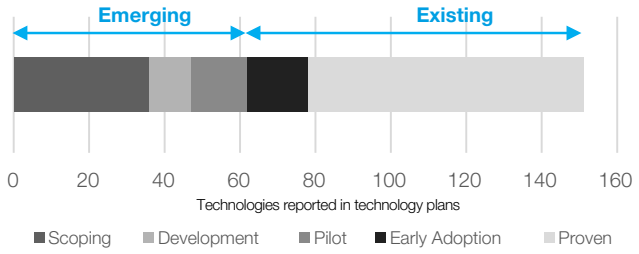
- 3 in 1 heavy oil flowmeter with real time flowrate, density and viscosity capability. Currently at development stage with OGTC support

5. Reservoir and well management

Technology categories



Technology maturity



Industry insights

- Advances in well and reservoir monitoring technologies enable recovery optimisation, supporting asset and field life extension. These technologies could be used more widespread
- A range of technologies, including foam and rigid pigs, ice slurry, heating systems and chemical treatments have been deployed to target ongoing wax and scale flow assurance challenges
- Operators work with an established supply chain which provides the majority of technology solutions, most of which are proven or at a stage of early commercialisation
- Digital technologies and supporting data analytics could advance real time monitoring, advancing production and increasing flow rates
- There is a continued investment in cost effective EOR technologies, in particular polymer EOR and low salinity, with alternative methods receiving interest (e.g. microbial and thermal treatments)

5.1 Operators' technology map

Reservoir and well management

Operator	Surveillance and inspection	Data analytics	Artificial lift and flow assurance	Well interventions	IOR and EOR
Alpha Petroleum					
Anasuria Operating Company					
Apache North Sea					
BP Exploration					
Bridge Petroleum					
Centrica Storage					
Chevron Corporation					
Chrysaor					
CNOOC					
Corallian Energy					
Decipher Energy					
EOG Resources					
Equinor					
Faroe Petroleum					
Hurricane Energy					
I3 Energy					
Independent Oil & Gas					
Marathon Oil UK					
National Iranian Oil					
Neptune Energy					
Perenco					
Pharis Energy					

Operator	Surveillance and inspection	Data analytics	Artificial lift and flow assurance	Well interventions	IOR and EOR
Premier Oil					
Repsol Sinopec					
Shell UK					
TAQA Europa					
Total Upstream UK					
Whalsay Energy					
Wintershall					
Zennor Petroleum					

Number of UKCS technology priorities reported by operators in their plans

0 1-3 4-8 9-13 14-17

5.2 Existing technologies

Reservoir and well management

Areas	Technologies	
Surveillance and inspection	• Natural tracers and introduced tracers for production monitoring, also phase-specific applications to oil, gas, water and HPHT (Apache, Total, Bridge, Alpha) • Fibre DAS, distributed temperature sensing (DTS) (BP, Apache, Wintershall, Equinor) retrofit in mature wells (Repsol Sinopec, Spirit Energy) • Carbon fibre rods for DTS DAS (TAQA) • Cost effective production logging tool (PLT) (Total)	• Saturation logging tool pulsed neutron log (PNL) in chalk formations (BP) • Permanent downhole pressure gauges for suspended wells (Apache, Hurricane) • Subsea B-annulus pressure monitoring (Total) • Anuli non intrusive inspections (Total) and leak detection temp/acoustic sensing (Apache) • Monitoring casing strings conditions (Total)
Data analytics	• Analytics for distributed sensing (BP, CNOOC) • Data mining efficiencies (Anasuria)	• Automatic production optimisation and water injection systems (Equinor) • Cycling wells optimisation (Total)
Artificial lift and flow assurance	• Automated gas lift optimisation (Apache, Alpha) • CBM and control algorithms for ESP reliability and long life (Equinor, Perenco, Corallian, Decipher, Chevron, EnQuest) • Foam applications for liquid loading (Wintershall) automated foaming operations (Spirit Energy) • Surfactants and demulsifiers to enhance water injection rates (Apache, Spirit Energy)	• Capillary strings retrofit (Chrysaor) • Scaling - acid treatment downhole screens (Spirit Energy), acoustic break up (Total) • Waxing – removal methods e.g. foam pigs, bidirectional rigid pigs, pressure jets, ice slurry, and heating systems (Chrysaor) • Autonomous inflow control devices (Alpha, Apache)
Well Intervention	• Coiled tubing (CT) interventions (Apache, Total) • Artificial lift (AL) retrofit (EnQuest, Apache) • Water shut offs, flow conformance chemicals (Apache)	• Leak remediation, expandable tubing, resins (Chrysaor) • Wellbore sand CT vacuum removal (Perenco)
IOR / EOR	• Polymer EOR (Bridge, Equinor, Chevron, BP, Premier) • Low-Sal EOR (BP)	• Microbial EOR (CNOOC)

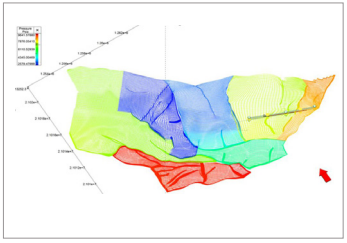
Exemplars

Surveillance

- Fibre optic monitoring utilising distributed acoustic and distributed temperature sensors provide valuable information on:
  - production zones
  - cross flow
  - production and injection profiles
- Permanent installation allows for dynamic flow conditions supporting effective decision making
- A disposable, low cost fibre line well monitoring system has been successfully trialled onshore in the US and the UK. The system has been commercially deployed onshore United States and South America. It is currently involved in offshore trials for different operators in the UKCS

Data analyitcs

- Apache UK utilises a reservoir simulator that takes full advantage of parallel and multi-core processing
- The system can process large data volumes of varied types at speed
  - seismic
  - rock properties
  - well history



- Supports a range of simulations including compositional, thermal and black oil models
- The system has since been deployed in another basin where Apache has interests

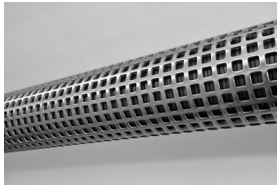
5.3 Emerging technologies

Reservoir and well management

Areas	Technologies
Production surveillance	• HT logging tools (CNOOC) • Downhole flow meters and gauges (Whalsay Energy) • Fibre, permanent sensors, wireless (Total)
Artificial lift and flow assurance	• Retrofit gas lift (BP) • Capillary string in subsea wells (Shell) • Sand control alternatives, bullhead (Spirit Energy) • Wireline deployed ESPs (Perenco) • ESP new design for improved reliability and life (Equinor) • Twin screw pumps for heavy oil (Whalsay Energy) • Water shut off, advanced methods using nanotechnology (CNOOC, OGTC) • Scale prevention / inhibition (Marathon) prevention of subsurface safety valve (SSSV) issues (Total) • Wax prevention and remediation (Apache, Chrysaor, Hurricane, EnQuest) • HF localised electric heating for flow assurance (Tullow)
Well integrity	• Overburden monitoring and permanent 4D using fibre DAS and vertical seismic profiles (Total) • Detection and repair of parted conductors (Total) • Autonomous inflow control devices (Alpha, Apache)
IOR / EOR	• Water injection, voidage replacement optimisation (CNOOC, Apache, Spirit Energy) • Subsea raw water injection (i3, Apache, Chrysaor) • Low-cost, non damaging polymers (Chevron) • Foam EOR (Neptune) • Next generation designer water (BP) • Reservoir recovery parameters, Improved oil recovery (IOR)/EOR screening and pilots programmes (Apache, Anasuria, EnQuest)

Exemplars

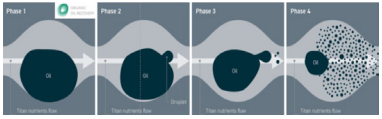
Advances in flow assurance



- Flow assurance is an ongoing challenges
- Technology and mitigation processes are under development (e.g. chemical, ultrasonic disruption and localised heat treatment)
- Using a lightweight intervention vessel (LWIV), Shell cost effectively deployed ceramic sand screens in its Gannet field
- These are been assessed by Shell for HPHT applications

EOR

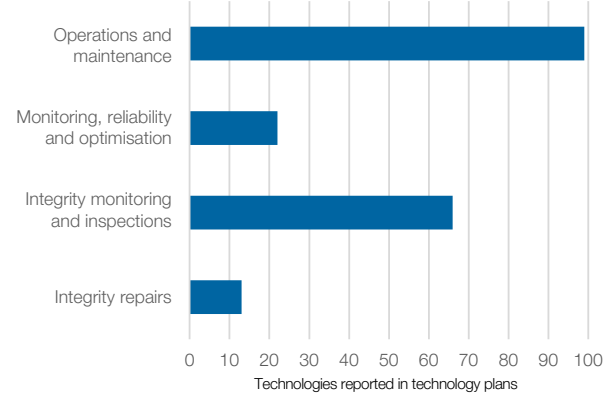
- There are EOR technologies that could deliver value for the UKCS
  - polymer
  - low salinity
  - miscible gas
- BP's low salinity Clair ridge development is expected to deliver an additional 35 million barrels of oil
- Chevron plan to use polymer EOR for the Captain development with several new field developments being made polymer ready



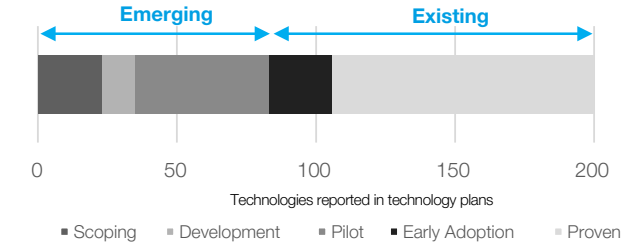
- Other EOR methods are demonstrating potential (e.g. microbial, steam, foam and CO_2)

6. Facilities management

Technology categories



Technology maturity



Industry insights

- Technology investment has allowed assets to operate beyond their design life, delivering additional production and field development opportunities
- Remotely operated inspection technologies for hazardous or hard to reach areas deliver cost, safety and efficiency benefits
- There should be a wider uptake of NII technologies for vessel inspection
- Exploiting digital based technologies has increased across the UKCS. The use of wearable and wireless technologies, integrated with ATEX tablets provides efficient workflows
- Integrated operation centres, digital twins and virtual machines have improved production efficiency, optimising real time asset management
- Most technologies are developed by, or in partnership with, vendors. Many solutions are available ‘off the shelf’ but there are opportunities for operators to pilot and trial new and emerging technologies

6.1 Operators' technology map

Facilities management

Operator	Operations and maintenance	Monitoring, reliability and optimisation	Integrity, monitoring and inspections	Integrity repairs
Anasuria				
Apache North Sea				
BP Exploration				
CATS Management				
Centrica Storage				
Chevron Corporation				
Chrysaor				
CNOOC				
CNR				
ConocoPhillips				
Dana Petroleum				
EnQuest				
EOG Resources				
Faroe Petroleum				
Marathon Oil UK				
NSMP				
Oranje-Nassau Energie B.V.				
Perenco				
Premier Oil				
Repsol Sinopec				
Serica Energy				
Shell UK				
TAQA Europa				
Total Upstream UK				
Whalsay Energy				
Wintershall				

Number of UKCS technology priorities reported by operators in their plans

0 1-3 4-8 9-13 14-17

6.2 Existing technologies

Areas	Technologies
Wearable and wireless technologies	• Wider 4G coverage • More devices ATEX rated • Body-mounted cameras, mobile data/communication (5+ operators))
Hard-to-reach area inspections	• Drones (10+ operators), splash zone and subsea crawlers (Chrysaor, Shell, Dana, Repsol Sinopec, CNR) • Visual (10+ operators), forward looking infrared (FLIR) (Repsol Sinopec, BP, EnQuest, Shell, Spirit Energy), CT pipeline scanner (Shell, Repsol Sinopec)
Composite repairs	• Fabric repairs (10+ operators) • Structural repairs (Repsol Sinopec, CNOOC, ConocoPhillips, Shell) • Repairs in splash zone and other very harsh areas (Shell)
Corrosion detection and monitoring	• Detection - ultrasound (thickness), pulse-eddy current (flaws), x-rays (internal) (10+ operators) • Monitoring (Shell, Chevron)
Real-time asset monitoring	• Condition based maintenance (CBM) rotating equipment (5+ operators) • Subsea electrical fault finding (BP, Marathon, Shell, Total) • Onshore virtual centres (5+ operators)
Asset digitisation	• 3D asset surveying – photogrammetry and laser scanning (10+ operators), including subsea (Shell), point and shoot survey (Shell)

Exemplars

Wearable cameras and communication (voice/visual/data)

- Mobile working reduces inspection cycle time delivering operational efficiencies
- Operators Repsol Sinopec and Chrysaor have deployed wearable technology on their brownfield assets improving reporting and enabling data trending
- Technology enables service level operations from supply chain

Drones for hard to reach areas

- Anasuria and Total have deployed on FPSOs and large complex assets

- New sensors are multiplying capability (e.g. FLIR, laser imaging, detection and ranging (LiDAR)
  - OPEX efficiencies
  - safety improvements
  - asset life extension
- The supply chain is delivering more value, integrating data collection and analysis processes

Integrated operating centres

- Operators (Chevron, Repsol Sinopec, ConocoPhillips and BP) have deployed integrated operating centres (IOC) on their asset portfolio
- Integrated with vendors' fault finding systems
- The Montrose and Arbroath IOCs (Repsol Sinopec) have increased uptime, aided production optimisation, enhanced safety and reduced OPEX

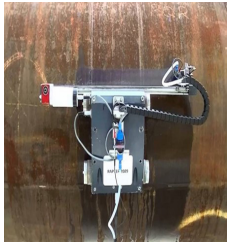
6.3 Emerging technologies

Facilities management

Technologies	Value
Non intrusive inspections	• On-line vessel/tank inspection without entry - ultrasonic corrosion mapping, time of flight diffraction (5+ operators, OGTC) • Corrosion detection without insulation removal, enhanced/pulse-eddy current (Repsol Sinopec, CNOOC, Chrysaor, CATs, Taqa, OGTC)
Autonomous and robotic systems	• Beyond line of sight drones (Spirit Energy) • Robotic arms, autonomous multitasking robots (Total, Shell, Chevron, OGTC) • Autonomous drone external corrosion survey (BP)
Corrosion prevention	• Live-line and surface tolerant coatings, protective and self healing coatings, hydrophobic and free draining coatings (CATs, Centrica Storage, Chevron, Repsol Sinopec, Shell) • Flange and bolt protection (Shell, Chevron, CNOOC, CATs)
Predictive maintenance	• HUMS, digital analytics (5+ operators) • Vibration analysis cameras (Apache)
Additive manufacturing	• Offshore component manufacture (Shell, Total)

Exemplars

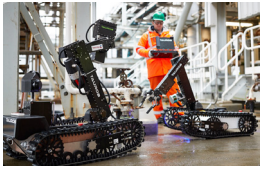
Non-intrusive inspection



- Total and the OGTC completed on-line field trials on the Elgin Franklin platform
- Repsol Sinopec have widely adopted NII
  - results correlate with traditional techniques
  - no downtime or safety challenges
  - in many cases NII is being seen as more effective than an internal visual inspection

Autonomous and robotic systems

- Total and the OGTC are trailing an autonomous inspection robot at the Shetland Gas Plant. An offshore trial is planned on the Alwyn platform
- System performs visual inspections, reading dials, gauges and valves
  - safety and cost benefits
  - supports alternative facility designs
- Development has transferred from academia to real world trialling

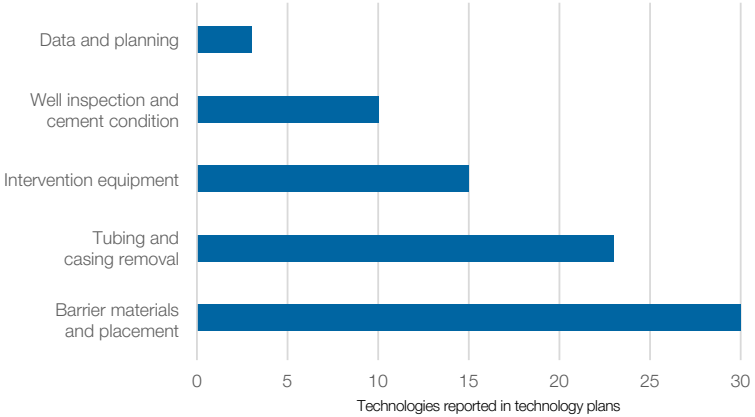


Corrosion prevention

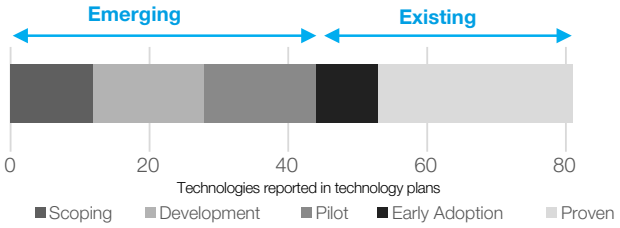
- New coating technology advances corrosion monitoring to prevention
- Total and CNOOC have trialled a self healing ceramic phosphate coating on aging assets
- Shell have successfully used hydrophobic barriers on Shearwater and Nelson
- Supply chain transferring technology from other sectors (e.g. downstream)

7. Well plugging and abandonment

Technology categories



Technology maturity



Industry insights

- To achieve the target of a 35% reduction in decommissioning costs, operators must reduce the overall cost of well plugging and abandonment (P&A)
- Rig-less operations, improved casing milling tools alongside alternative cutting technologies (e.g. laser, plasma, water jet) could reduce costs
- Alternatives barriers to cement (e.g. bismuth alloys, resin, thermite, natural barriers) are under trail and assessment
- The majority of technology needs are looking to emerging solutions, but existing and enhanced technologies are delivering real benefits
- Through tubing logging remains a challenge, but advances in tools (e.g. pulsed neutron, x-ray, ultrasonic) and data processing techniques are improving imaging
- Collaborative initiatives can provide an essential contribution to technology development

7.1 Operators' technology maps

Well plugging and abandonment

Operator	Data and planning	Well inspection and cement condition	Intervention equipment	Tubing and casing removal	Barrier materials and placement
Alpha Petroleum					
Anasuria					
BP Exploration					
Centrica Storage					
Chevron Corporation					
Chrysaor					
CNOOC					
CNR					
ConocoPhillips					
Endeavour Energy					
EnQuest					
Fairfield Energy					
INEOS					
Ithaca Energy					
Marathon Oil UK					
Parkmead					
Perenco					
Premier Oil					
Repsol Sinopec					
Shell UK					
Spirit Energy					

Operator	Data and planning	Well inspection and cement condition	Intervention equipment	Tubing and casing removal	Barrier materials and placement
TAQA Europa					
Total Upstream UK					
Tullow Oil					

Number of UKCS technology priorities reported by operators in their plans

0 | 1-3 | 4-8 | 9-13 | 14-17

7.2 Existing technologies

Well plugging and abandonment

Areas	Technologies
Data and planning	• Multi-well campaign planning (Tullow, ConocoPhillips, Spirit Energy)
Well inspection and cement conditions	• Efficient logs and surveys in the planning phase with preparation for intervention (Anasuria, Premier) • Use of cement bond logging and data modelling (Marathon, Shell)
Intervention equipment	• Efficient clean up tools (Total) • CT deployed perforating guns and isolation tools (Tullow)
Tubing and casing section removal	• Tubing agitator technology (ConocoPhillips) • Optimised section milling (CNR) One trip section milling (ConocoPhillips) • Abrasive water jetting for well head removal (Total, Marathon) • Downhole pulling technologies (Fairfield) • Hydraulic mast / heavy duty workover for P&A (CNR)
Barrier materials and placement	• Anulus perf / wash / cement (ConocoPhillips, Chrysaor, Shell, Endeavour) • Thru-tubing abandonment technologies, including perf, expanding slurries, agitators, pressure testing (Shell)

Exemplars

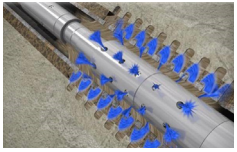
Multi well campaigns

- Multi-operator and multi-well campaigns can help de-risk well abandonments, delivering cost and programme efficiencies
- Enabling technologies (e.g. AI, data mining) can assist the abandonment planning process
- ConocoPhillips and Spirit Energy realised significant savings by collaborating on a joint SNS well P&A campaign, sharing knowledge, expertise and bespoke equipment

Tubing and casing removal

- Innovations in existing cutting techniques and technologies have reduced cutting times and support one trip operations
- Shell, CNR, Total and Marathon have deployed enhanced cutting tools in P&A (e.g. improved section milling, abrasive water jet)

Barrier deployment



- Perf, wash and cement technology could potentially reduce the costs of plugging across multiple annuli without milling
- This technique is used in other basins, but it has not been deployed extensively in the UKCS
- It is under assessment by a number of UK operators

7.3 Emerging technologies

Well plugging and abandonment

Technologies	Value
Well inspection and cement conditions	• Advanced cement bond logging interpretation (BP) • Advanced bond logging, e.g. pulsed neutron (Premier) • Bond logging through multiple casing strings (ConocoPhillips)
Intervention equipment	• LWIV riserless P&A subsea wells (Ithaca, Spirit Energy) • Casing punch tool to intervene in HPHT anulus (Shell)
Tubing and casing section removal	• Next generation tubing casing removal solutions (ConocoPhillips) • Improved section milling tooling (Fairfield) • Innovative casing removal methods (Fairfield) laser technology (Total, Shell, ConocoPhillips) • Plasma bit (Repsol Sinopec)
Barrier materials and placement	• Swelling shale and swelling clay barrier (BP, ConocoPhillips) • Squeezing salt barrier (ConocoPhillips) • Scale formation barrier (Repsol Sinopec, Spirit Energy) • Thermite plug (6+ operators) • Bismuth alloy plug (Repsol Sinopec, Shell, ConocoPhillips, BP • Resin barrier (ConocoPhillips)

Exemplars

Cement and multiple casing logging

- Effective cement logging through multiple casing strings would provide cost and time benefits, but remains challenging
- The OGTC are supporting a tier one supplier on an early stage multiple casing logging tool
- The wider supply chain is working to develop a range of additional technologies (e.g. enhanced ultrasonic, x-ray, advanced algorithms)

Casing removal

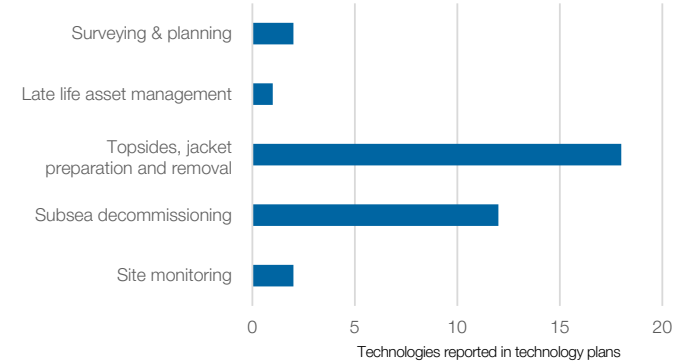
- To improve work flows and reduce costs further, alternatives to section milling are being sought
- Shell and ConocoPhillips have undertaken trails of a conductor laser cutting system
  - capability to sever multistring casings
  - fast and accurate

Barriers (alternatives to cement)

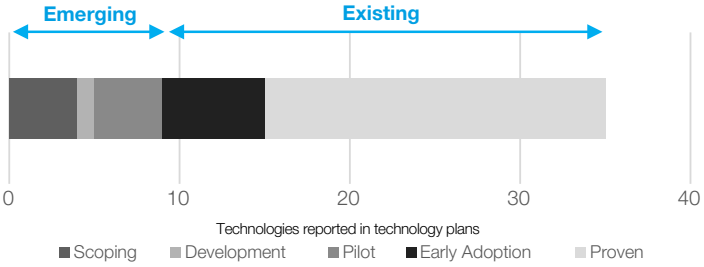
- Alternatives to cement, could result in significant operational and cost benefits
- In 2019 Spirit Energy and the OGTC targeted an offshore test of a thermite based technology
- Resin has been used as a temporary barrier. Use as a permanent barrier is under assessment
- To reduce the need for remedial cementing there are ongoing studies on the functional use of natural barriers (e.g. swelling shales, squeezing salt)

8. Facilities decommissioning

Technology categories



Technology maturity



Industry insights

- Technology has focused on subsea and surface structure removal (e.g. topside one piece/single lift removal, flotation lift systems, leg cutting). Ongoing developments will provide further efficiencies
- Ancillary technologies (e.g. modelling, use of alternative/ temporary energy sources and infrastructure) will provide for more effective decommissioning workflows
- Utilising existing technologies to their optimum effect is an industry priority, with opportunities to learn from other industry sectors (e.g. salvage, nuclear)
- The engaged supply chain provides most of the technology solutions. Operators' experience has provided some in-house developments
- Decommissioning has environmental challenges. Technologies to analysis drill cutting piles, site monitoring and cell isolation have been identified and present collaboration opportunities

8.1 Operators' technology map

Facilities decommissioning

Operator	Surveying and planning	Late life asset management	Topside and jacket preparation removal	Subsea decommissioning	Site monitoring
Alpha Petroleum					
Apache North Sea					
Chevron Corporation					
Chrysaor					
CNOOC					
CNR					
Endeavour Energy					
EnQuest					
Fairfield Energy					
Ithaca Energy					
NSMP					
Perenco					
Premier Oil					
Shell UK					
TAQA Europa					
Total Upstream UK					
Tullow Oil					

Number of UKCS technology priorities reported by operators in their plans

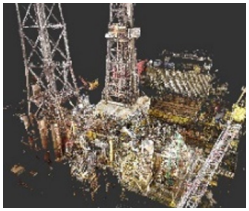
0 1-3 4-8 9-13 14-17

8.2 Existing technologies

Areas	Technologies
Surveying and planning	• 3D printing – complete scale model of platform for planning of module removal sequence (CNR)
Late life asset management	• Low-power lighting for 'light house mode' (Perenco)
Topsides and jacket preparation and removal	• Gravity-based structures content sampling (Shell, Apache) • Jacket lifting clamps (CNR) • Remotely operated latching pins for jackets (CNR) • Supersizing diamond wire cutting (CNR) • Remotely operated vehicles (ROV) and cutting tooling (Fairfield) • Single lift for topsides and jackets (Shell, Apache, Chrysaor, EnQuest) • Shear keys for gravity based legs (Shell)
Subsea decommissioning	• Pipeline decommissioning (NSMP) • Long-term subsea substrate modelling (Perenco) • Tool to cut, seal and lift bundles (CNR) • Methods to hot tap, flush and grout subsea pipelines (CNR) • Anchor handling vessel and reverse reel for riser removal (Ithaca)

Exemplars

Late life facilities



- Digital technologies and asset management tools utilised on producing assets will provide future CoP efficiency benefits
  - detailed asset and material knowledge
  - support planning/selection of decommissioning processes
- To support decommissioning of the Murchison platform, CNR utilised an interactive 3D topsides model. Premier have built a virtual walk through model of the Balmoral floating production vessel (FPV)
- Like the nuclear industry, operators should consider how to use additive manufacturing for use in facilities in late life stage

Structure removal

- To maintain efficiency gains innovative for surface and subsea structure removal is necessary
  - enhance current techniques (e.g. hydraulic grapple tools)
  - alternative technologies (e.g. buoyancy barges)
- Shell's Brent decommissioning programme has delivered ongoing technology innovation
  - attic oil sonar survey
  - oil recovery from topsides
  - conductor laser cutting
  - use of shear keys and single lift interface system

8.3 Emerging technologies

Areas	Technologies
Surveying and planning	• Decommissioning planning (CNOOC, OGTC)
Topsides and jacket preparation and removal	• Alternative, more cost-effective cutting and removal techniques for jacket and topsides (Perenco, Apache, TAQA) • External hydraulic lifting tools (CNR)
Subsea decommissioning	• Leaving mattresses in place, potential rock dumping for 'trawlability' (Alpha) • Drill cutting analysis vacuum tool (Total)
Site monitoring	• Ocean power technologies for site monitoring and guard buoys (Premier) • AUV technologies for site monitoring (Shell)

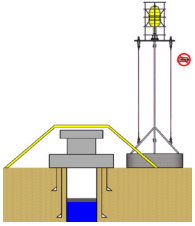
Exemplars

Cutting and removal

- Cost effective alternatives to the cutting and removal of steel could provide economic and operational benefits
- Accelerated corrosion through electrochemical dissolution is one potential technology
  - OGTC have supported a feasibility study, inclusive of proving the technique on workshop-scale steel components
  - follow-up preparations are underway for larger-scale trials

Site monitoring technologies

- Technologies to validate and monitor decommissioned sites when required are under assessment
- Challenged by remote location and lack of supporting infrastructure, linking local power generation, communication buoy technology or passive sensors may provide a solution
- Industry efficiencies could result from a campaign or joint operator approach



Conclusions

Findings

- Operators' technology plans represent a broad spectrum of UKCS technology priorities over the whole asset life cycle
- Individual operators have technical strengths as well as opportunities to learn from their peers
- Only a minority of operators invest directly in technology development
- The majority of them source technology solutions straight from vendors

Expectations

- The OGA expects that operators deploy existing technologies where these can add value
- Operators should share lessons learned to support others successfully deploying technologies
- Operators need to maintain a close dialogue with the supply chain to consider the latest innovation
- Further emerging technologies are critical for MER UK, and the industry is expected to engage with the work by the TLB and OGTC

Oil & Gas Authority

technology leadership board

The Oil & Gas Technology Centre
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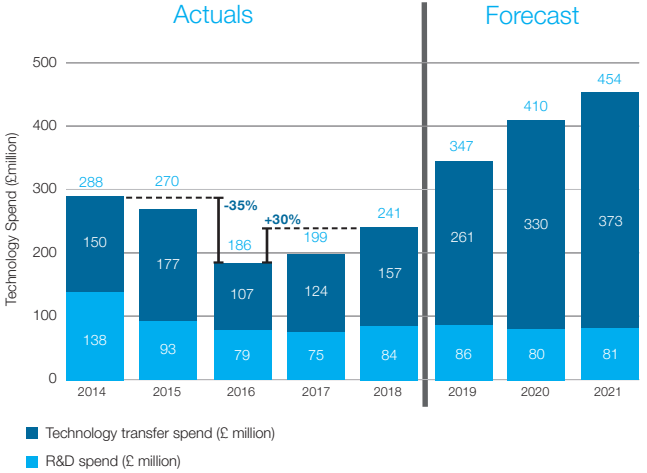
Image courtesy of Tenzor Geo

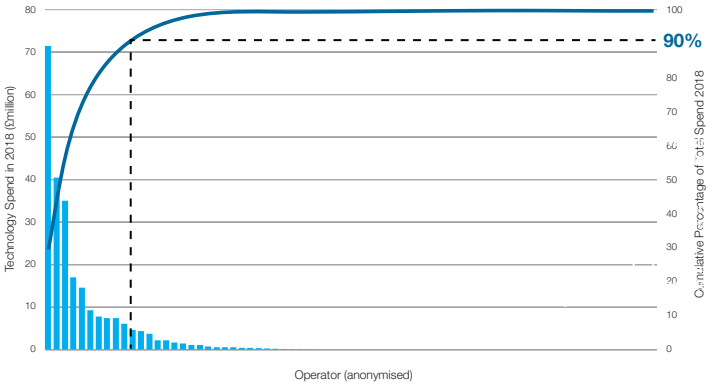
Appendix - Technology spend

UKCS operators' technology spend (actuals and forecast, £m)



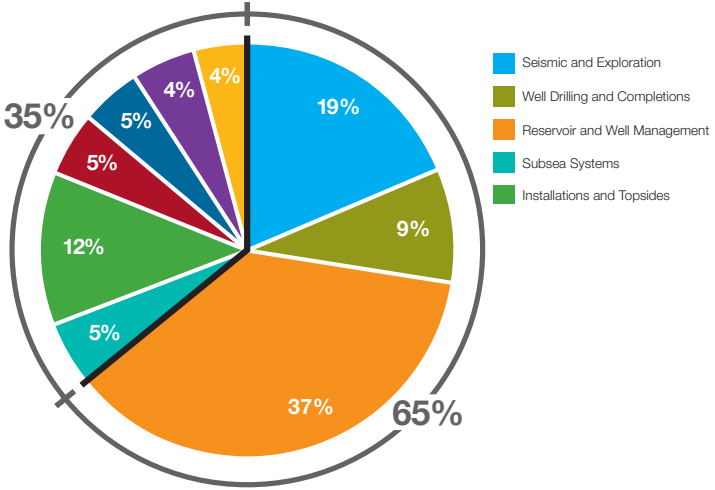
Following a 35% decline from peak (2014) to 2016, the operators' technology spend has started to grow again (+30% from 2016 to 2018).

Total technology spend by operator (anonymised)



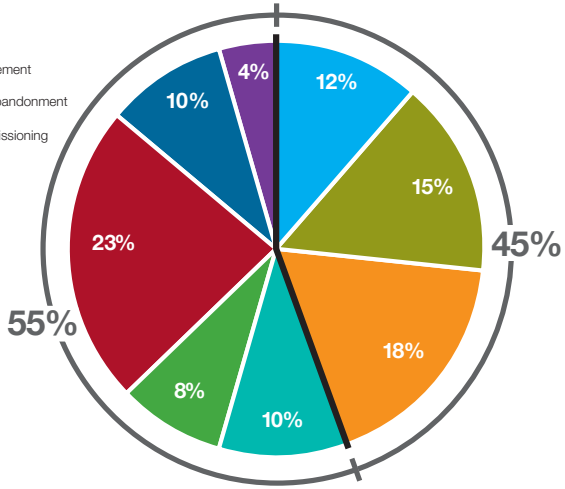
Ten operators, of 74 in total, account for 90% of the technology spend. This includes companies that have located international research programmes in the UK.

Technology spend by category (£)



Direct operators' spend is only part of overall industry R&D investment. It is supplemented by supply chain investment. The survey data shows that operators' spend has a strong focus on subsurface, wells and reservoir technology where operators can achieve a strategic advantage.

Number of technologies in the plans



In contrast, technologies to deliver and manage facilities and infrastructure have a strong demand. These are in areas where operators source developed solutions from the supply chain.

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