REPORT

Decommissioning on the Norwegian Continental Shelf – Cost Effective and Innovative Solutions

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Project Title: **Decommissioning on the Norwegian Continental Shelf – Cost Effective and Innovative Solutions**

Document/Rev No: J75064A-A-RT-00001/D1

Date: September, 2019

Rev	Date	Description	Issued by	Checked by	Approved by	Client Approval
A1	01/08/2019	Issued for IDC	AH	MP	MP	
B1	15/08/2019	Issued for Client Review	AH	MP	MP	
D1	18/09/2019	Issued for Use	PMB	AH	MP	

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ABBREVIATIONS

ABEX	Abandonment Expenses
AIV	Autonomous Inspection Vehicle
AUV	Autonomous Underwater Vehicle
BTA	Buoyancy Tank Assembly
CoP	Cessation of Production
CSV	Construction Support Vessel
CT	Coiled Tubing
DSV	Diving Support Vessel
FFFA	Fire/Fergus/Flora/Angus Fields
HLV	Heavy Lift Vessel
HPHT	High Pressure High Temperature
HSE	Health, Safety and Environment
IV/RR	Ivanhoe Rob Roy Fields
LNG	Liquified Natural Gas
LWIV	Light Well Intervention Vessel
MDR	Module Drilling Rig
MMI	Mobile Metal Ions
MODU	Mobile Offshore Drilling Unit
MSF	Module Support Frame
NCS	Norwegian Continental Shelf
NPD	Norwegian Petroleum Directorate
OSPAR	Oslo Paris Convention
OPEX	Operating Expenses
P&A	Plug & Abandonment
PSV	Platform Supply Vessel
PWC	Perforate, Wash, Cement

ROP	Rate of Penetration
SAR	Search and Rescue
SIMOPS	Simultaneous Operations
SWAT	Suspended Well Abandonment Tool
UT ROV	Utility Remotely Operated Vehicle
WASP	Well Abandonment Straddle Packer

1.0 EXECUTIVE SUMMARY

As older oil and gas fields in the NCS approach the end of economic production, disposal activities are required, representing a significant cost to the Norwegian state. This report aims to identify, shortlist and present proposals that could achieve improved cost effectiveness in decommissioning of offshore oil and gas infrastructure including wells.

The study was completed using a four-step process as summarised below:

Step 1: Identify an indicative breakdown of decommissioning expenditure for a "typical" decommissioning project on the NCS;

Step 2: Identify decommissioning project cost areas and key cost drivers that have the greatest impact on decommissioning project cost;

Step 3: Describe the proposals that have the potential to deliver cost effectiveness in disposal projects for the cost areas identified above, grouped by the following categories;

- Technical (including developing technology and techniques);
- Commercial; and
- Guidance and Practice

Step 4: Screen the proposals identified for impact and likelihood of implementation to identify a screened shortlist of proposals that could be applied to future projects.

From steps 1 and 2 it was identified that well decommissioning (P&A), topsides and substructure removal and subsea infrastructure and pipelines removal are typically the three largest contributors to decommissioning project cost.

Note that this study did not consider facility running costs, post cessation of production. These operating costs are largely a function of manning levels required to keep the necessary facilities available during decommissioning and can also be a significant cost element of the overall decommissioning liabilities. These costs may be reduced through for example, rationalisation of operations and reduction of the period from cessation of production to topsides removal.

Using the above focus cost areas, study steps 3 and 4 were then completed and the following conclusions and recommendations are made.

In the technical category, no technology or technique that would immediately deliver a step-change in decommissioning and abandonment costs was identified. However, several individual areas of varying maturity were identified. If implemented, these areas could potentially yield significant incremental efficiencies and improvements, these include:

- Thermite well plugging and sealing;
- VR360 for verification and assurance on cement quality / integrity;
- Topsides single-lift, for e.g. Allseas Pioneering Spirit;
- High capacity HLVs (Hereema Sleipnir);
- External buoyancy technology.
- UT ROV (for subsea)

Note that the deployment of technology may mitigate some risks and deliver cost savings, either directly or through operational time savings. However, some of the benefit (e.g. financial reward) would most likely be retained by the technology developer, rather than passed on as project cost savings. In other words, the price of the technology is typically driven by market competition, rather than its cost. It is also worth noting that innovative technologies may initially increase risk (and thereby, cost).

From a techniques perspective, providing the opportunity for schedule flexibility in the contracting strategy would allow the contractor to use the decommissioning scope as 'fill-in' or opportunistic work during quiet periods and to target economies of scale, in order to realise cost efficiencies.

Focus on maturing and developing existing techniques further, i.e. further developing expertise in executing these methods, and having fall back options, or contingency plans, in place to manage the unexpected (i.e. risk). The focus here is on efficiency and preparedness and introducing / encouraging market competition to the supply chain.

Key to this strategy is in the early engagement with regulators and the supply chain. Early regulator engagement can help understand the scope of the project, and early engagement with the supply chain would give them the time and motivation for innovation on how their equipment and working practices may be modified to deliver cost-effective decommissioning.

Introduction of techniques and practices from other industries (e.g. salvage industry) and geographical regions (e.g. Gulf of Mexico, or the Far East) may also yield cost reductions.

As in development projects, decommissioning projects involve a large number of risks, many of which can be identified and mitigated through early planning and preparation and by having a focus on front end loading of decommissioning projects.

The main commercial opportunities identified relate to trying to increase cooperation across licenses and operating companies to allow removal scopes to be aggregated to maximise efficiency gains / lessons learnt and to provide a predictable work lookahead for contractors to plan for. Another area of significant opportunity is to consider transferring assets to a third party decommissioning specialist company to allow integrated planning, economies of scale and batching of decommissioning projects in a way that minimises cost and risk.

Alternative reuse scenarios in order to avoid the requirement for decommissioning were also considered. In general, it was concluded that the opportunity in this area was limited in most scenarios. However, it was identified that with the development of floating wind turbines that re-purposing existing infrastructure could be complimentary to these developments. Assessment on a case by case basis would be required to determine the commercial and technical feasibility of such a proposal.

The opportunities identified present a diverse range of possibilities and vary in maturity from “initial idea or concept” to recently proven in use. This study has been completed as a desktop exercise utilising previous project experience and recent research to inform the findings. Further work will be required to confirm the value of the opportunities identified. Next steps could include engagement with decommissioning project stakeholders from inside and outside of the industry to further develop the findings of this study and to identify a roadmap for how these and/or other future opportunities could be incorporated into future decommissioning projects.

2.0 INTRODUCTION

2.1 Study Background

As oil and gas fields on the NCS approach the end of economic production, disposal activities are expected to increase, representing a significant cost to the Norwegian state. The Norwegian Petroleum Directorate (NPD) has commissioned Genesis to undertake a study to identify market related opportunities that have the potential to enable significant cost reduction in these decommissioning projects.

2.2 Study Objective and Purpose

The objective of the study is to identify and assess proposals (opportunities) to bring about cost effectiveness in the decommissioning of offshore infrastructure and wells, such as through, innovative technologies and techniques, licensees' incentives, area-wide solutions, etc.

The study was framed to consider opportunities in the following areas:

- Technical (including developing technology and decommissioning techniques);
- Commercial;
- Guidance and Practice.

The purpose of this report is to document and summarise the findings and outcomes from the study. The findings presented are based on the accumulated knowledge and experience of Genesis and on reported lessons learned from previous decommissioning projects that have been presented at public forums and conferences.

3.0 STUDY APPROACH

3.1 Outline of the Process

The following steps outline the process by which proposals have been identified, collated and screened.

Step 1: Identify indicative breakdown of decommissioning expenditure for a 'typical' decommissioning project on the NCS [Ref. 1].

Step 2: Identify key areas of project expenditure (cost areas) and the key cost drivers in each of these areas

Stage 3 Describe the proposals that have the potential to deliver cost effectiveness in disposal projects, grouped by the following categories;

- Technical (including developing technology and techniques);
- Commercial; and
- Guidance and Practice

Where possible, for the technical solutions under development, a further review was undertaken to provide a considered estimate of the potential value which may be realised, in terms of cost savings under each of the ideas, against the likelihood of the solution coming to market.

Stage 4 Screen the proposals, based on the status today, against the following criteria

- Impact: Target value (i.e. higher cost savings, score higher)
- Likelihood: Can the idea be implemented in a realistic / useful timeframe (shorter time frames score higher)?

The technical opportunities have been by assessed using the screening matrix shown below, to identify those ideas that were considered to have a significant potential to impact disposal costs. Such impacts may be achieved by new technologies and techniques, efficiency improvements or a combination of both.

Impact (Potential Benefit) →

Likelihood of coming to market ↑	[1] Insignificant	[2] Minor	[3] Moderate	[4] Major	[5] Considerable
[5] Almost Certain	5	10	15	20	25
[4] Likely	4	8	12	16	20
[3] Possible	3	6	9	12	15
[2] Unlikely	2	4	6	8	10
[1] Very Unlikely	1	2	3	4	5

4.0 SUMMARY OF COST AREAS AND COST DRIVERS

4.1 Significant Cost Areas and Cost Drivers

An indicative representation of the breakdown of decommissioning expenditure for the key components of a decommissioning project on the NCS is depicted in Figure 4-1. This activity / cost breakdown is derived from data collated for the Northern North Sea and West of Shetland region [Ref. 1].

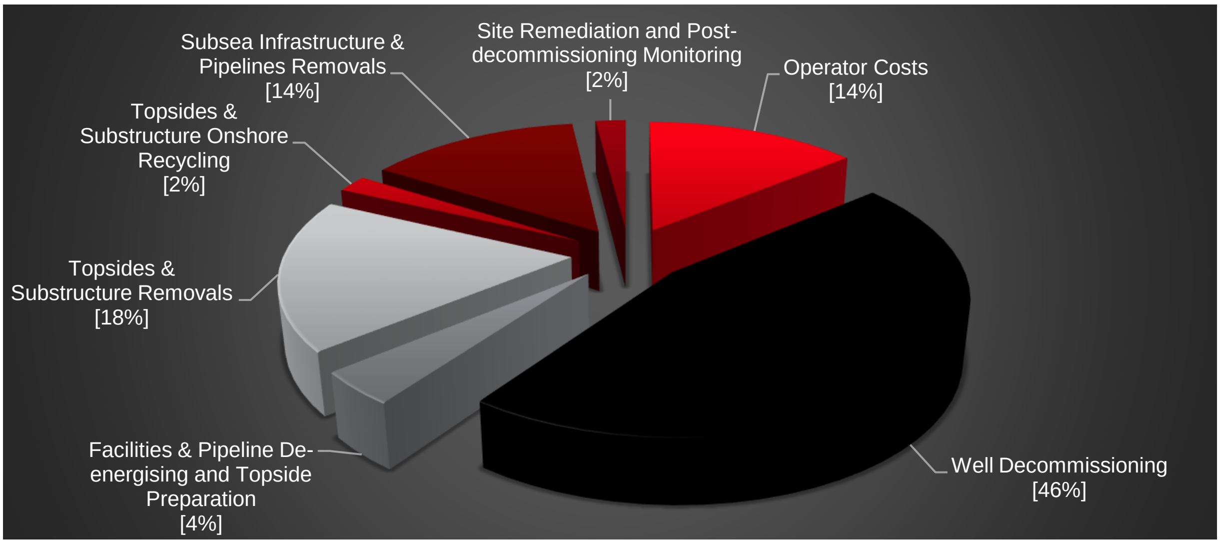


Figure 4-1: Indicative Proportion of Decommissioning Expenditure

The profile of expenditure depicted in Figure 4-1 can be expected to vary somewhat depending on the type of development being decommissioned. For instance, a subsea only development will have minimal surface facility decommissioning costs. However, for a basin wide analysis that includes decommissioning of many different types of developments in varying water depths, Figure 4-1 is considered to be a reasonable assessment of the average anticipated largest areas of spend for decommissioning projects across the whole of the NCS.

In order to identify proposals with the aim of bringing about cost effectiveness in decommissioning, the following three key areas of decommissioning project spend from Figure 4-1 are the main cost areas and are therefore considered further in this study:

- **Well Decommissioning (P&A)**: The spread rate and services associated with decommissioning wells - The permanent isolation of any rock formations with flow potential and restoration of a seabed to its previous state.
- **Topsides & Substructure Removal**: The removal activities for topsides and substructures.
- **Subsea Infrastructure & Pipelines Removal**: The removal of pipelines, mattresses and subsea structures.

Note that Operator costs have not been considered further in this study. Operator costs in Figure 4-1 represent a combination of cost associated with decommissioning project management and the cost of operating an offshore facility, post cessation of production (Post-CoP OPEX). Cost effectiveness in post-CoP OPEX is generally driven by improving operational efficiency, e.g. converting the facility to minimally manned or normally unattended operations, reducing the duration from CoP to topsides removal, etc.

The main cost drivers within each of these significant cost areas are identified in Table 4-1. This shows, at a high level, which activities can be considered to be driving the overall cost. The drivers were used as a point of reference to identify significant cost reduction opportunities and are based on previous project experience.

A summary of the key drivers for each of the cost identified for further study is presented in Table 4-1 below.

Table 4-1: Key Cost Drivers

Focus Area	Key Cost Drivers
Well Decommissioning	P&A Activity / Campaign Durations Incl. Intervention Method / Marine Support Rates: - Well integrity and cement quality verification, e.g. Tubing and casing section removal requirements; - Subsea Wells: Mobile Offshore Drilling Unit (MODU) i.e. Jack up, semi-sub drill rig vs. Light Weight Well Intervention Vessel (LWWIV). - Platform Wells: Fixed drill facilities (existing) vs. Mobile Offshore Drilling Units (MODU) vs. Modular Drilling Rig (MDR) / modular equipment spreads. Additional Marine Support Vessel (MSV) campaign duration(s) / rates.
Topsides & Substructure Removal	Marine Support Requirements: - Heavy Lift Vessel (HLV) campaign duration(s) / rates. - Dive Support Vessel (DSV) campaign duration(s) / rates. - MSV campaign duration(s) / rates. - Flotel durations / rates. - Sea fastening requirements.
Subsea Infrastructure & Pipelines Removal	Marine Support Requirements - Survey, DSV, Lifting (crane vessel) campaign duration(s) / rates. - Marine construction vessel, e.g. lay-barge, reel ship, etc.

5.0 COST AREA – WELL PLUG & ABANDONMENT

According to Oil & Gas UK Decommissioning Insight 2018, it is expected that an average of 22 wells in the NCS will be decommissioned each year through to 2024, after which a significant increase is forecast. Between 2025 and 2027 some large decommissioning projects are expected to start, with annual well decommissioning expected to increase to an average of 70 wells per year" [1].

A reduction in the overall cost of well plugging and abandonment delivered by; key emerging technologies and techniques (see Section 5.1), commercial advances (see Section 5.2) and/or guidance and practice (see Section 5.3) has the potential to significantly positively impact well decommissioning and abandonment costs.

5.1 Technical Opportunities – Technology and Techniques

A summary of existing and emerging well decommissioning (P&A) technology focus areas and value drivers that have the potential to reduce overall P&A cost / risk, are presented in Table 5-1.

Table 5-1: Summary of Technology Focus Areas for Well Decommissioning

Focus Area	Existing Technologies / Value Drivers	Emerging Technologies / Value Drivers
Well Inspection and Cement Conditions	- Efficient logs and surveys in the planning phase with preparation for intervention. - Use of cement bond logging and data modelling.	- Advanced cement bond logging interpretation - Advanced bond logging, e.g. pulsed neutron - Bond logging through multiple casing strings
Intervention Equipment	- Efficient clean up tools. - Coiled tubing deployed perforating guns and isolation tools.	- Light Weight Intervention Vessel (LWIV) riserless P&A of subsea wells - Casing punch tool to intervene in HPHT annulus
Tubing and Casing Section Removal	- Tubing agitator technology - Optimised section milling / one trip section milling - Abrasive water jetting for well head removal - Downhole pulling technologies - Hydraulic mast / heavy duty workover for P&A	- Next generation tubing casing removal solutions - Improved section milling tooling - Innovative casing removal methods, incl. LASER technology - Plasma bit
Barrier Material and Placement	- Annulus perforation, wash and cement. - Thru-tubing abandonment technologies, including perf, expanding slurries, agitators, pressure testing.	- Swelling shale and swelling clay barrier - Squeezing salt barrier - Scale formation barrier - Thermite plug - Bismuth alloy plug - Resin barrier

A summary list of a selection of identified emerging technologies and innovative techniques for well plug and abandonment are presented in Table 5-2 and Table 5-3 respectively. Brief datasheet summaries for the shortlisted emerging technologies are included within Appendix A.1.

Table 5-2: Selection of Emerging Technologies for Well Plug and Abandonment

Technology	Description	Maturity / Tech Feasibility	Impact	Impact on Other Activities	Risk/opportunity	Likelihood	Impact	Score
Extreme Concepts - Melt / Burn well elements in-situ								
Interwell The Superior P&A Solution	Method of abandoning a well whereby well elements are melted in-situ using ignitable compounds	Supported by the Research Council of Norway, Equinor, BP. Feasibility Statement obtained from DNV, pilot well tests completed	Estimate of up to 50%* overall time reduction in Well P&A. Does not require use of a MODU or verification of cement behind casing. (*For a well requiring significant intervention.)	None significant Wireless verification, if available to be used in conjunction with other technologies, would be of interest	Need to assess plug length required, vis à vis regulatory guidelines. Better plug material than cement claimed, however t is not expected that this solution will comply with the guidelines as they are written today.	[4] Likely	[5] Considerable	**20**
Baker Hughes - Laser Plug and Abandon	Method of abandoning a well whereby well elements are melted in-situ using high power laser	Patent applied (2015), other examples of similar patents also exist	Potentially does not require MODU, or verification of cement quality behind casing	None significant	Unlikely to satisfy plug length guidelines. The ability to deliver significant energy via laser over the appropriate area is potentially a risk.	[1] Very Unlikely	[5] Considerable	**5**
Milling Alternatives / Advances (Only of benefit if cement quality/integrity behind casing cannot be verified)								
GA Drilling - PLASMABIT	Non-contact alternative to traditional mechanical milling techniques using focused electrical plasma	Technology was qualified through onshore field tests in 2016, offshore field tests have also been completed.	GA Drilling estimate a 50% milling time reduction and running on coiled tubing to enable a rig-less operation	None significant - needs confirmation of power requirements	GA Drilling are still welcoming project partners in the development of this technology. Relies on independent development of offshore deployment technologies by others	[2] Unlikely	[3] Moderate	**6**
HydraWell HydraWash / HydraHemera	Combined perforate, wash & cement (PWC) capabilities where annular remediation is required	In Operation. ~ 135operations completed using these tools	Saves time over traditional milling (and swarf handling) techniques. Applicable to cases where cement is known to be poor/non-existent.	None significant	A requirement for evaluation and confirmation of cement quality may negate a substantial portion of the time savings achieved by deploying this type of technology	[5] Almost Certain	[1] Insignificant	**5**
Shallow Plug - Alternative Suppliers								
Baker Hughes - WASP	(Well Abandonment Straddle Packer) tool offers a means of setting the shallow plug utilising a vessel of opportunity (This performs the same task as SWAT)	Available for use	Possibly negligible effect, but noted that SWAT tool was driver for a £20m reduction (2011) in the estimate Could reduce commercial risk attached to single sourced technology	None significant	Commercial benefits of additional competition	[5] Almost Certain	[1] Insignificant	**5**
Scale Removal								
ZerLux Scale Removal Laser	Laser Transmitted by Fibre Optic via Coiled Tubing superheating the scale, to allow recovery to the surface	Unclear on exact stage of development Initial lab tests undertaken Part of a wider aim of a program to develop Laser Drilling	Potential for assisting with non-contact scale remediation and recovery without need for MODU	None significant	Early stage of development – no information on commercialisation	[2] Unlikely	[2] Minor	**4**
Weatherford Ultrasonic Scale Removal	Concept whereby ultrasonic energy is used to remove scale from the well	No information available on a commercially available product Patent has been retained for extended period of time (since 1998), but expected to expire Nov. 2019.	Potential for assisting with non-contact scale remediation and recovery without need for MODU	None significant	No commercial development to date	[2] Unlikely	[2] Minor	**4**
Foro Energy High-power laser cutting and scale removal	Foro Energy uses high power lasers to rapidly and precisely cut away steel and cement. Downhole lasers can also be utilized for flow assurance applications. Foro is actively developing downhole laser systems for removal of scale or other restrictive materials	Under development, however downhole multi-string cutting technology already available	Potential for assisting with non-contact scale remediation and recovery without need for MODU	None significant	however downhole multi-string cutting technology already available. Scale removal capability under development	[3] Possible	[2] Minor	**6**
Schlumberger Re-Solve Milling Tool	Wireline Milling Tool	Available now	Impressive ROP quoted from case study (57ft/hr milling 4,650ft of barium sulphate scale) Rigless treatment of scaled production tubing	None significant	Cooling of drill bit ROP quoted is from a single project	[5] Almost Certain	[2] Minor	**10**
Downhole Assessment - Well Condition / data gathering								

Technology	Description	Maturity / Tech Feasibility	Impact	Impact on Other Activities	Risk/opportunity	Likelihood	Impact	Score
Visuray VR90/VR360	VR90 enables Wellbore imaging in 'Dirty' fluids using X-ray backscatter technology to build up a 3D model of the conditions. VR360 will enable cement evaluation through multiple casings	VR 90 used for the first time commercially at the end of 2015 (TAQA onshore well) Prototype VR360 built, commercialisation is still expected;	Availability of Data Confirmation of quality/integrity of cement behind casings to determine whether or not casing milling is required	None	Very novel technology (or adaption of X-Ray technology for use in high temperature and pressures) Technology is currently limited to 100ºC Calibration of the tool is unknown for VR360 application	[4] LIKELY	[4] MAJOR	**16**
Various (ITF) Well Condition / Data Gathering	Several ideas quoted by ITF latest call for proposals on Through Tubing Logging.	Immature -proposals for funding requests only	Limited impact on well P&A costs	None significant	Subject to obtaining sufficient development funding and significant amount of development time	[1] VERY UNLIKELY	[1] INSIGNIFICANT	**1**
Aarbakke Innovation AS Annuli Penetration & Test Tool	E-Line deployed tool that penetrates and pressure tests the annuli, providing verification of a pressure tight barrier	Immature - proposal for funding request only	Could define level of work required before Rig arrival	None significant	Subject to obtaining sufficient development funding	[1] VERY UNLIKELY	[1] INSIGNIFICANT	**1**
Alternative Barrier Materials (to conventional cement)								
BiSN – M2M Bridge Plug	Bismuth based alloy is melted in situ to create a metal to metal seal (with the casing) which is highly corrosion resistant.	Field Tests carried out to 5000psi in 2014 Qualified to VO ISO 1430	If enhanced properties over cement are qualified, this may allow for shorter plugs to be set (requiring a shorter interval of 'good' cement in the annulus)	None significant May be of interest if reliable annular cement verification tool were available	The fact that this plug is entirely independent of the annulus may continue to give rise to concerns about annular seal quality	[3] POSSIBLE	[3] MODERATE	**9**
M. Khalifeh Cap Rock Restoration	Possible use of aplite based geo-polymers for permanent zonal isolation. Several ingredients in the geo-polymer cement can be waste products from other industries.	Ongoing work by PhD student at the university of Stavanger, under the project titled 'Materials for Optimised P&A Performance'	If enhanced properties over cement are qualified, this may allow for shorter plugs to be set (requiring a shorter interval of 'good' cement in the annulus)	None significant	Academic project only at this time.	[1] VERY UNLIKELY	[1] INSIGNIFICANT	**1**
Aarbakke MicroTube removal tool	Wireline tool to remove control lines and cables from the outside of production tubing	Concept only – commercialisation proposed through strategic relationships with service providers	Remediates one issue restricting leaving the tubing downhole (leak paths from control lines and cables) Wireline deployment	None	Determining the location of the control lines on the outside of tubing Proposed operation seems complex Still relies on annular cement quality	[1] VERY UNLIKELY	[1] INSIGNIFICANT	**1**

Table 5-3: Selection of Innovative Techniques for Well Plug and Abandonment

Technique	Description	Maturity / Tech Feasibility	Impact	Impact on other Activities
LWIV Campaign Pre-Rig Arrival	For risk and uncertainty management, to acquire data at a relatively modest cost to prepare appropriate programmes of work for the rig that may follow	Successfully adopted by Hess for FFFA well P&A	Allows efficient execution of well P&A by avoiding, or preparing for, the unexpected	Opportunity to undertake other types of evaluation such as cement logging, production logging for cross-flow or fluid level confirmation
Plug & Lubricate	Staged approach to platform well abandonment, essentially to acquire data on well condition and resolve problems in advance of main P&A programme	Adopted by Shell for Brent 'D' wells	Allows efficient execution of well P&A by avoiding unexpected problems	Requires careful planning to ensure that the effect on other post CoP activities is considered. Improve efficiency by batching wells, based on P&L findings.
Efficient Milling	If the decision to mill is taken, then the success of the operation can be highly dependent on the amount of advance preparation and experience brought to bear, as well as executing a known technique as efficiently as possible.	Technique successfully adopted by Hess for the FFFA and IV/RR wells	Potential costs reduction by eliminating requirement for cement evaluation and reliance on cement quality.	Potential to mill where it was not required. Opportunity to reduce longer-term risk by assuring 'permanence' of rock-to-rock plug seal
Open Water CT	For risk and uncertainty management, to acquire data at a relatively modest cost to prepare appropriate programmes of work for the rig that may follow	Successfully adopted by Hess for FFFA well P&A	Allows efficient execution of well P&A by avoiding, or preparing for, the unexpected	Opportunity to undertake other types of evaluation such as cement logging, production logging for cross-flow or fluid level confirmation

5.1.1 Technologies Summary

Of the developing technologies considered for Well P&A, the Interwell "Superior Well P&A (thermite) Solution" and the Visuray "VR360" were assessed to potentially offer the greatest benefit.

The thermite solution, deployed for the subsea wells without the requirement for the costly MODU (and associated hire charges and rig moves), would eliminate the requirement for prolonged down-hole operations such as casing milling (e.g. if the quality/integrity of the cement outside the casing cannot be verified). It may also be used for platform wells, if suitable platform-based drilling facilities for carrying out down-hole operations are not available or require to be re-instated.

Note that a stated aim of the thermite solution is to deliver a superior well abandonment by using natural geological material for the plug, rather than cement, thereby reducing the long-term risk of further intervention requirements.

The VR360, if successful, would allow verification and assurance of the quality/integrity of the cementing, thereby eliminating, or confirming, any requirement for annular remediation. It would therefore define what operations are required, in advance of arriving at the well with a MODU.

5.1.2 Techniques Summary

Diminished well integrity, corrosion and build-up of well material in the tubing can hinder access to ageing wells and lead to unexpected encounters and costly schedule delays in the well P&A programme. Well P&A operations, particularly if section milling is required, can also be troublesome and time consuming. For the subsea wells, where a costly MODU is deployed to execute the well P&A, schedule overruns can result in significant additional cost.

A pre-MODU arrival campaign, using, for example, a less costly light well intervention vessel (LWIV) to access the wells so that potential restrictions can be resolved, or at least confirmed, in advance of the MODU deployment, could yield cost savings by reducing MODU durations. Such a campaign could also allow other well evaluation to be undertaken in advance, such as cement logging, so that the well P&A programme can be planned accordingly.

Given the large number of wells to be decommissioned in the NCS, it could be possible to drive efficiency and reduce execution times by developing and retaining dedicated well P&A teams and deploying efficient work practices (e.g. technical limit working).

5.2 Commercial Opportunities

Studies have shown that contracting strategies such as aggregation of scopes and multi-well campaign planning can result in significant execution efficiency gains. These efficiency gains can be realised through 'learnings' from multiple well decommissioning campaigns; i.e. as crews gain increasing experience of well decommissioning activities, their durations reduce, sometimes by up to 60%.

Some other examples of potential commercial cost reduction opportunities include;

- Information sharing on scope and abandonment plans;
- Sharing P&A execution experience/ lessons learned;
- Campaigns to achieve economies of scale, through higher rig and crew utilisations, faster learning curves and continuity of crews;

- Visibility of future rig and service demand profiles to help supply chain to plan models;
- Appoint single entity to P&A all wells in the basin (economies of scale);
- Encourage new entrants to increase competition in the supply chain, or plan activity to coincide with periods of low activity in the industry, to increase competition and drive down equipment charter rates.

5.3 Guidance and Practice Opportunities

A significant area of risk in well decommissioning execution comes from the poor knowledge of the integrity of the well at the time of decommissioning. Because of the principle of the time value of money, there is considerable incentive for operators to defer well decommissioning, which can result in the deterioration of well integrity.

The impact on cost of delaying well decommissioning is illustrated by the simple model shown in Figure 5-1, below. The parameter values shown in this figure are indicative and only used to illustrate the impact of time delay on well P&A. In this Figure, P represents the occurrence frequency (or the number of wells found to have impaired integrity). Wells with poor integrity take longer to plug and abandon and as time passes, both the integrity of the wells can be expected to deteriorate and the number of wells with impaired integrity can be expected to increase.

The regulator might consider fiscal incentives or penalties to influence behaviours, e.g. by restricting tax incentives to drive schedules. Similar incentives could also be used to drive innovation and collaboration between operators.

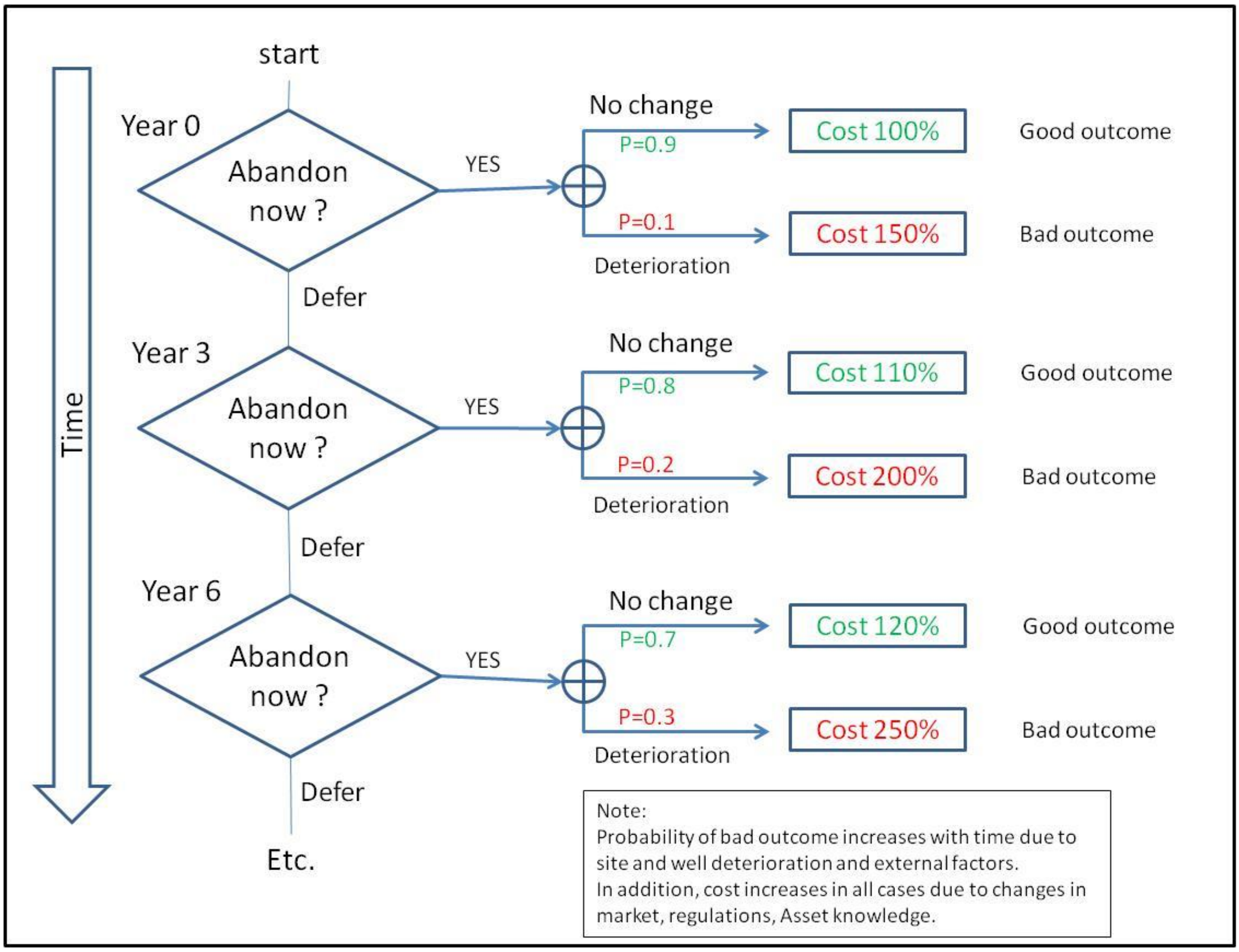


Figure 5-1: Simple Model for Cost Escalation due to Delaying Well Abandonments

6.0 COST AREA – TOPSIDES AND SUBSTRUCTURE REMOVAL

6.1 Technical Opportunities – Technology and Techniques

The cost drivers for topsides and substructure removal are largely driven by the marine support (HLV, DSV, etc.) costs. These may be mitigated through a combination of techniques/technologies (e.g. to reduce durations, and contracting strategies in order to reduce hire rates).

The majority of new technology developments are looking at emerging solutions, however the enhancement of existing technologies is also delivering real benefits to the sector. A summary review of existing and emerging topsides and substructure removal technology focus areas and value drivers is presented in Table 6-1.

Table 6-1: Summary of Existing and Emerging Technology Development Areas for Topsides and Substructure Removal

Focus Area	Existing Technologies / Value Drivers	Emerging Technologies / Value Drivers
Surveying and planning	- 3D printing, complete scale model of platform for planning of module removal sequence	- Efficient planning and organisation to minimise post CoP OPEX (e.g. conversion of the facility to NUI operation, or reduced manning and supply requirements through mothballing of redundant systems)
Topsides and jacket preparation and removal	- Supersizing diamond wire cutting - Novel sea fastening solution - Flowline sealing using expanding cement (e.g. FlexSEAL Advanced Flexible Expanding Cement)	- Increasing capacity of crane vessels (larger lifts possible, less cutting required) - Single-lift vessels (i.e. for jacket & topsides removal) requiring reduced offshore deconstruction and preparation activity. - External buoyancy assisted jacket removal (large jacket removal without the requirement of a HLV) - Cutting technologies (larger and more reliable cutting technologies)

A summary list of a selection of identified emerging technologies and innovative techniques for topsides and substructure removal are presented in Table 6-2 and Table 6-3 respectively.

Brief datasheet summaries for the shortlisted emerging technologies and techniques identified are included within Appendix B.1 and Appendix B.2 respectively.

Table 6-2: Selection of Emerging Technologies for Topsides and Substructure Removal

Technology	Description	Maturity / Tech Feasibility	Impact	Impact on Other Activities	Risk/opportunity	Likelihood	Impact	Score
Single Lift Technologies								
Allseas Pioneering Spirit	New build twin-hulled vessel for single lift removal of large structures (currently topsides only).	First three decommissioning Projects completed successfully; 14,000te YME & 24,000te Brent Delta and 25,000te Brent Bravo	Transfers topsides preparation and removal activities from offshore to onshore reducing marine support requirements	None	Commercial risk from single-lift monopoly and availability. Structures may require significant remedial strengthening for single-lift removal Potential to reduce post-CoP OPEX	[5] Almost Certain	[4] Major	20
Shandong Twin Marine Lifter	Similar to Pioneering Spirit but uses two independent vessels instead of twin-hulled vessel.	Detailed design completed, claimed plans to be operational in 2019	Transfers topsides preparation and removal activities from offshore to onshore reducing marine support requirements. Expected to be cheaper than the Pioneering Spirit	None	As above	[2] Unlikely	[4] Major	8
Other, less mature single-lift technologies, GM Constructor & NESSIE	Semi-submersible hull form for jacket and topsides removal by single-lift	Concept	Similar to above	None	Low design maturity considered unlikely to become available in time.	[1] Very Unlikely	[2] Minor	2
Heavy Lift Technologies								
HMC Sleipnir (Heerema)	New DP3 semi-submersible crane vessel with tandem lift capability	Construction complete and Delivery due H2 2019. Dunlin A topsides removal is first major decommissioning contract win.	Additional market capacity for facilities removal by heavy lift	None	Potentially increases HMC dominance of the heavy-lift market	[5] Almost Certain	[3] Moderate	15
Aker Solutions Buoyancy Tank Assembly	Removal of Jackets using buoyancy tanks attached to legs (without use of a Vessel)	Available, although customisation necessary. Marketed through a new cooperative agreement, Aker provide the BTA's and Boskalis the marine operations	Potential competition for traditional HLV removal of jackets. Given there is now a new owner / promoter (Boskalis) and the same tanks could potentially be used for both jackets, there may be significant impact of conventional HLV assisted removal	None	Difficulties with attachments and transfer to quay may limit competition for disposal yards. Unlikely to be competitive against conventional heavy lift removal.	[5] Almost Certain	[2] Moderate	10
Ardent Modular Buoyancy Tank Assembly	Removal of Jackets using buoyancy tanks attached to legs (without use of a Vessel)	Concept	Potential competition for traditional HLV removal of jackets. Potential for significant impact over conventional HLV assisted removal	None	Difficulties with attachments and transfer to quay may limit competition for disposal yards. Unlikely to be competitive against conventional heavy lift removal.	[5] Almost Certain	[2] Moderate	10
Cutting Technologies								
Aberdeen University Subsea Laser Cutter	Project to develop tool/technique for cutting steel underwater using a CO_2 laser.	BP, Shell and ConocoPhillips supported this between 2009-2013. Project completed phases 1 and 1a working in collaboration with Cambridge University. The project has since stalled and talks are ongoing regarding further funding to complete phases 2, 3 and 4.	Fast, efficient deployment for multiple underwater cuts compared to current methods.	None	Current jacket cutting cost estimates are a relatively small part of overall platform decommissioning costs	[3] Possible	[2] Moderate	9
TWI (The Welding Institute) & OC Robotics Laser Cutter	Initially developed for the Nuclear industry, Laser is delivered alongside jets of pressurised air, to create a dry environment on the surface of the target material	Proof of concept has been shown by cutting 35mm thick steel, 30cm underwater, in phase 1 of the project	Fast, efficient deployment for multiple underwater cuts compared to current methods.	None	Current jacket cutting cost estimates are a relatively small part of overall platform decommissioning costs	[3] Possible	[3] Moderate	9
Sea Fastening (for marine transportation)								
Aker Solutions FlexSeaFast	Technology to enable the rapid sea fastening structures when set down on a transportation	Successfully used in on the Frigg TCP2 MSF removal	Reduces offshore work on transportation barge and reliance on weather window	None	Works only for removed structures with a low centre of gravity	[5] Almost Certain	[2] Minor	10
Return-to-Scene platform visualisation	3D photographic visualisation tool (c.f. Google street view)	Available and in use	Potential to aid onshore engineering for topsides preparation activities	None	None	[5] Almost Certain	[2] Minor	10

Table 6-3: Selection of Innovative Techniques for Topsides and Substructure Removal

Technology	Description	Maturity / Tech Feasibility	Impact	Impact on Other Activities
Single Lift	See above	See above	Reduces post-CoP OPEX and requirement to maintain services and utilities offshore. Avoids potential SIMOPS with e.g. Well P&A, etc.	Commercial risk from lack of competition and availability of suitable vessel.
Piece Small / Piece-Medium	Deconstruction of the topside modules in-situ, to a size which can be transferred to shore without the requirement for a heavy lift vessel.	Considered to be more suited to stick-built constructions (e.g. integrated decks) than modular constructions.	None	Increase in offshore man hours (hazards, costs, etc.) must be weighed against HLV hire charges. May require prolonged maintenance of offshore services and utilities (crane, power, etc.) Opportunity to engage onshore contractors to increase competition offshore
Delayed Jacket Removal	Delay jacket removal	Available	Increased flexibility in contracting heavy lift work scopes by separating them. Potential for synergies enabled by a campaign approach or reduce present value by discounting expenditure stream.	Delaying the removal of the jacket would require regulatory approval. Risk of change in regulations for derogation cases
Value of Data	Completeness and quality of asset data.	Should be available, but may require considerable effort to collate for platforms which have changed ownership	None	Asset data forms basis of contractor's bid. Poor data can lead to poor scope definition, incorrect preparation and cost / schedule overrun.
Minimise post CoP OPEX	Strategies can be implemented at an early stage of planning to give priority to reducing the duration of Post CoP OPEX	Needs careful planning and late-life shift in objectives from maximising production to minimising overall decommissioning costs	Often requires shift in priorities during late-life from maximising production to minimising post CoP activities, which may affect production rates.	
Regulatory Environment (OSPAR Decision 98/3)	Current regulations permit application for derogation. This is reviewed every 5 years and may change before some candidates are decommissioned	N/A	None	NPD should monitor any changes to the regulatory regime.
Contracting Models	Objectives for development projects is first oil, whereas for decommissioning projects it is overall cost. This presents opportunities to adopt alternative contracting models	Successfully used for NW Hutton	None	Requires careful study to optimise outcome
Salvage Industry	Utilisation of contractors from the salvage industry (e.g. SMIT, Ardent, Mammoet, etc.) to bring an approach more suited to Decommissioning, than approach derived from offshore construction experience. (Ref Ettrick/Blackbird)	Established capability in the offshore marine sector, but not in the oil & gas sector.	Could potentially deliver cost reductions	Subject to regulator approval, and salvage company working within HSE standards set by the Oil & Gas industry, stakeholders, etc.

6.1.1 Technologies Summary

Of the developing technologies considered for topsides and substructure removal, the single-lift solutions for topsides were assessed to potentially offer the greatest benefit.

The single-lift capability for topsides removal allows the transfer of the physical deconstruction and preparation for lift activities, from the harsh offshore environment to an onshore environment at a selected deconstruction yard. This significantly reduces the offshore marine support costs and post CoP platform running (OPEX) costs. However, these savings are offset by the single-lift vessel costs such that using the single-lift vessel is not expected to give a step change reduction in the overall decommissioning project cost.

The HLVs with increased lift capacities also offer some cost reduction potential, as they allow fewer, larger lifts to be carried out, reducing offshore separation and preparations scopes.

The external buoyancy technologies could potentially also reduce heavy lift vessel (HLV) and transportation barge hire costs. However, it is expected that designing a system which can be applied to most jacket forms, and that could readily transfer the jacket from the quayside to the deconstruction yard, would be challenging.

6.1.2 Techniques Summary

Decommissioning Projects are essentially no different to any other projects, in that early planning i.e. front-end loading ensures that issues are identified and addressed early in a projects life cycle, reducing overall risk. The earlier in the process that changes are identified and made, the much less expensive they are compared to changes made late in the process.

For decommissioning projects identifying the regulatory requirements at the beginning of the project life cycle is essential. This is achieved through early engagement with the relevant regulatory authorities.

When production ceases the operating costs continue but with no production income to offset them. The platform will still require to be operational and manned to allow decommissioning activities to be carried out such as well P&A and hook down. Thus, continued maintenance of key safety and support equipment become critical – such as cranes, power generation and utilities – many systems may be more heavily utilised and improved reliability required during decommissioning, than during late-life production.

During late-life operations, key decommissioning risks should be identified and actively managed by the asset team through the asset planning cycle, including monitoring of well condition, brownfield integrity challenges for key equipment to be retained post cessation, decommissioning cost uncertainty, timing uncertainty, etc.

Early engagement with the supply chain allows them the time and provides the motivation for innovation on how their equipment and working practices may be modified to deliver cost-effective decommissioning One example of this is in the novel use of two dual-crane semi-submersible crane vessels (i.e. quad-lift) for removing topsides onto transportation barges, as a single lift. This technique, whilst not yet applied to a decommissioning project, has successfully been trialled.

6.2 Commercial Opportunities

Innovative Contractual Arrangements

The oil and gas industry has contracted supply chain companies based on terms and conditions derived from the historic drivers of development projects and operating imperatives. This may not be optimum for contracting in an immature but growing decommissioning market. The use of contracts derived from the drivers of development projects could also be seen to be stifling innovation and maintaining existing methods and processes.

By industry being more open to different and simpler contract terms and less prescriptive expectations of techniques, a different and innovative approach could be nurtured. For instance, the setting of removal goals rather than prescriptive methods.

This approach could open-up the market to new players from the salvage and onshore demolition markets, for instance. This is feasible if the evaluation process allows the time to nurture new entrants and help develop their ideas and methods.

Assets transferred to third party Decommissioning Specialist Company

This approach would allow the current owners to focus their efforts on production opportunities and leave the decommissioning phases to decommissioning specialists. By transferring ownership, jointly funded by the Norwegian Government and the existing owners, such a specialist company could better plan and manage the NCS portfolio to achieve not only the benefits of scale and batching to encourage new industry players, but also develop and retain expertise and learnings.

These could be translated into a common and consistent set of standards and contractual arrangements more appropriate to the risk profile of the work being undertaken, again encouraging a more stable, innovative and receptive supply chain.

The opportunity could also be that it severs the links between the decommissioning and development supply chains. This may provide sufficient surety of demand and timing for a specialist market to develop, improving the cost base of decommissioning projects.

The third-party Decommissioning Specialist Company could also provide ownership of the complete NCS decommissioning portfolio and take over responsibility for the continued maintenance for the retention of strategic infrastructure and for management of the longer-term liabilities, in the national interest.

6.3 Guidance and Practice Opportunities

If the operators were encouraged to decommission and remove topsides, but potentially leave the steel jacket substructures installed until multiple jackets become available for removal, then the facility running costs would significantly reduce and reduced jacket removal costs could be achieved for the jacket removal and onshore disposal costs, through economies of scale and surety of demand for the supply chain.

An additional benefit of postponing jacket removal would be a reduced present value of the discounted future removal and disposal expenditure stream.

7.0 COST AREA – PIPELINES AND SUBSEA REMOVAL

7.1 Technical Opportunities – Technology and Techniques

The cost drivers for pipelines and subsea decommissioning are largely driven by the marine support (CSV, DSV, etc.) costs. These may be mitigated though a combination of techniques/technologies (e.g. to reduce durations, and contracting strategies in order to reduce hire charges).

A summary of existing and emerging pipelines and subsea decommissioning technology focus areas and value drivers is presented in Table 7-1.

Table 7-1: Summary of Existing and Emerging Technology Development Areas for Pipelines and Subsea Decommissioning

Focus Area	Existing Technologies / Value Drivers	Emerging Technologies / Value Drivers
Subsea decommissioning	- Pipeline decommissioning - Long-term subsea substrate modelling (to determine/confirm whether buried lines will remain buried over the long term) - Tool to cut, seal and lift bundles, currently a lengthy and costly operation for long bundles - Methods to hot tap, flush and grout-seal subsea pipelines - Anchor handling vessel and reverse reel for riser removal as a cost-effective alternative to marine construction vessels	- Leaving mattresses in place, potential rock dumping for 'over-trawlability' - Drill cutting analysis - vacuum tool for recovering samples
Site monitoring	- MMI surveys by dedicated survey vessel	- Ocean power technologies for site monitoring and guard buoys - AUV technologies for site monitoring

A summary list of a selection of identified emerging technologies and innovative techniques for pipelines and subsea decommissioning are presented in Table 7-2 and Table 7-3 respectively.

Brief datasheet summaries for the shortlisted emerging technologies and techniques are included within Appendix C.1 and Appendix C.2 respectively.

Table 7-2: Selection of Emerging Technologies for Pipelines and Subsea Decommissioning

Technology	Description	Maturity / Tech Feasibility	Impact	Impact on Other Activities	Risk/opportunity	Likelihood	Impact	Score
Ecosse Subsea Ambient Lift	Use controlled buoyance to lift subsea infrastructure from the seabed without the requirement for a crane vessel	Still at concept stage, but sea trials have been completed – contract awarded for the installation of a foundation (450te) in the renewables sector, for which detailed design has been completed.	Crane vessel hire costs for subsea structure removal are approximately, 1% of overall ABEX estimate, and 17% of subsea structure decommissioning cost estimate.	None	Requires step change in operation. Investment in shore side infrastructure required to recover structures from towing vessel to quayside	[4] LIKELY	[2] MINOR	**8**
IHC Hi-Traq (See also Imenco / Osbit Power Subsea Multi-tool)	Subsea Vehicle with multiple tooling configurations to carry out a range of decommissioning tasks. DSV alternative, controlled remotely from a vessel – enabling diver less operations	First model is under construction (Expected Q2 2016], to service trenching in the renewable energy sector	Alternative to DSV and therefore less weather dependent. Potential range of capability; dredging, cutting, mattress recovery	None	Local soil conditions may limit the use of this technology. Could potentially allow execution over the winter months. Concept only	[4] LIKELY	[3] MODERATE	**12**
Utility ROV Services UT ROV	ROV unit with common connections for electrics, hydraulics and communications and modular tooling for cutting, dredging, mattress recovery, grabs, etc. The unit is suspended from an umbilical but also has 4 thrusters, allowing movement within a 15m radius	Operational. Potential for increased capability tooling	Potential alternative to DSV for subsea activities. Reduced day rate compared to DSV and reduced diver exposure. Deployed from a PSV.	None	Reduced DSV utilisation, cost saving and reduced diver exposure.	[4] LIKELY	[4] MAJOR	**16**
CUT Sub Bottom Cutter	Integrated diamond wire cutting and dredging technologies, in order to reduce the excavation volume required to make an external cut.	Prototypes built and tested; expected to need project sanction to progress further	Potential alternative approach to foundation excavation (using DSV) for the large number of subsea structures, as currently assumed in ABEX	None	Reduces large scale excavation Concept only at this time	[3] POSSIBLE	[2] MINOR	**6**
Subsea 7 AIV	Integrated diamond wire cutting and dredging technologies, in order to reduce the excavation volume required to make an external cut.	Prototypes built and tested; expected to need project sanction to progress further	Alternative to Survey Vessel	None	Reduces large scale excavation Concept only at this time	[4] LIKELY	[2] MINOR	**8**
Ecosse Subsea SCARMAX Plough	Autonomous (tether less) ROV, deployed from a platform or vessel of opportunity in its own basket. Capable is carrying out survey of a pre-planned route (feature based) before returning to basket for recovery	Upscaling of existing technology. Design was completed in Q1 of 2015. Construction completed in Q4 2015	Potential for decommissioning of large diameter pipelines and bundles exposed on the seabed.	None	Eliminates requirement for surface mother vessel for general inspection. Direct application to any post removal monitoring. May be developed further for e.g. depth of burial surveys.	[4] LIKELY	[2] MINOR	**8**

Table 7-3: Selection of Innovative Techniques for Pipelines and Subsea Decommissioning

Techniques	Description	Maturity / Tech Feasibility	Impact	Impact on Other Activities
Flexible Contracting Model	Schedule flexibility, to allow contractor to use as 'fill-in' or opportunistic work during quiet periods and maintaining flexibility to compete in the lucrative short notice spot market.	Mature	Potential to offer cost benefit to project	Schedule flexibility should have constraint so that condition is not compromised before eventual decommissioning.
Batching / Campaigning	Batching could take the form of completing work by location or by specific task with the aim of achieving maximum efficiency. Campaigning may offer the contractor ability to find synergies within own portfolio of projects and delivers cost saving to NPD.	Mature	Potential for economies of scale, encourage market competition, and competitive rates	There is sufficient infrastructure within the NCS portfolio to allow batching activities for campaign execution, through collaboration with other operators or projects in the same area
Efficient Vessel Utilisation	Current ABEX estimate built up from single element decommissioning costs, e.g. surveys, mob/demob. The current ABEX estimate assumes intervention and recovery by DSV, with immediate transfer to barge. Considered to be an unrealistic assumption due to sea state constraints - more likely to transfer to DSV deck. DSV deck space constraints would require frequent trips to shore, if that were the chosen method (unaccounted for in current estimate).	Mature	Assessment of impact requires ABEX to consider decommissioning the full field infrastructure as a whole, with revised assumptions.	Potential to use cheaper, more appropriately suited CSV for recovery of items from sea bed and transfer to shore, after DSV interventions completed.
Salvage Industry	Utilisation of contractors from the salvage industry (e.g. Ardent, SMIT, Mammoet, etc.) to bring an approach more suited to Decommissioning, than approach derived from offshore construction experience.	Established capability in the offshore marine sector, but not in the oil & gas sector.	Could potentially deliver cost reductions	Subject to regulatory approval, and salvage company working within HSE standards set by the Oil & Gas industry, stakeholders, etc.

7.1.1 Technologies Summary

Of the emerging subsea decommissioning technologies considered, the UT ROV, developed for the intervention and recovery of subsea infrastructure, was assessed to offer the greatest potential impact pipelines and subsea decommissioning cost. Note that the UT ROV is already available; but has not yet been utilised for decommissioning specifically.

The UT ROV is deployable from a vessel of opportunity, available at a substantial reduction to other means of intervention.

Deployment of this technology, or others for means of reducing reliance on expensive vessels, should be followed with consideration to reducing the cost of subsea abandonment.

7.1.2 Techniques Summary

Similarly, schedule flexibility, would allow the contractor to use the decommissioning scope as 'fill-in' or opportunistic work during quiet periods while maintaining flexibility to compete in the lucrative short notice spot market. Unlike development projects, decommissioning projects are driven by cost, rather than schedule (e.g. to ‘first oil). Allowing some degree of flexibility should attract more competitive rates from vessel owners.

7.2 Commercial Opportunities

The subsea infrastructure lends itself to more collaborative campaigns because deferring decommissioning is less dependent on the aggressive material deterioration seen in topsides and wells left unmaintained. It is already recognised that many lines are jointly owned or available between groups of operators and that because of crossings and other dependencies, final timing of decommissioning access is likely to remain uncertain.

Therefore, collaborative arrangements between operators to prepare aggregated campaigns of work and achieve economies of scale was seen as a potential cost reduction area.

7.3 Guidance and Practice Opportunities

Currently subsea pipelines and umbilicals are not specifically addressed by OSPAR Decision 98/3 and the decommissioning scope for these tend to be assessed on a case-by-case basis. A more considered and simplified approach to categorising pipeline and associated infrastructure types would provide greater certainty on cost estimates. For example, pipelines and umbilicals that are trenched and buried to a sufficient depth such that they are considered unlikely to interfere with demersal fishing activity may be decommissioned in-situ. Similarly, small-diameter flexible lines that are surface-laid, can readily be recovered by reverse reeling methods, may be recovered without a requirement for justifying this through detailed comparative assessment study.

Such categorisation would be determined by demonstrating acceptable thresholds for leaving in situ and greatly assist in focussing efforts on improving cost effectiveness measures for those items that must be removed.

The big prize here would be certainty around outcomes but would also need some resolution to the long-term liability management. Options here to be investigated would be insurance funds, government ownership or some third-party organisation.

Having ownership retained by a single entity should allow the risk of any unplanned low probability consequences to be spread amongst a wider portfolio.

8.0 ALTERNATIVES TO DECOMMISSIONING

8.1 Overview of Option Categories

Opportunities for ‘alternative use’ scenarios are largely situational and will depend on the asset being decommissioned. Potential reuse options are discussed below.

8.1.1 Lifetime Extension

8.1.1.1 Continued Oil and Gas Production

Permission for Cessation of Production (CoP) is only granted following a clear demonstration that incremental development opportunities, both within the field and the surrounding acreage, are uneconomic. Continued hydrocarbon production at the same location is therefore seldom considered as a reuse option.

It is noted that operating costs (OPEX) can have a high impact on the economics of continued production and efforts to reduce the OPEX can delay the CoP date for the asset.

8.1.1.2 Third Party Oil and Gas production and transportation

The asset may occupy a strategic position with respect to major trunk pipeline systems providing export routes for nearby future developments. This can beneficially reduce the cost of export systems for new projects and delay or reduce the decommissioning scope of the asset.

8.1.2 Non Oil and Gas Uses

A multitude of blue sky ideas have been proposed for redundant oil and gas platform alternative uses. These ideas range from highly speculative to some having merit although economic cases have always proved elusive. These are discussed in more detail in Section 8.2, below.

8.1.3 Re-use in an alternative location

Typically, the topsides and jacket structure, together with the original installed equipment, is normally at the end of its nominal design life which limits re-use. In addition, topsides modules are likely to be smaller and lighter but split into more modules than typical new designs today. This is a consequence of the limited capacity of the HLVs available at the time of installation.

With older assets, there are also complications with locating and compiling the necessary documentation, certification etc. and agreement on the matter of the various liabilities which could arise on the completion of sale.

For the above reasons, it is only in very specific cases that re-use of platform structures, equipment or facilities is likely to be feasible. It is noted that the selected onshore disposal contractor may choose to retain, refurbish and offer for sale particular items of plant and equipment (subject to terms of contract with the operator).

8.2 Identified Options for Alternative Use

8.2.1 General

A previous decommissioning study for a platform in the North Sea identified and evaluated over 30 options for alternative use of the decommissioned platform. A list of alternatives was developed and can be broken down and summarised as follows:

1. Oil and gas related projects (10 ideas identified).
2. Alternative Energy Opportunities (5 ideas identified).
3. Marine Related Industries (4 ideas identified)
4. Offshore Application of Onshore Based Activities (14 ideas identified)
5. Leisure (2 Ideas identified)

8.2.1.1 Oil and gas related projects (10 ideas identified) - Category 1

All the identified items were found to be uneconomic and/or infeasible. There are considered to be no particular characteristics of the platform studied which would be likely to result in a different outcome for other oil and gas producing platforms installed on the NCS.

8.2.1.2 Alternative Energy Opportunities (5 ideas identified) - Category 2

The ongoing maintenance costs together with the remote location generally result in these energy production schemes being uneconomic.

With specific reference to wind turbine schemes, whilst technology is advancing with development of floating turbine technology as one example, the key issues of water depth, remoteness from potential consumers and the distribution grid remain as barriers.

It is also noted that the installing of turbines onto an existing platform faces the problems of major topsides modifications for a relative small power return.

Despite the summary above, it is acknowledged that in the future, a facility located in the "right" location could provide the opportunity to consider re-use to support alternative energy generation and/or distribution for supply to either offshore and/or onshore consumers.

8.2.1.3 Marine Related Industries (4 ideas identified) - Category 3

These tend to be concepts at inshore locations and as such there are expected to be few existing facilities in an optimum location to support these activities. Plus, the additional overheads of an offshore location also negatively impact the economics of these solutions. It is understood that discussions are ongoing regarding deep-sea fish farming and developments in this area should continue to be monitored.

8.2.1.4 Offshore Application of Onshore Based Activities (14 ideas identified) - Category 4

These tend to have much higher operating costs than their equivalent onshore comparison with minimal extra benefits or revenue to compensate for the higher costs. Likely transport costs and offshore shift rotas costs would be prohibitively high in most cases. For almost all scenarios there is no strong reason to relocate onshore based activities offshore.

8.2.1.5 Leisure (2 Ideas identified) - Category 5

These ideas range from marginal interest to implausible so were not considered further.

9.0 CONCLUSIONS

For the identified focus areas of well decommissioning (P&A), topsides and substructure removal and subsea infrastructure and pipelines removal an opportunity identification and shortlisting process has been completed to identify potential solutions to reduce the future decommissioning cost base on the NCS.

The study has considered opportunities/proposals in the following areas:

- Technical (including developing technology and decommissioning techniques);
- Commercial;
- Guidance and Practice.

In the technical category, no technology or technique that would immediately deliver a step-change in decommissioning and abandonment costs was identified. However, several individual areas, of varying maturity were identified. If implemented, these areas could potentially yield significant incremental efficiencies and improvements, these include:

Technologies that were considered to have the highest impact potential include:

- Thermite well plugging and sealing;
- VR360 for verification and assurance on cement quality / integrity;
- Topsides single-lift, for e.g. Allseas Pioneering Spirit;
- High capacity HLVs (Hereema Sleipnir);
- External buoyancy technology.
- UT ROV (for subsea)

Note that the deployment of technology may mitigate some risks and deliver cost savings, either directly or through operational time savings. However, some of the benefit (e.g. financial reward) would most likely be retained by the technology developer, rather than passed on as project cost savings. In other words, the price of the technology is typically driven by market competition, rather than its cost. It is also worth noting that innovative technologies may initially increase risk (and thereby, cost).

From a techniques perspective the following opportunities were identified including:

Providing the opportunity for schedule flexibility would allow the contractor to use the decommissioning scope as 'fill-in' or opportunistic work during quiet periods.

Targeting economies of scale to realise cost efficiencies. For example, operators in other regions have reported that the time taken to execute well P&A operations reduces significantly, i.e. by as much as 30%, as the well abandonment crew learns from experience.

Focus on maturing and developing existing techniques further, i.e. further developing expertise in executing these methods, and having fall back options, or contingency plans, in place to manage the unexpected (i.e. risk). The focus here is on efficiency and preparedness and introducing / encouraging market competition to the supply chain may be one available approach for increasing efficiency.

Key to this strategy is in the early engagement with regulators and the supply chain. Early regulator engagement can help understand the scope of the project, and early engagement with the supply chain would give them the time and motivation for innovation on how their equipment and working practices may be modified to deliver cost-effective decommissioning.

Introduction of techniques and practices from other industries (e.g. salvage industry) and geographical regions (e.g. Gulf of Mexico, or the Far East) may also yield cost reductions. However, these may entail significant departure from established Oil & Gas operating company standards and would require investment in time and money (either individually or jointly with other operators) to achieve.

As in development projects, decommissioning projects involve risks, which may be mitigated through early planning and preparation and by having a focus on front end loading of decommissioning projects.

The main commercial opportunities identified relate to trying to increase cooperation across licenses and operating companies to allow removal scopes to be aggregated to maximise efficiency gains / lessons learnt and to provide a predictable work lookahead for contractors to plan for. Another area of significant opportunity is to consider transferring assets to a third party decommissioning specialist company to allow integrated planning, economies of scale and batching of decommissioning projects in a way that minimises cost and risk.

Alternative reuse scenarios in order to avoid the requirement for decommissioning were also considered. In general, it was concluded that the opportunity in this area was limited in most scenarios. However, it was identified that with the development of floating wind turbines that re-purposing existing infrastructure could be complimentary to these developments. Assessment on a case by case basis would be required to determine the commercial and technical feasibility of such a proposal.

The opportunities identified present a diverse range of possibilities and vary in maturity from "initial idea or concept" to recently proven in use. This study has been completed as a desktop exercise utilising previous project experience and recent research to inform the findings. Further work will be required to confirm the value of the opportunities identified. Next steps could include engagement with decommissioning project stakeholders from inside and outside of the industry to further develop the findings of this study and to identify a roadmap for how these and/or other future opportunities could be incorporated into future decommissioning projects.

10.0 REFERENCES

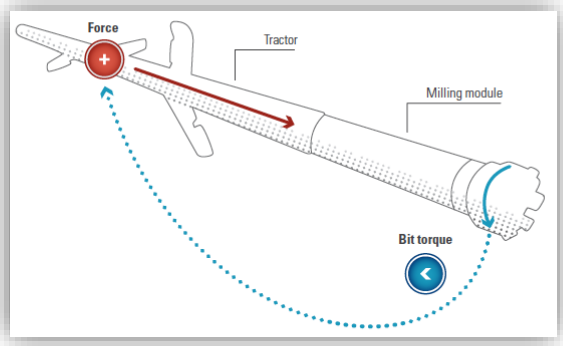
1. Oil and Gas UK, Decommissioning Insight 2018, ISBN 978-1-9164677-4-3, 2018.
2. Oil & Gas Authority, UKCS Technology Insights, April 2019.
3. Oil & Gas Authority, UKCS Technology Insights, April 2018.

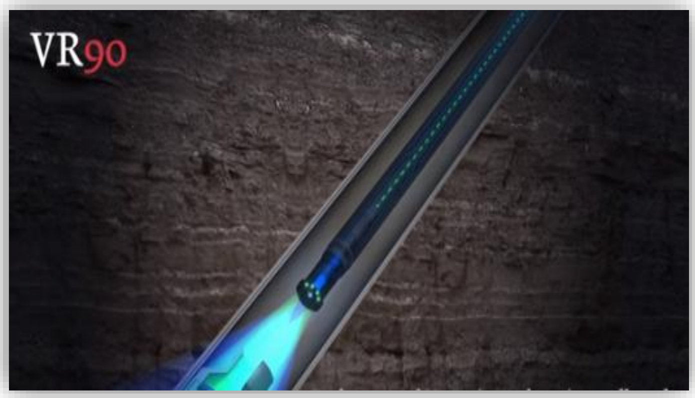
APPENDIX A: WELL DECOMMISSIONING (P&A)

A.1: Well Decommissioning (P&A) Technologies Identified

Technology	Area of Application
The Superior P&A Solution	Well Abandonment – Melting In-situ
Re-Solve	Scale Removal
Visuray VR90 / VR360	Well Assessment / Imaging

Technology	**The Superior P&A Solution**
Owner	Interwell
Supported by	Research Council of Norway, Equinor, BP
Area	Well Abandonment – Melting In-situ
Key Feature	Method of abandoning a well whereby well elements are melted in-situ. P&A method using e-line deployed Tool System consisting of a Heat Shield, followed by a Barrier Tool positioned in the cap rock region.
Description	P&A solution whereby well elements including the rock formation are melted in-situ to create the required barrier. Melting well elements in situ negates the need to add or remove any material to/from the well, as in conventional Well P&A. Enabled by the exothermic (3000-3500°C) reaction of a heat generating mixture (aluminium and iron oxide) placed at the desired location within the well. Once ignited this exothermic reaction creates a new rock as the 'natural' reservoir barrier, by melting the well materials and the surrounding environment (host rock). This method reinstates impermeable properties in the well cross section, from formation to formation. A traditional downhole plug deployed as the base plug with a heat shield to prevent it from melting during the reaction. Designed for E-Line Deployment. 
Stage of Development	JIP started in 2013. The technology development is per date (Feb 2019) focusing on Single Casing Solutions and we have completed 16 plug settings in 11 different wells. We are continuing our trial program through Q1-19 and evaluate the results together with asset owners and regulators. Patents have been secured in Norway, Europe, Eurasia, China, USA. We are expecting similar approvals in other key countries.
Review Comments	Estimate of up to 50%* overall time reduction in Well P&A and does not require use of a MODU (20-25%-day rate saving for Subsea Wells). Company admits it cannot be sure of the quoted saving, due to stage of development and the fact this has never been done before. Could also be used to remove specific well elements rather than abandoning the well, made possible simply by altering the placement and amount of heat generating mixture. Interwell are aware that qualification of the barrier is a challenge. They hope to overcome this, at least in part, with the use of their own Barrier Verification System, which wirelessly reads the pressures and temperatures across the plug. Designed to meet the requirements of NORSOK D010. It is thought that the composition and volume of the heat generating mixture can be altered to achieve the desired barrier properties, which would be favourable over cement. Note that others are looking at similar technologies in the USA and have since filed patents describing a similar method of performing P&A. *50% time saving is based on an example of a well with significant intervention required, milling / pulling casing etc.
Further Detail	https://www.interwell.com/plug-abandonment/category538.html

Technology	**Re-Solve**
Owner	Schlumberger
Supported by	N/A
Area	Scale Removal
Key Feature	Removal of Scale with E-Line tool
Description	Wireline milling tool, utilising a custom designed bit optimised for maximum ROP when milling hard scale build up in tubulars. A wireline tractor device drives the milling tool forward and resists rotation whilst the milling tool's rotating bit engages the scale. Tool incorporates software to automatically coordinate operation between the milling system and the tractor, enabling a single intelligent system. This communication enables the tool to automatically respond to variations in the amount of scale by adjusting the pushing force. If the bit stalls, the tool automatically retracts and then resumes milling operation. 
Stage of Development	Available
Review Comments	Project quoted ROP of 57 ft/h milling 4,650ft of Barium Sulphate scale. It is assumed that this operates as a 'no returns' device meaning the milling products (broken down scale) fall to the bottom of the well. The effectiveness of the tool face may be limited by having no circulation to cool and lubricate the bit and to actively displace 'cuttings' although the case study quoted performance looks effective.
Further Detail	

Technology	**Visuray VR90 / VR360**
Owner	Visuray
Supported by	ITF (initial funding to prove concept), Demo2000 (BP, Equinor, Shell, Research Council of Norway), Petromaks & Petromaks 2
Area	Well Assessment / Imaging
Key Feature	Assessment / Imaging of Well Bore through multiple casings
Description	Founded in 2004, Visuray completed a DEMO2000 JIP in 2006/7 focusing on the ground breaking core technology required for use of x-ray imaging system downhole. These core technology developments are the cornerstone of the VR90 model, allowing images to be taken of items within the wellbore. As the electronically triggered x-ray system is not activated until the tool is deployed deep down in the well there is no radiation experienced at surface. The tool works in any type of 'dirty' fluid, unlike alternative methods with require an opaque fluid. It is the potential to further develop this technology to image the condition behind multiple casings that justifies its inclusion. Images from patent related to further development shown are below, bottom. VR360 tool diameter means it is will be a through tubing application. 
Stage of Development	VR90 first commercial application was completed toward the end of 2015. The tool is now a commercially available product is limited to operate in up to 100°C & 20kpsi but is under continual development. Further information was expected on the 360 model toward the end of 2015 (not yet released). Latest correspondence stated 2017 commercialisation for VR360.
Review Comments	The next Visuray tool, still very much at the development phase, VR360 will be able to provide 3-D build-up of casing and cement – limited info available on this technology at this time. It is unclear how VisuRay will be calibrated to determine cement bond quality. This may be done by calibration against existing evaluation tools but would be better if verification could be achieved using actual physical samples of well bonded steel / cement where cement quality is known. X-Rays are generated electrically downhole requiring a cooling system but the device does not require a natural radioactive source. Similar proposal (using x-ray backscatter) in one of the submissions to ITF latest calls from a company in the US.
Further Detail	https://www.visuray.com/home

APPENDIX B: TOPSIDES & SUBSTRUCTURE REMOVAL

B.1: Topsides & Substructure Removal Technologies Identified

Technology	Area of Application
Pioneering Spirit	Facilities – Single Lift
Sleipnir	Facilities – Offshore Lift
Buoyancy Tank Assembly	Jacket Removal

Technology	**Pioneering Spirit**
Owner	Allseas
Supported by	N/A
Area	Facilities – Single Lift
Key Feature	Removal of Topsides and Jackets – New build Vessel Single Lift
Description	Pioneering Spirit is a 382m long, 124m wide Catamaran due for completion in 2016. Designed as a platform installation and decommissioning vessel, aimed at the North Sea market, it has a topside lift capacity of 48,000te. Topside lift capacity is provided by hydraulic clamps mounted on the eight horizontal lifting beams. Designs also exist for the addition of a 25,000te capacity jacket lift system at a later date. Complementing the lifting systems is a 5000 t special purpose crane for additional lifts such as lighter topsides and jackets, modules and bridges. 
Stage of Development	Built at the DSME shipyard in South Korea (2011–14), the vessel commenced offshore operations in 2016 with removal of the 13,500 t Yme production unit offshore Norway. The vessel redefined heavy lifting with the single-lift removal of Shell's iconic 24,000 t Brent Delta platform topsides from the North Sea in April 2017 - a world record for an offshore lift. In June 2018 Pioneering Spirit executed the fastest installation of a large, fully completed topside, and heaviest single-lift installation to date, when it set down Equinor's 22,000 t Johan Sverdrup DP topsides on its jacket offshore Norway.
Review Comments	Allseas have announced their intention to construct a second, larger, single-lift vessel.
Further Detail	http://allseas.com/equipment/pioneering-spirit/

Technology	**Sleipnir**
Owner	Heerema Marine Contractors
Supported by	N/A
Area	Facilities – Offshore Lift
Key Feature	Removal of Topsides and Jackets – New build Vessel Market Competition – reverse installation
Description	New DP3 semi-submersible crane vessel designed for the installation and decommissioning of offshore facilities. Equipped with two Huisman heavy-lifting offshore cranes of 10,000 tonne lifting capacity each and a large reinforced work deck area. The NSCV will be the largest semi-submersible crane vessel in the world. 
Stage of Development	Construction and testing completed June 2019 SSCV Sleipnir, the world's largest crane vessel, completed 15,300 tonnes lift in September 2019, installing the topsides for Noble Energy's Leviathan development in the Mediterranean.
Review Comments	A greater lift capacity model than Heerema's existing heavy lift vessels, Thialf, Hermod , and Saipem's S7000.
Further Detail	https://hmc.heerema.com/fleet/sleipnir/

Technology	**Buoyancy Tank Assembly**
Owner	Aker Solutions
Supported by	Boskalis
Area	Jacket Removal
Key Feature	Removal of Jackets – Without use of a Vessel
Description	Aker designed and patented a method of removing a jacket using buoyancy tanks. Buoyancy tanks are ballasted and attached to the jacket legs using a combination of clamps and guides specifically designed to suit the jacket legs. De-Ballasting the tanks causing the jacket to float at a calculated distance above the seabed (~10m for Frigg DP2), enabling a controlled tow to a suitable reception facility (deep water). The structure must be then removed from the water or cut up subsea for removal.  
Stage of Development	Available, although customisation necessary. Marketed through a new cooperative agreement, Aker provide the BTA's and Boskalis the marine operations
Review Comments	Buoyancy Tanks manufactured for the removal of DP2 jacket (~11,000te Inc. MSF) weighed in at almost the same as the jacket itself. The method of attachment is also Jacket specific and therefore not reusable. Technology never used since DP2 project.
Further Detail	https://akersolutions.com/what-we-do/products-and-services/decommissioning/

B.2: Topsides & Substructure Removal Techniques Identified

Technique
Delayed Jacket Removal
Contracting Models

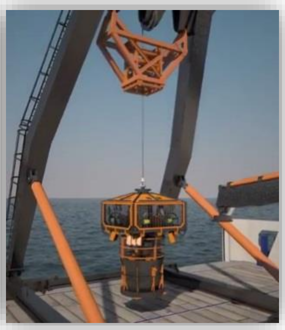
Technique	Delayed Jacket Removal
Remarks	Jacket removal need not sit on the critical path, if better value can be found through delaying this activity. This approach could, enable a campaigning approach for the removal of jackets, in cooperation with nearby fields (NPD owned or other), or benefit from technology developments (e.g. the Pioneering Spirit Jacket Removal System). Delaying the removal of the jacket would require regulatory approval, but if it can be shown to reduce the overall cost, without impacting on safety, this process should not constitute a major stumbling block. OPEX related to such an option is expected be low, following the placement of navigational aids an additional cost may occur in the need to survey the structure at a period to be agreed with the regulator. Experience of removing large jackets to date has shown that the use of a number of cutting methods is the most efficient scenario.

Technique	Contracting Models
Remarks	Consideration should be given to the use of alternative contracting models than those in place during the development or operational phase of the asset life. Alternative models can be specifically tailored to benefit both operators and the emerging supply chain, examples of varying complexity are provided below. Framework agreements should be tailored for use in the decommissioning / late life project to reflect the change in drivers of the project. Depending on the drivers it may be seen that mutually advantageous contracts could be achieved compared to those previously in place. As an example the key driver for the operator during development and asset lifecycle is likely to have been schedule; whilst in late life for many services it is switched to overall cost. The use of Target Contracts should be considered whereby the contractor(s) have financial incentive to beat targets. As stated above these targets are likely to be more biased toward overall cost than time, of course dependent on the project scheduling. This type of contract has the advantage of promoting and rewarding creative and innovative approaches to high value challenges. It is possible we may see the emergence of a new type of Operating Company or decommissioning Project Management Company specialising in Late Life/Decommissioning. In such a scenario a transaction would take place at a time and price which satisfied the needs of both parties. The existing operator could divest the asset at or before the time when it is no longer economic to them, but may still be to a specialist late life operator, who is structured in such a way to maximise return from this type of asset. This would also allow the existing operator to focus on the exploration and production projects, which they are more familiar with. A difficulty lies in the ability to transfer the tax relief on the asset but this is an issue which has previously attracted, and still is attracting, attention from industry groups and could possibly be overcome by other means. Further difficulties can be found in the issue of long term liability (how do you determine the value of 'in perpetuity'?) which contributes to the other problem of how you determine the transaction value. The issues identified above perhaps lend themselves to a hybrid approach of the target contract and specialist operator/contractor to take over the asset in late life.

APPENDIX C: SUBSEA INFRASTRUCTURE & PIPELINES REMOVAL

C.1: Subsea Infrastructure and Pipelines Removal Technologies Identified

Technology	Area of Application
UT ROV	Subsea Infrastructure Intervention / Removal

Technology	**UT ROV**
Owner	Utility ROV Services
Supported by	N/A
Area	Subsea Infrastructure
Key Feature	DSV Alternative for intervention activities
Description	ROV unit which provides common connections for electrics, hydraulics and communications with modular tooling. Deployment from a vessel of opportunity (system currently installed on FS Pegasus PSV). The unit is suspended from an umbilical but also has 4 thrusters, allowing independent movement within a 15m radius. Modular tooling includes; cutting, dredging, mattress recovery, grabs. 
Stage of Development	Operational. Potential for increased capability tooling.
Review Comments	Potential alternative to DSV for works at subsea locations. Much reduced day rate when compared to a DSV and reduced diver exposure. At locations where a large amount of intervention is required this could be a viable alternative to reduce the DSV work scope.
Further Detail	http://www.utrov.com

C.2: Subsea Infrastructure and Pipelines Removal Techniques Identified

Technique
Flexible Contracting Model

Technique	**Flexible Contracting Model**
Remarks	Subsea decommissioning work scope items which do not contain interdependences, i.e. do not sit on the project critical path, may be contracted with a flexible schedule. Contractor is able to use the work to fill in their schedule during quiet months whilst also maintaining the flexibility to compete in the lucrative short notice spot market. Additional synergies for the contractor can be found through integrating with other projects, e.g. performing work or collection of materials on fly-by from another project or through batch / campaign of project management, engineering and execution. It is perceived that the above mentioned flexibility will result in preferential rates.