Rev UKCS Decommissioning Project

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Acronyms / Abbreviations

AHP	Analytical Hierarchy Process
API	American Petroleum Institute
BEIS	Department for Business, Energy and Industrial Strategy
CA	Comparative Assessment
CATS	Central Area Transmission System
CNS	Central North Sea
CoP	Cessation of Production
DECC	Department of Energy and Climate Change
EIA	Environmental Impact Assessment
EMT	Environmental Management Team (at BEIS)
JNCC	Joint Nature Conservation Committee
kg	Kilogram
km	Kilometre
kN	Kilonewton
kNm^2	Kilonewton per square metre
m	Metre
mm	Milimetre
MCDA	Multi-Criteria Decision Analysis
MS	Much Stronger
MW	Much Weaker
NCS	Norwegian Continental Shelf
ODU	Offshore Decommissioning Unit (at BEIS)
OGA	Oil and Gas Authority
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
S	Stronger
SEPA	Scottish Environment Protection Agency
SFF	Scottish Fishermen's Federation
SMYS	Specified Minimum Yield Strength
SSIV	Rev Subsea Isolation Valve
Te	Tonne
UKCS	United Kingdom Continental Shelf
VMS	Very Much Stronger
VMW	Very Much Weaker
W	Weaker

Executive Summary

Repsol Norge AS (Repsol) has conducted a Comparative Assessment (CA) in support of the Rev UKCS Decommissioning Programme. The following steps from the Oil and Gas UK CA Guidelines have been completed:

This CA report presents the methodology, decisions which needed to be taken, the preparation works carried out, and the outcomes (recommendations) from the internal and external (with stakeholders) workshops.

The CA for the Rev UKCS infrastructure has focussed on two pieces of infrastructure only:

- Pipeline - Approximately 4.8 km of trenched 12 inch gas condensate pipeline from the UK median line to the end of the 12-inch flexible coming from the SSIV (Subsea Isolation Valve) close to the Chrysaor-operated Armada platform (but excluding the SSIV itself); and
- Umbilical - Approximately 5.0 km of the Rev electrical and hydraulic control cable (umbilical) from the UK median line to the point at which it joins the junction box close to Armada (but excluding the box itself).

The CA process has recommended the following outcomes:

Outcomes of Comparative Assessment		
Pipeline or Group	**Recommended Option**	**Justification**
Pipeline	Leave in place	The pipeline is buried to a depth of at least 1 m (in many cases between 1 m and 2 m) along the entire length. In terms of short term impact and cost, de-burying and removing the pipeline is predicted to be a factor of 10 times the activity required to make the pipeline safe and leave it in place. Additionally, the potential long term impacts are minimal due to the depth of burial which has been demonstrated to be broadly constant since installation in 2008. The exposed section of the pipeline up to the 12-inch flexible from the SSIV will be fully removed (150 m).
Umbilical	Remove – reverse reeling	The umbilical has been left to naturally backfill, and although backfill has occurred the depth of burial and the trench profile combined pose a risk in the long term that significant remedial work may be required to ensure the umbilical is safe. Removal by reverse reeling is achievable, safe and economical in the long term.

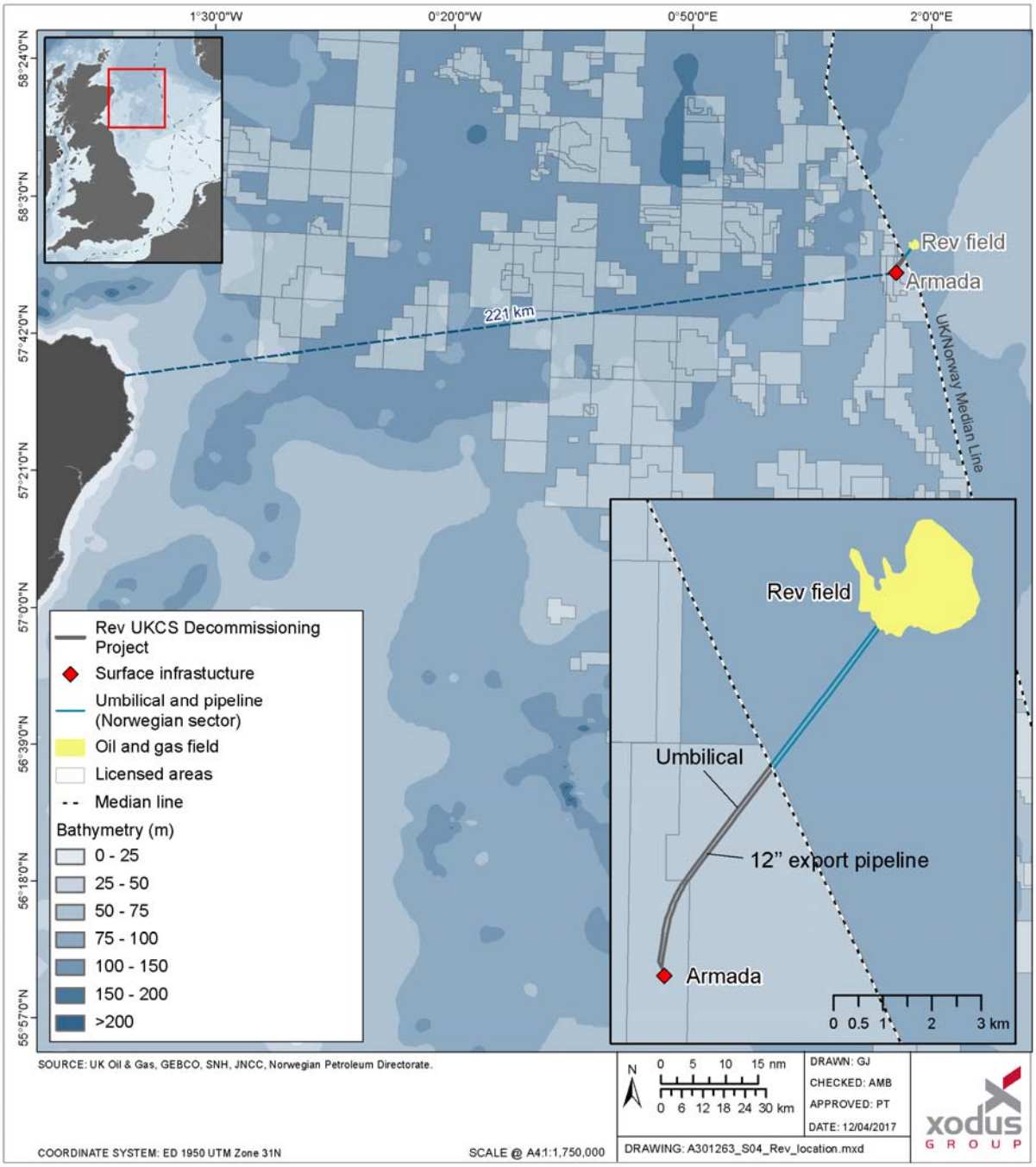
These recommendations mean that the only infrastructure remaining from the Rev field in the UKCS will be the buried pipeline. All other infrastructure, including the exposed section of the pipeline, will be fully removed for processing onshore.

1 Introduction

1.1 Overview

Repsol Norge AS (Repsol) is the operator of the Rev field which is located in Block 15/12 on the Norwegian Continental Shelf (NCS), in the Central North Sea (CNS) approximately 221 km from the Aberdeenshire coast in Scotland and 225 km southwest of Stavanger in Norway. The field is located approximately 3 km from the UK Norway median line in water depths of 90 – 110 m **(**Figure 1-1).

Figure 1-1 Location of the Rev field and Rev UKCS Decommissioning Project



The field was discovered in 2001 and the Plan for Development and Operations was approved in June 2007 with production starting in January 2009. The Rev field comprises two separate areas, Rev West and Rev East. Whilst the Rev field (West and East) is in the Norwegian sector of the North Sea, the export pipeline and umbilical cross over into the UKCS and connect to the Chrysaor-operated Armada installation (Block 22/05). Gas and condensate production from the Rev wells is exported to the Armada platform for processing at the Central Area Transmission System (CATS) terminal and further export to the UK (Figure 1-2).

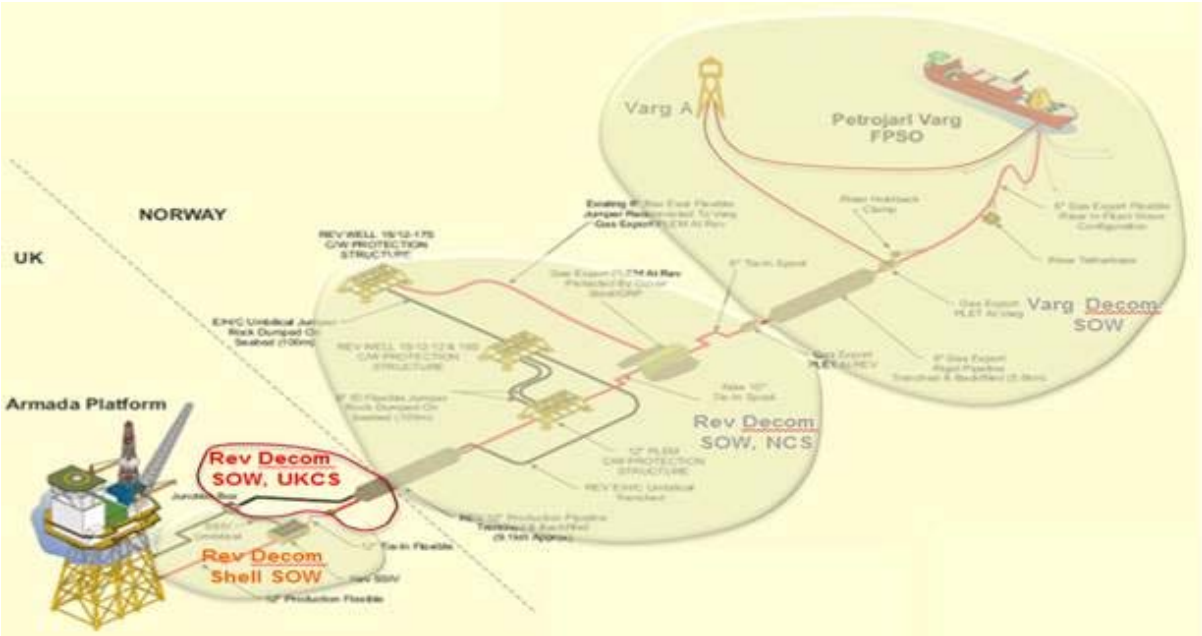
1.2 The Rev Field Decommissioning Project

In 2012 pressure at the Rev field began to decrease and has become so low that the field now only produces intermittently (at times of appropriate reservoir pressure). Based on the periodic nature of production of the Rev Field, the rights holders (Repsol Norge AS and Petoro AS) are planning to cease production of the field, the latest date is 31st March 2020, but could be earlier. Once CoP has taken place the field infrastructure will be fully decommissioned.

The Rev Field Decommissioning Plan was prepared based on the requirements of the Oslo Paris (OSPAR) Convention and of the Norwegian Petroleum law. This plan was issued to the Norwegian Ministry of Petroleum and Energy in August 2015 and proposes the completion of the offshore removal activities within 2021.

As part of the Rev infrastructure extends into the UKCS the additional documentation requirements of the UK Department for Business, Energy and Industrial Strategy (BEIS) also need to be addressed as part of the Project.

Figure 1-2 Layout of the Rev field in the context of the wider area



1.3 Purpose

The purpose of this document is to present a Comparative Assessment (CA) for the Rev UKCS infrastructure in support of the decommissioning programme. The document describes the field

infrastructure, the decommissioning options considered, the method used in the CA and the recommendations made during the CA process.

1.4 Report Structure

This CA Report contains the following:

- Section 2 – An overview of the CA methodology;
- Section 3 – A description of each decision required to be made through the CA and the preparation work undertaken;
- Section 4 – Presents the results of the CA process;
- Section 5 – Summary and recommendations;
- Section 6 – References
- Appendix A – Pairwise Methodology Explanation
- Appendix B – CA Workshop Attendance Sheet
- Appendix C – Attributes Tables and Pairwise Comparison
- Appendix D – Decision Output Charts

2 Comparative Assessment Methodology

2.1 Overview

Comparative Assessment is a process by which decisions are made on the most appropriate approach to decommissioning. As such it is a core part of the overall decommissioning planning process being undertaken by Repsol for the Rev UKCS infrastructure.

Guidelines for CA were prepared in 2015 by Oil and Gas UK, where seven steps to the CA process were recommended. Table 2-1 provides commentary on each of these steps to demonstrate the Repsol position.

Title	Scope	Status	Commentary
Scoping	Decide on appropriate CA method, confirm criteria, identify boundaries of CA (physical and phase), and identify and map stakeholders	✓	Scoping letter sent to a small group of external stakeholders introducing the project, the proposed approach to decommissioning, the environmental baseline, and the approach to CA, EIA and decommissioning programme. It also solicited feedback via a series of questions around these topics.
Screening	Consider alternative uses and deselect unfeasible options.	✓	No formal screening process carried out, although proposed options for CA were presented in the Scoping letter described above.
Preparation	Undertake technical, safety, environmental studies plus stakeholder engagement	✓	Study and survey work undertaken in parallel with continued stakeholder engagement.
Evaluation	Evaluate the options using the chosen CA methodology	✓	Repsol conducted a single internal CA workshop.
Recommendation	Create recommendation in the form of narrative supported by charts explaining key trade-offs.	✓	The workshops above produced a set of emerging recommendations which Repsol presented as emerging recommendations to external stakeholders.
Review	Review the recommendation with internal and/or external stakeholders	✓	Workshop held with external stakeholders (JNCC, SFF and BEIS, apologies received from OGA, Marine Scotland and SEPA) on Thursday 06 April 2017.
Submit	Submit to BEIS as part of/alongside Decommissioning Programme	✓	This report is available alongside the Decommissioning Programme for the Rev UKCS infrastructure.

Table 2-1 CA Process Overview

2.2 CA Methodology

Repsol has selected a Multi Criteria Decision Analysis (MCDA) methodology for the evaluation phase of the CA. This methodology uses a pairwise comparison system based on the methodologies of the Analytical Hierarchy Process (AHP) by T.L. Saaty, described in various publications, such as Analytical Hierarchy Process ref. [1]. This allows the relative importance of each differentiating criteria to be judged against each other in a qualitative way, supported by quantification where appropriate. The key steps for the evaluation phase of the CA are as follows:

- Define Differentiating Criteria – this was completed in March 2017;
- Define Options – this was completed as part of CA Scoping;
- Pre-populate worksheets for internal CA workshops – based on the study work and surveys undertaken the worksheets were pre-populated in advance of the internal CA workshop;
- Perform internal CA workshop:
    - Discuss attributes of each option against each differentiating criteria – the discussion was recorded 'live' during the workshop in order that informed opinion and experience was factored into the decision-making process;
    - Perform scoring (see Appendix A.3);
    - Perform sensitivity analyses to test the decision outcomes;
    - Export CA worksheets as a formal record of the workshop attendees' combined opinion on the current preferred options, the 'Emerging Recommendations';
    - Evaluate whether the CA needs to 'recycle' to the Preparation phase to obtain any further information to help inform decision making; and
- Discuss Emerging Recommendations with stakeholders (April 2017).

The sections below describe how the MCDA methodology has been applied. Appendix A contains a more detailed explanation of the workings behind the MCDA tool.

2.3 Differentiating Criteria & Approach to Assessment

A key step in setting up the CA was agreeing and defining the appropriate criteria that differentiates between each of the tabled options. As a starting point, the criteria considered for this CA were taken from the BEIS Guidelines for Decommissioning of Offshore Oil and Gas Installations and Pipelines ref. [2] which are as follows (in no particular order):

- Safety
- Environmental
- Technical
- Societal
- Economic

These differentiating criteria were found to be appropriate for the decommissioning options tabled and were taken forward as the primary differentiating criteria for the CA. Additional sub-criteria and definitions were added for clarity and are shown in Table 2-2.

Differentiator	Sub-Criteria	Description
1. Safety	1.1 Personnel Offshore	This sub-criterion considers elements that impact risk to offshore personnel and includes, project team, project vessel crew, diving teams, supply boat crew, and survey vessel crew. It should be noted that crew changes are performed via port calls.
	1.2 Personnel Onshore	This sub-criterion considers elements that impact risk to onshore personnel. Factors such as any requirement for dismantling, disposal operations, material transfer and onshore handling may impact onshore personnel.
	1.3 Other Users	This sub-criterion covers the impact associated with the risk to other users. Considers elements such as collision impact whilst performing activities. Users such as fishing vessels, commercial transport vessels and military vessels are considered.
	1.4 High Consequence Events	This sub-criterion relates to any inherent potential for high consequence events i.e. major accident hazard, major environmental hazard type events. It applies to all onshore and offshore personnel involved in the project. Considerations such as dropped object concerns, support vessel risks, are considered.
	1.5 Residual Risk	This sub-criterion addresses and residual risk to other sea users i.e. fishermen, military vessel crews, commercial vessel crews and passengers, other sea users, that is provided by the option. Issues such as residual snag risk, collision risk, etc. may be considered.
2. Environment	2.1 Marine Impacts	This sub-criterion covers elements such as noise generated by vessels, cutting operations, explosives etc. It also covers any damaging discharges to sea from vessels and / or activities performed.
	2.2 Emissions	This sub-criterion relates to the amount of damaging atmospheric emissions associated with a particular option.
	2.3 Consumption	This sub-criterion relates to the amount of Energy / Resource consumption such as fuel use, recycling of materials, use of quarried rock, production of replacement materials.
	2.4 Disturbance	This sub-criterion relates to both direct and indirect seabed disturbance. Both short and long term impacts are considered.
	2.5 Protections	This sub-criterion relates to the impact of the options on any protected sites and species. It also covers potential legacy environmental impacts to the marine environment.
3. Technical	3.1 Technical Risk	This sub-criterion relates to the various technical risks that could result in a major project failure. Concepts such as: Technical Novelty and Potential for Showstoppers can be captured along with impact on the schedule due to overruns from technical issues such as operations interrupted by the weather. Technical Feasibility and Technical Maturity is also considered.
4. Societal	4.1 Fishing	This sub-criterion addresses the impact of the option on commercial fishing operations. It includes consideration of impacts from both the decommissioning activities any residual impacts post decommissioning such as reinstatement of access to area.
	4.2 Other Users	This sub-criterion addresses any socio-economic impacts on other users both onshore where the impact may be from dismantling, transporting, treating, recycling and land filling activities relating to the option and offshore. Issues such as impact on the health, well-being, standard of living, structure or coherence of communities or amenities are considered here e.g. business or jobs creation, increase in noise, dust or odour pollution during the process which has a negative impact on communities, increased traffic disruption due to extra-large transport loads, etc.
5. Economic	5.1 Short-term Costs	This sub-criterion addresses the cost of delivering the option as described. No long-term cost element is considered here. Cost uncertainty (a function of activity maturity) is also recorded.
	5.2 Long-term Costs	This sub-criterion addresses the costs associated with any long-term liabilities such as on-going monitoring and any potential future remediation costs.

Table 2-2 CA Differentiating Criteria

2.4 Differentiator Weighting

The 5 differentiating criteria all carry a 20% weighting. That is, all criteria are neutral to each other. Table 2-3 shows the pairwise comparison matrix. Repsol decided that equal weightings offer the most transparency and a balanced view from all perspectives.

Differentiating Criteria	1. Safety	2. Environmental	3. Technical	4. Societal	5. Economic	Weighting
1. Safety	N	N	N	N	N	20%
2. Environmental	N	N	N	N	N	20%
3. Technical	N	N	N	N	N	20%
4. Societal	N	N	N	N	N	20%
5. Economic	N	N	N	N	N	20%

Table 2-3 Example Pairwise Comparison Matrix (N=Neutral)

2.5 Option Attributes

The next step in the CA process was to describe and discuss the attributes of each option with respect to each of the differentiating criteria. In preparation, all relevant data and information developed during the preparation phase were pre-populated into the attributes table for each option. Appendix C contains the completed Attributes Tables.

Any additional discussion around the relative merits of the options was also recorded in the attributes matrix. A summary discussion of why options are considered more or less attractive with respect to each of the differentiating criteria was also recorded.

2.6 Option Pair-Wise Comparison

Once the option attributes were compiled and discussed, a pair-wise comparison was performed for each of the differentiating criteria where the proposed options were compared against each other. The pairwise comparison adopted in this case used phrases such as neutral, stronger, much stronger, weaker, much weaker, etc. to make qualitative judgements (often based on quantitative data) of the options against each other. Adopting these phrases rather than the more common numerical 'importance scale' from the Analytical Hierarchy Process (AHP) is often more intuitive and representative of the sentiment of a workshop.

One of the challenges of applying the numerical importance scale historically, is that often when scoring a pair of options against each other as a score of 3, delegates implied the comparison was 3 times better, etc. rather than 'slightly better' as the importance scale suggests.

To manage this, Repsol chose to apply the principles of the AHP by replacing numbers in the pairwise comparison matrix with a narrative or descriptive approach. This is already programmed into the AHP

in the importance scale explanations (see Appendix A, Table A.1). It was agreed that three positions from equal (and their reciprocals) would be sufficient for this CA. These positions were:

Phrase	Meaning
Neutral	Equal Importance, equivalent to 1 in the importance scale from Table A-1
Stronger (S) / Weaker (W)	Moderate importance of one criteria / option over the other, equivalent to 3 in the importance scale from Table A-1
Much Stronger (MS) / Much Weaker (MW)	Essential / strong importance of one criteria / option over the other equivalent to 5 or 6 in the importance scale from Table A-1
Very Much Stronger (VMS) / Very Much Weaker (VMW)	Extreme importance of one criteria / option over the other equivalent to 8 or 9 in the importance scale from Table A-1

Table 2-4 Explanation of Phrasing Adopted for Pairwise Comparison

Using this transposed scoring system made it simpler and, more importantly, more effective at capturing the mind-set and feeling of the attendees at the workshops. Phrases such as 'what are the relative merits of pipeline removal on a project versus rock dumping from a safety perspective? Are these Neutral to each other? Are they stronger? If so, how much stronger? If you had to prioritise one over the other, which would it be?'. This promoted a collaborative dynamic in the workshop and enabled the collective mind-set of the attendees to be captured. Where there was quantitative data to provide back-up and evidence to support the collective assertions, so much the better.

2.7 Visual Output and Sensitivities

The decision-making tool used the above judgements to automatically generate a visual output indicating the highest scoring option i.e. the option which represents the most 'successful' solution in terms of its overall contribution to the set of differentiating criteria. At this stage, opportunity was provided to fine tune the judgements provided, to ensure that all attendees were happy to endorse the outcome. The visual outputs from each decision point are included in section 4.

The CA output could then easily be stress tested by the workshop attendees by undertaking a sensitivity analysis such as by modifying the pair-wise comparison of the options against each other within the differentiating criteria where appropriate.

3 Comparative Assessment Decisions & Preparation

3.1 Decisions

The CA for the Rev UKCS infrastructure has focussed on two pieces of infrastructure only:

- Pipeline - Approximately 4.8 km of trenched 12 inch gas condensate pipeline from the UK median line to the end of the 12-inch flexible coming from the SSIV (Subsea Isolation Valve) close to the Chrysaor-operated Armada platform (but excluding the SSIV itself); and
- Umbilical - Approximately 5.0 km of the Rev electrical and hydraulic control cable (umbilical) from the UK median line to the point at which it joins the junction box close to Armada (but excluding the box itself).

Figure 3-1 shows these sections of infrastructure. The CA recommended outcome is also described for completeness, but for these two sections of infrastructure the following options were considered:

- Pipeline:
  - Option 1 – Full removal
  - Option 2 – Leave *in situ* – Cut and remove ends, potential for rock placement at ends or any areas of low burial depth
- Umbilical:
  - Option 1 – Full removal
  - Option 2 – Leave *in situ* – Cut and remove ends
  - Option 3 – Leave *in situ* – Material placement to increase burial depth

3.2 Preparation

In advance of the internal CA workshop the preparation phase output was consolidated into the attributes tables of the MCDA tool, in order to allow workshop attendees to focus on understanding the key differences between options.

The following surveys and studies were conducted:

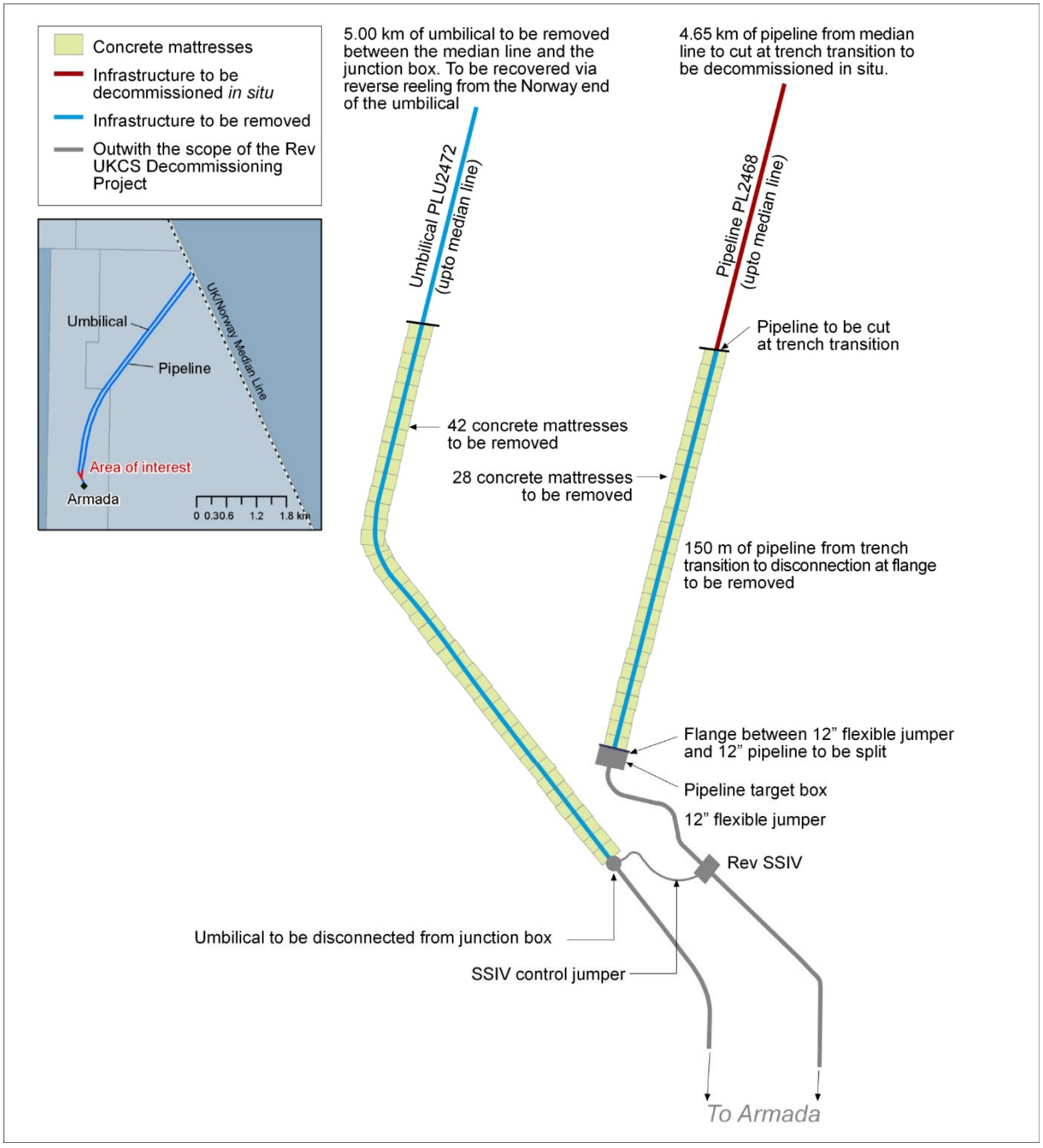
- Repsol internal study on methodology and cost for all options;
- Xodus Group environmental baseline review (presented as part of the Environmental Impact Assessment (EIA) report); and
- Repsol-commissioned pipeline and umbilical inspection survey.

Repsol conducted the UKCS-specific stakeholder meetings shown in Table 3-1 in advance of the CA workshop. This was in addition to the Scoping letter described in section 2.1.

Table 3-1 Summary of key stakeholder activities

Date	Engagement
Dec 2014	Proposed impact assessment for the decommissioning of the Rev field installations within the Norwegian sector sent for consultation to 35 Norwegian bodies; 6 of which responded with comments. Responses were reported in the Norwegian Impact Assessment report and a copy was forwarded to DECC (now BEIS) in 2015.
Q1 2016	Meeting with the BEIS Offshore Decommissioning Unit (ODU) and Environmental Management Team (EMT) to discuss the proposed decommissioning project.
Q4 2016	Meeting with ODU.
Q1 2017	Meeting with EMT.
Q2 2017	Comparative Assessment Workshop attended by BEIS ODU, Scottish Fishermen's Federation (SFF) and JNCC (apologies received from Marine Scotland, SEPA and OGA). Feedback received in the workshop has been built into the CA process.

Figure 3-1 Infrastructure to be decommissioned that is the subject of the UKCS Decommissioning Programme *(note – shows emerging recommendations for pipeline and umbilical)*



4 Comparative Assessment Results

4.1 Decision 1: Pipeline

4.1.1 Characteristics

The 12" export pipeline is a rigid pipe between the Rev well locations and the Armada Platform with a diverless 10 k American Petroleum Institute (API) flange at the Armada end. The API flange on the Armada end of the flowline is tied into the 12" flexible jumper going to the Rev SSIV. Table 4-1 contains details of the features of the 12" export pipeline. The pipeline is trenched and back filled and is protected by concrete mattresses between the SSIV and the trench transition. Note, the section of pipeline included in scope is shown on Figure 3-1.

Table 4-1 Components of the 12" export pipeline

Component Products	Unit	Value
Length	km	5
Diameter	mm	323.8
Wall thickness	mm	22.2
Material	DNV-OS-F101 (offshore standard for pipelines)	SML 450I SUPD (X65)
Weight	kg/m	Steel: 173 Plastic: 21
Specified minimum yield strength (SMYS)	MPa	448
Coating	mm	PP 39.6mm

4.1.2 Options

The following options were considered:

- Option 1 – Full removal
- Option 2 – Leave *in situ* – Cut and remove ends, potential for rock placement at ends or any areas of low burial depth

4.1.3 Recommendation

The recommendation from the CA workshop is for Option 2, leave *in situ.* Further information is provided in the summary on the next page, and within the Attributes tables provided at Appendix C.

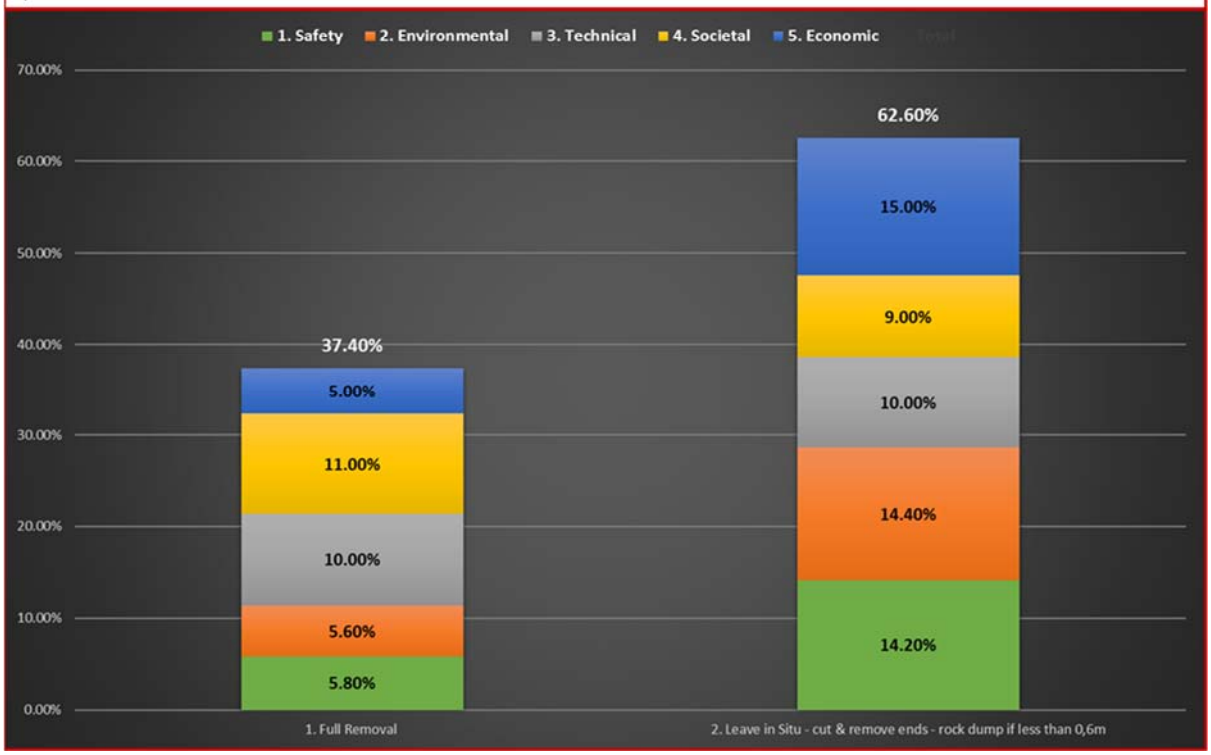
Group 1 – Pipelines

Option 1 Full Removal	Option 2 Leave *in situ* – Cut and remove ends, potential for rock placement at ends or any areas of low burial depth

Safety	Environment	Technical	Societal	Economic
The CA workshop found that regarding personnel offshore and onshore Option 1 was **Very Much Weaker** than Option 2. In the cases of other users and potential for high consequence events, Option 1 was found to be **Much Weaker** than Option 2. For all four of these categories the differentiating factor relates to the volume of activity associated with Option 1 when compared with Option 2. However, in terms of residual risk Option 1 was found to be **Much Stronger** than Option 2 as Option 1 removes the liability.	In the cases of marine impacts, emissions and consumption the workshop found Option 1 to be **Very Much Weaker** than Option 2. This was due to the volume of activity associated with the execution of Option 1. However, with regards disturbance to the seabed, the workshop found Option 1 to be **Stronger** than Option 2 due to the (albeit small) amount of rock potentially required to make Option 2 safe. No differentiation in terms of protections (sites/species).	Options 1 and 2 are similar in that they are both routine, undertaking well proven activities, using off the shelf, proven technology. Option 1 was therefore assessed as **Neutral** to option 2 from a Technical Risk perspective.	From a fishing perspective there was found to be no change from current situation for either option. Option 1 was therefore assessed as **Neutral** to option 2. In terms of the impact on other users (onshore and offshore) the two options were largely similar but credit was given to Option 1 due to the potential that exists to recycle the pipelines. Option 1 was therefore found to be **Stronger** than Option 2 for Societal – Other Users.	Total costs associated with Option 1 are between 5 and 10 times higher than Option 2. Option 1 also carries more cost risk. Overall, Option 1 was assessed as **Much Weaker** than Option 2 from an Economic perspective.

Summary

The graph below demonstrates cumulative outcome of the assessment of each of the differentiating criteria, with the tallest bar representing the preferred option from the analysis conducted. Option 2 is preferable in the criteria of safety, environmental and economics. It is even with Option 1 from a technical perspective and only marginally worse from a societal perspective. Cumulatively, Option 2 was assessed as the preferred option and is therefore recommended to be taken forward from the CA process.



4.2 Decision 2: Umbilical

4.2.1 Characteristics

The umbilical is initiated with a J-tube pull-in at the Armada platform. The umbilical is installed in a trench between Armada and Rev and protected by concrete mattresses until the umbilical enters the trench at the Rev end location. Table 4-2 provides details on the features of the umbilical. The umbilical has been left to naturally backfill. The section of umbilical included in scope is shown on Figure 3-1.

Table 4-2 Components of the umbilical

Component Products	Unit	Value
Length	km	5.5
Diameter	mm	158.5
Weight (nominal mass)	kg/m	Plastic: 30 Copper: 8
Master boot record (storage)	m	2.5
Bending stiffness at 20 C°	kNm2	12.1
Minimum breaking load	Te	82.4
Allowable compression	kN	5
Allowable crush load	Te/m	15

4.2.2 Options

The following options were considered:

- Option 1 – Full removal
- Option 2 – Leave *in situ* – Cut and remove ends
- Option 3 – Leave *in situ* – Material placement to increase burial depth

4.2.3 Recommendation

The recommendation from the CA workshop is for Option 1, full removal. Further information is provided in the summary on the next page, and within the Attributes tables provided at Appendix C.

Group 2 – Umbilicals

Option 1 Full Removal	Option 2 Leave *in situ* – Cut and remove ends	Option 3 Leave *in situ* – Material placement to increase burial depth

Safety	Environment	Technical	Societal	Economic
The CA workshop found slightly different outcomes for each of the individual safety criteria, however in combination Option 2 was found to be preferred from a safety perspective, mostly due to it being the option with the least amount of activity. Although Option 1 was least preferred overall, it was found to be **Much Stronger** from a residual risk perspective; an important aspect which has influenced the overall conclusion reached below.	In the cases of marine impacts, emissions, consumption and disturbance, the workshop consistently found Option 3 to be the least preferred option. This was due to the volume of activity associated with the execution of Option 3, and the high potential for needing to introduce new material. Option 1 was marginally weaker overall than Option 2 purely due to the level of short-term activity involved. No differentiation in terms of protections (sites/species).	Options 1, 2 and 3 are similar in that they are all routine, undertaking well proven activities, using off the shelf, proven technology. All options were therefore assessed as **Neutral** to each other from a Technical Risk perspective.	From a fishing perspective Option 1 removes the potential for a snag hazard therefore was ranked as **Much Stronger** than Option 2 and **Stronger** than Option 3. With a likely inability to recycle the umbilical, however, Option 1 was found to be **Weaker** than Options 2 and 3. Despite this, overall, Option 1 was preferred from a societal perspective.	Whilst durations are lower, overall cost profile for Option 1 short-term operations is likely to be similar to Option 3 due to the higher cost associated with the reverse reeling vessel. Option 2 short-term costs will be lower than both Option 1 and Option 3 due to the short duration of the activities. Once long-term costs are factored in, from an economic perspective, Option 1 is assessed as **Neutral** to Option 2 and **Stronger** than Option 3. Option 2 was assessed as **Neutral** to Option 3.

Summary

The graph below demonstrates cumulative outcome of the assessment of each of the differentiating criteria, with the tallest bar representing the preferred option from the analysis conducted. Despite Option 2 being marginally preferable over Option 1, the consensus in the CA workshop was that the difference between Options 1 and 2 was not significant enough to justify a shift from a clean seabed position. For this reason, Option 1 was concluded to be the preferred option and is therefore recommended to be taken forward from the CA process.

5 Summary of Final Recommendations

The CA for the Rev UKCS infrastructure has focussed on two pieces of infrastructure only:

- Pipeline - Approximately 5 km of trenched 12 inch gas condensate pipeline from the UK median line to the end of the 12-inch flexible coming from the SSIV (Subsea Isolation Valve) close to the Chrysaor-operated Armada platform (but excluding the SSIV itself); and
- Umbilical - Approximately 5.5 km of the Rev electrical and hydraulic control cable (umbilical) from the UK median line to the point at which it joins the junction box close to Armada (but excluding the box itself).

The CA process has recommended the following outcomes:

Outcomes of Comparative Assessment		
Pipeline or Group	**Recommended Option**	**Justification**
Pipeline	Leave in place	The pipeline is buried to a depth of at least 1 m (in many cases between 1 m and 2 m) along the entire length. In terms of short term impact and cost, de-burying and removing the pipeline is predicted to be a factor of 10 times the activity required to make the pipeline safe and leave it in place. Additionally, the potential long term impacts are minimal due to the depth of burial which has been demonstrated to be broadly constant since installation in 2008. The exposed section of the pipeline up to the 12-inch flexible from the SSIV will be fully removed (150 m).
Umbilical	Remove – reverse reeling	The umbilical has been left to naturally backfill, and although backfill has occurred the depth of burial and the trench profile combined pose a risk in the long term that significant remedial work may be required to ensure the umbilical is safe. Removal by reverse reeling is achievable, safe and economical in the long term.

These recommendations mean that the only infrastructure remaining from the Rev field in the UKCS will be the buried pipeline. All other infrastructure, including the exposed section of the pipeline, will be fully removed for processing onshore.

6 References

1.	Analytical Hierarchy Process	The Analytical Hierarchy Process by T.L. Saaty, McGraw Hill, 1980.
2.	Guidelines for Decommissioning of Offshore Oil & Gas Installations and Pipelines	Guidance Notes Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998, Version 6, Dated: March 2011, Issued by: Department of Energy & Climate Change.

Appendix A Pairwise Methodology Explanation

A1 Introduction

In order to support the decision-making process for the Rev UKCS infrastructure, Repsol has adopted the use of Xodus' Multiple Criteria Decision Analysis (MCDA) tool for delivering the required Comparative Assessment.

Whilst the key attributes and steps taken in the use of this tool are discussed in the main body of this report, an elaboration of the calculation methods used has been deemed appropriate.

A2 The Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a general theory of measurement used to derive ratio scales or priorities which reflect the relative strength of comparisons. It was developed during the 1970s by Thomas L. Saaty, a mathematician at University of Pennsylvania and is considered a fundamental approach to multi-criteria decision making. It has been used extensively in a wide variety of applications and industries and is the subject of many books, papers and other publications.

Whilst a detailed discussion of the AHP is beyond the scope of this document it is however, worth discussing a number of the key mathematical elements of the process and how these are implemented.

A2.1 Initial Setup

One of the key concepts of AHP is the hierarchical nature of the decision-making process. This is demonstrated by the need for any decision to have the following elements:

- Objective – the primary goal or objective for the decision.
- Decision criteria – the primary criteria by which the decision will be measured.
- Sub-criteria – the second tier (and potentially other tiers) of criteria that primary criteria may be split into
- The proposed alternatives (options) which may satisfy the objective.

In the context of Rev, the above elements are:

- Objective – to select the optimum decommissioning strategy, for each decision point, given the prevailing legislation.
- Criteria – Safety | Environment | Technical | Societal | Economic
- Sub-criteria:
    - Safety – Personnel Offshore | Personnel Onshore | Other Users | High Consequence Events | Residual Risk
    - Environmental – Marine Impacts | Emissions | Consumption | Disturbance | Protections
    - Societal – Fishing | Other Users
    - Economic – Short-term Costs | Long-term Costs

A2.2 Pairwise Comparison Matrix

The focal point of multi-criteria decision making and AHP is the construction of matrices by performing pairwise comparisons where the relative merits of pairs of criteria are considered against each other. AHP uses a hierarchical system of these matrices to allow the relative merits of options against the defined criteria and objective to be calculated.

These pairwise comparison matrices are constructed by listing the parameters being considered in rows and columns and considering what the relevant importance of each versus the others is. Most applications of the AHP use a 1 to 9 numeric scale as defined in Table A.1.

Importance Value	Definition	Explanation
1	Equal Importance	The criteria / options are considered equally important to each other.
3	Moderate importance	Experience and judgement moderately favour one criteria / option over the other.
5	Essential or strong importance	Experience and judgement strongly favour one criteria / option over the other.
7	Very Strong importance	A criteria / option is strongly favoured over the other and can be demonstrated in practice.
9	Extreme importance	The evidence favouring one criteria / option over the other is of the highest possible order.
2 / 4 / 6 / 8	Intermediate values between the two adjacent judgements	Can be used where compromise is needed.

Table A.1 Standard AHP Importance Scale

It should be noted that finer judgements can be made by applying further intermediate ranges such as 1.1, 1.2. etc. to add fidelity as required. Equally, the 1 to 9 numerical scale could be extended to say 1 to 100 as well if required. However, caution is advised in departing significantly from the widely accepted 1 to 9 numerical scale with the descriptions as detailed in Table A.1 as these have been shown over many applications to reflect the appropriate decision.

It should be further noted that only the upper triangle of the pairwise comparison matrix is completed as this represents the row versus column judgement, with the reciprocal being automatically inserted in the lower triangle of the pairwise comparison matrix.

An example is shown in Table A.2 of the standard AHP importance scale applied to decision relating to the relevant importance of criteria in the decision-making process of buying a personal vehicle. In this example, the first pairwise comparison we make is Cost versus Style. Here, we make the decision that Cost is a much stronger consideration than Style, and so, from Table A.1 an importance metric of 7 may be selected (with a reciprocal of 1/7 automatically inserted in the corresponding Style versus Cost cell).

The next comparison is Cost versus Fuel Economy. In this case, the use of the personal vehicle could be over limited mileage and thus Cost could be considered vastly more important than Fuel Economy. Again, using the importance scale from Table A.1 a 9 is inserted with 1/9 as the reciprocal.

The remaining comparisons are made with the final pairwise comparison matrix shown in Table A.2.

	Cost	Style	Fuel Economy	Reliability
Cost	1	7	9	3
Style	1/7	1	1/3	1
Fuel Economy	1/9	3	1	1/3
Reliability	1/3	1	3	1

Table A.2 Example Pairwise Comparison

The scale of priorities or relative weighting of the criteria from Table A.2 has been shown by the AHP to be derived by calculating the primary eigenvector of the above matrix and normalising the result. Again, detailed discussion of how this calculation is performed and the associated priorities arrived at is beyond the scope of this discussion. In this example, this derives the following priorities:

- Cost – 0.6445
- Style – 0.0812
- Fuel Economy – 0.1001
- Reliability – 0.1742

A3 Xodus Application of the AHP

Section A2 details a standard application of the AHP and can be found described in many public domain papers and publications. Over the years, Xodus has applied these principles of the standard AHP in many applications, ranging from prioritising the order of competing work scopes by comparing their relative benefits, to identifying the most attractive option during the concept select phase of many projects.

In delivering these decision support activities, our consultants have gathered a breadth of experience that has enabled them to identify and implement improvements to the application of the standard AHP. In terms of Xodus' implementation of the AHP, and as engineered into our tool, there are two departures from the standard AHP. These are:

- Using phrases rather than numbers in the importance scale.
- Tuning of the importance scale.

A3.1 Words v Numbers

One of the challenges that has faced Xodus when asking assembled audiences to apply the importance scale to a particular comparison, was to encourage them to apply the scale according to the descriptions and explanations rather than implying that adopting a 3 in the matrix meant the comparison was 3 times better, etc.

To manage this, Xodus changed the way we apply the principles of the AHP by replacing numbers in the pairwise comparison matrix with a narrative or descriptive approach. This is already programmed into the AHP in the importance scale explanations. Whilst implementing this change, Xodus also decided that three positions from equal (and their reciprocals) would be sufficient for most applications. These positions are described in Table A.3.

Neutral	Equal Importance, equivalent to 1 in the importance scale from Table A.1.
Stronger (S) / Weaker (W)	Moderate importance of one criteria / option over the other, equivalent to 3 in the importance scale from Table A.1.
Much Stronger (MS) / Much Weaker (MW)	Essential / strong importance of one criteria / option over the other equivalent to 5 or 6 in the importance scale from Table A.1.
Very Much Stronger (VMS) / Very Much Weaker (VMW)	Extreme importance of one criteria / option over the other equivalent to 8 or 9 in the importance scale from **Error! Reference source not found.**.

Table A.3 Definitions of positions from equal

Using this transposed scoring system makes it, in our experience, simpler and more importantly, more effective at capturing the mind-set and feeling of the attendees at the workshops. Phrases such as 'what are the relative merits of pipeline removal on a project versus rock dumping from a safety perspective? Are these Neutral to each other? Are they stronger? If so, how much stronger? If you had to prioritise one over the other, which would it be?'. This promotes a collaborative dynamic in the workshop and enables the collective mind-set of the attendees to be captured. Where there is quantitative data to provide back-up and evidence for the collective assertions, so much the better.

Once the matrix is complete, deriving the priority scale is performed in exactly the same manner as for the standard AHP i.e. the primary eigenvector of the matrix is solved (with Stronger replaced with 3, Much Stronger replaced with 6 and Very Much Stronger replaced with 9 (and similarly for the reciprocals)).

A3.2 Tuning Importance Scale

A further adjustment from the standard AHP has been implemented by Xodus in the last few years of applying AHP for decision making. This takes the form of tuning the importance scale to reflect the sentiment of the workshops. This is best illustrated by a 2-option decision matrix.

Let us take two options, option 1 and option 2 and apply the standard AHP importance scale to them with the Xodus Stronger / Much Stronger / Very Much Stronger wording relating to that standard scoring. This provides the derived priorities as shown in **Error! Reference source not found.**Table A.4.

Original AHP Importance Scale		Derived Priority	
Option 1	**Option 2**	**Option 1**	**Option 2**
1 (Neutral)	**1 (Neutral)**	**0.5000**	**0.5000**
2	1/2	0.6667	0.3333
3 (Stronger)	**1/3 (Weaker)**	**0.7500**	**0.2500**
4	1/4	0.8000	0.2000
5	1/5	0.8333	0.1667
6 (Much Stronger)	**1/6 (Much Weaker)**	**0.8571**	**0.1429**
7	1/7	0.8750	0.1250
8	1/8	0.8889	0.1111
9 (Very Much Stronger)	**1/9 (Very Much Weaker)**	**0.9000**	**0.1000**

Table A.4 Standard AHP Importance Scale and Derived Priorities

As can be seen, criteria / options that are scored as Neutral to each other have a relative priority of 0.500 each, which reflects what we would expect. If we then look at priority derived from considering criteria / options Stronger / Weaker to each other, we get a (0.7500, 0.2500) split. Following this through, for Much Stronger / Much Weaker we get priorities of (0.8571, 0.1429) and finally for Very Much Stronger / Very Much Weaker we get priorities of (0.9000, 0.1000).

When delivering comparison sessions, Xodus felt that the Stronger / Weaker sentiment in the room did not reflect a 75 / 25 split between the options and that this resulted in a contribution which was too dominant in these areas. It was felt that the Much Stronger / Much Weaker providing an 86 / 14 split was also more dominant than was intended by the workshop attendees. Finally, Very Much Stronger / Very Much Weaker with a 90 / 10 split seemed about right for the intentions of the workshops.

As such, Xodus decided to tune the relative importance scale to ensure that the sentiment of the workshop attended was reflected correctly when selecting the Stronger / Much Stronger / Very Much Stronger assessment. The outcome of that tuning process is shown in Table A.5.

Revised Xodus Importance Scale		Derived Priority	
Option 1	**Option 2**	**Option 1**	**Option 2**
1 (Neutral)	**1 (Neutral)**	**0.5000**	**0.5000**
1.5 (Stronger)	**1/1.5 (Weaker**	**0.6000**	**0.4000**
2	1/2	0.6667	0.3333
3 (Much Stronger)	**1/3 (Much Weaker)**	**0.7500**	**0.2500**
4	1/4	0.8000	0.2000
5	1/5	0.8333	0.1667
6	1/6	0.8571	0.1429
7	1/7	0.8750	0.1250
8	1/8	0.8889	0.1111
9 (Very Much Stronger)	**1/9 (Very Much Weaker)**	**0.9000**	**0.1000**

Table A.5 Xodus Tuned AHP Importance Scale and Derived Priorities

In this revised system the following splits are obtained:

- Stronger / Weaker provides a 60 / 40 split
- Much Stronger / Much Weaker provides a 75 / 25 split
- Very Much Stronger / Very Much Weaker provides a 90 / 10 split

Xodus believes this importance scale more accurately reflects what workshop attendees actually mean when they assess a criteria / option as stronger, much stronger or very much stronger than another.

A4 Worked Example

A key question when considering the Xodus application of AHP to our multi-criteria decision-making activities is, what is the impact of Xodus modifications to the standard importance scale? Xodus believes the modifications to have been identified and implemented for valid reasons. To illustrate the impact of these changes, an example decision has been calculated using both the standard AHP importance scale and the tuned Xodus version and the derived priorities from these are illustrated in Figures A.1 to A.5.

1. Safety	1. Leave - End Removal - Limited Rock Placement	2. Leave - End Removal - Full Rock Placement	3. Full Removal - Reverse Reel	Standard AHP Priorities	Xodus AHP Priorities
1. Leave - End Removal - Limited Rock Placement	N	N	MS	46.15%	42.86%
2. Leave - End Removal - Full Rock Placement	N	N	MS	46.15%	42.86%
3. Full Removal - Reverse Reel	MW	MW	N	7.69%	14.29%

Figure A.1 Safety Pair-wise Comparison Matrix

2. Environmental	1. Leave - End Removal - Limited Rock Placement	2. Leave - End Removal - Full Rock Placement	3. Full Removal - Reverse Reel	Standard AHP Priorities	Xodus AHP Priorities
1. Leave - End Removal - Limited Rock Placement	N	S	S	58.42%	42.63%
2. Leave - End Removal - Full Rock Placement	W	N	W	13.50%	24.83%
3. Full Removal - Reverse Reel	W	S	N	28.08%	32.54%

Figure A.2 Environmental Pair-wise Comparison Matrix

3. Technical	1. Leave - End Removal - Limited Rock Placement	2. Leave - End Removal - Full Rock Placement	3. Full Removal - Reverse Reel	Standard AHP Priorities	Xodus AHP Priorities
1. Leave - End Removal - Limited Rock Placement	N	N	MS	46.15%	42.86%
2. Leave - End Removal - Full Rock Placement	N	N	MS	46.15%	42.86%
3. Full Removal - Reverse Reel	MW	MW	N	7.69%	14.29%

Figure A.3 Technical Pair-wise Comparison Matrix

4. Societal	1. Leave - End Removal - Limited Rock Placement	2. Leave - End Removal - Full Rock Placement	3. Full Removal - Reverse Reel	Standard AHP Priorities	Xodus AHP Priorities
1. Leave - End Removal - Limited Rock Placement	N	W	S	28.08%	32.54%
2. Leave - End Removal - Full Rock Placement	S	N	S	58.42%	42.63%
3. Full Removal - Reverse Reel	W	W	N	13.50%	24.83%

Figure A.4 Societal Pair-wise Comparison Matrix

5. Economic	1. Leave - End Removal - Limited Rock Placement	2. Leave - End Removal - Full Rock Placement	3. Full Removal - Reverse Reel	Standard AHP Priorities	Xodus AHP Priorities
1. Leave - End Removal - Limited Rock Placement	N	N	S	42.86%	37.50%
2. Leave - End Removal - Full Rock Placement	N	N	S	42.86%	37.50%
3. Full Removal - Reverse Reel	W	W	N	14.29%	25.00%

Figure A.5 Economic Pair-wise Comparison Matrix

A5 Final Priorities

As the name Analytical Hierarchical Process suggests, there is a strong hierarchical component to the process. The relationship between the objectives / goals, the success criteria, and associated sub-criteria and finally the proposed options has been introduced earlier in this appendix.

The priorities derived for each of the proposed options, with respect to the identified criteria from the example detailed above (using Xodus importance scale only) are summarised in Table A.6.

	Safety	Environment	Technical	Societal	Economic
Option 1	0.4286	0.4263	0.4286	0.3254	0.3750
Option 2	0.4286	0.2483	0.4286	0.4263	0.3750
Option 3	0.1429	0.3254	0.1429	0.2483	0.2500

Table A.6 Priority Matrix – Options w.r.t. Criteria

Similarly, the priorities derived by performing a pairwise comparison of the criteria themselves are summarised in Table A.7. At this stage, the criteria have been considered as having equal priority. As such the derived priorities are 0.2000 for all criteria.

	Priority
Safety	0.2000
Environment	0.2000
Technical	0.2000
Societal	0.2000
Economic	0.2000

Table A.7 Priority Matrix – Criteria

In order to obtain the final priorities, each row of the 3 x 5 matrix (i.e. a 1 x 5 matrix) is multiplied by the 5 x 1, which provides priority values which relate to the contributions of the benefits associated with each option for each criteria, weighted by that criteria.

In this example, the overall priorities derived are shown in Table A.8.

	Safety	Environment	Technical	Societal	Economic	Total
Option 1	0.0857	0.0853	0.0857	0.0651	0.0750	**0.3968**
Option 2	0.0857	0.0497	0.0857	0.0853	0.0750	**0.3814**
Option 3	0.0286	0.0651	0.0286	0.0497	0.0500	**0.2219**

Table A.8 Final Priorities

A6 Discussion

Combining the priorities derived in the example presented and the method for deriving the final priorities described, we obtain the final priorities as shown in Table A.9 and Table A.10 and depicted graphically in Figure A.6.

Option	1. Saf.	2. Env.	3. Tech.	4. Soc.	5. Eco.	Total
1. Leave - End Removal - Limited Rock Placement	9.23%	11.68%	9.23%	5.62%	8.57%	**44.33%**
2. Leave - End Removal - Full Rock Placement	9.23%	2.70%	9.23%	11.68%	8.57%	**41.42%**
3. Full Removal - Reverse Reel	1.54%	5.62%	1.54%	2.70%	2.86%	**14.25%**

Table A.9 Outcome with Standard AHP Importance Scale

Option	1. Saf.	2. Env.	3. Tech.	4. Soc.	5. Eco.	Total
1. Leave - End Removal - Limited Rock Placement	8.57%	8.53%	8.57%	6.51%	7.50%	**39.68%**
2. Leave - End Removal - Full Rock Placement	8.57%	4.97%	8.57%	8.53%	7.50%	**38.14%**
3. Full Removal - Reverse Reel	2.86%	6.51%	2.86%	4.97%	5.00%	**22.19%**

Table A.10 Outcome with Xodus Tuned AHP Importance Scale

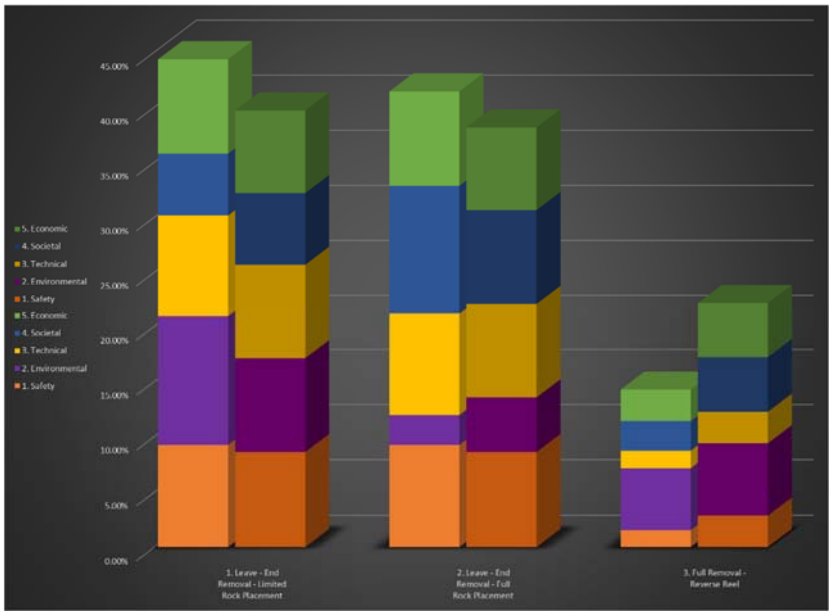


Figure A.6 CA Visual Output showing Standard v Xodus Tuned Importance Scale

In the graph shown in Figure A.6, the first column of each option shows the colour coded individual criteria priorities, whilst the stack-up shows the overall or final priority for the option under the standard AHP importance scale. The second column shows the equivalent using the Xodus tuned AHP importance scale.

As can be seen, and as would be expected given that Xodus tuning of the AHP importance scale reduces the impact of the Stronger and Much Stronger judgements (and their reciprocals), overall the priorities

of the stronger options are a little lower and this has the associated impact of increasing the priority of the less attractive options. In effect, this Xodus tuning compresses priorities together – an outcome Xodus believes more accurately reflects the sentiment associated with comparisons of options that are considered close to each other.

Overall, the outcome for this example decision point is not altered by adopting standard versus Xodus tuned AHP importance scale.

Appendix B CA Workshop Attendance Sheet

The following organisations were in attendance at the CA Workshop:

- Repsol;
- Xodus Group;
- JNCC;
- SFF;
- BEIS; and
- Petoro

In addition, invitations were sent to OGA, SEPA and Marine Scotland. These organisations were unable to attend.

REPSOL

xodus GROUP

Comparative Assessment Attendance Register

Project: REV UK Infrastructure Decommissioning
Date: Thursday April 6th 2017

Assignment Number: A301263-S04
Location: Xodus Offices, Huntly Street, Aberdeen

Name	Company	Role	Email
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Appendix C Attributes Tables and Pairwise Comparison

Project Differentiator Attributes

Differentiator	Sub-Criteria	Description	1. Full Removal	2. Leave in Situ - cut & remove ends - rock dump if less than 0,6m
1. Safety	1.1 Personnel Offshore	This sub-criterion considers elements that impact risk to offshore personnel and includes, project team, project vessel crew, diving teams, supply boat crew, and survey vessel crew. It should be noted that crew changes are performed via port calls.	10 Day duration. Need to cut pipe into sections to remove resulting in: - more operations under water - ROV - more lifts from seabed to deck - More material handling of pipe section on boat deck - more exposure to weather while working on deck No diving	1 Day duration. Minimal work offshore since only ends of pipeline are cut & removed to vessel, minimum number of lifts. Rock dumping may be required. Minimum number of people exposed.
		Summary	The activities involved are similar although full removal requires de-burial of the pipe. Following de-burial option 1 requires the cutting and lifting of over 4 km of pipeline compared to approximately 200 m for option 2. The safety exposure for offshore personnel is directly proportional to the time spent. In this case option 1 is 10 times more than option 2 (10 days versus 1 day). For this reason option 1 is assessed as being Very Much Weaker than option 2 from a Safety - Personnel Offshore perspective.	
	1.2 Personnel Onshore	This sub-criterion considers elements that impact risk to onshore personnel. Factors such as any requirement for dismantling, disposal operations, material transfer and onshore handling may impact onshore personnel.	Higher risk that option 2 due to following: - more transfer of pipe to quayside - more work onshore disposing of materials - potential more exposure to Hazardous waste	Minimal work onshore since only ends of pipeline returned to onshore for disposal
		Summary	Amount of onshore personnel safety exposure is directly proportional to the amount of material returned to shore (over 4 km versus approximately 200 m). For this reason option 1 is assessed as being Very Much Weaker than option 2 from a Safety - Personnel Onshore perspective.	
	1.3 Other Users	This sub-criterion covers the impact associated with the risk to other users. Considers elements such as collision impact whilst performing activities. Users such as fishing vessels, commercial transport vessels and military vessels are considered.	Due to greater level of activity over ca 4,5 km there is a greater potential for collisions with other marine vessels. Greater duration of the work with increased exposure. In addition there is work within 500m zone of Armada therefore risk of collision with vessels, for example standby, supply vessel, etc.	Shorter duration of exposure. All work within 500m zone of Armada therefore risk of collision with vessels, for example standby, supply vessel, etc. Note: Rock introduction (if required) would be performed from support vessel rather than dedicated Rock Dump vessel. This is due to the very limited amount of rock introduction required.
		Summary	Main interaction with other users relates to work in the 500 m safety zone at Armada. Option 2 has less activity in the 500 m zone. Overall, option 1 is assessed as Much Weaker than option 2 from a Safety - Other Users perspective.	
	1.4 High Consequence Events	This sub-criterion relates to any inherent potential for high consequence events i.e. major accident hazard, major environmental hazard type events. It applies to all onshore and offshore personnel involved in the project. Considerations such as dropped object concerns, support vessel risks, are considered.	Potential for high consequence events are: - Possible collision with platform by vessel. - Dropped object from cut and lift operations. Dredging and deburial activities considered routine.	Potential for high consequence events are: - Possible collision with platform by vessel. - Dropped object from cut and lift operations. Dredging and deburial activities considered routine.
		Summary	In both the area for potential collision risk and the number of lifting operations option 1 has more exposure. Overall option 1 is assessed as Much Weaker than option 2 from a Safety - High Consequence Events perspective.	
	1.5 Residual Risk	This sub-criterion addresses and residual risk to other sea users i.e. fishermen, military vessel crews, commercial vessel crews and passengers, other sea users, that is provided by the option. Issues such as residual snag risk, collision risk, etc. may be considered.	Full removal option so no long-term monitoring required beyond 2 off mandatory post decommissioning activity surveys. No long term risk to fisheries as fully removed.	There is a legacy risk from the on-going monitoring and potential remediation activities associated with this leave in-situ option. Note: trend demonstrates long term good burial status. Residual risk to fishing industry of a monitored and remediated, buried pipeline is considered similar to existing risk.
		Summary	Option 1 completely removes the residual risk whereas Option 2 does not. Whilst the residual risk associated with option 2 is considered minimal, any residual risk is considered a differentiator. Overall option 1 is assessed as being Much Stronger than option 2 from a Safety - Residual Risk perspective.	

Project Differentiator Attributes

Differentiator	Sub-Criteria	Description	1. Full Removal	2. Leave in Situ - cut & remove ends - rock dump if less than 0,6m
2. Environmental	2.1 Marine Impacts	This sub-criterion covers elements such as noise generated by vessels, cutting operations, explosives etc. It also covers any damaging discharges to sea from vessels and / or activities performed.	Longer duration of vessels / operations will result in greater noise impacts. Significant marine noise contribution from the additional cutting operations associated with this option.	Short durations of vessels / operations and limited cutting operations resulting in minimal marine noise impact.
		Summary	As pipeline will be flushed and there being no explosives used for either option, the key marine impact will be marine noise. The noise generated by vessels is largely proportional to the duration of the decommissioning activities. The other large marine noise impact is from subsea cutting operations. There are significantly more vessels / durations / cutting operations associated with option 1. Overall option 1 is assessed as being Very Much Weaker than option 2 from an Environment - Maine Impacts perspective.	
	2.2 Emissions	This sub-criterion relates to the amount of damaging atmospheric emissions associated with a particular option.	Atmospheric emissions (CO2 / NOx) are proportional to the 10 days of vessel time associated with this option. Should there be a need for backfilling operations, these durations and hence emission will increase.	Atmospheric emissions (CO2 / NOx) are proportional to the 1 day of vessel time associated with this option.
		Summary	The environmental impact of emissions are proportional to the vessels and duration of activities. As option 1 takes 10 times longer than option 2, option 1 is assessed as being Very Much Weaker than option 2 from an Environment - Emissions perspective.	
	2.3 Consumption	This sub-criterion relates to the amount of Energy / Resource consumption such as fuel use, recycling of materials, use of quarried rock, production of replacement materials.	Fuel consumption is proportional to the vessels / durations associated with this option. This option carries a small benefit due to the recycling and reuse offered by the c. 4km of returned steel pipeline.	Fuel consumption is proportional to the vessels / durations associated with this option. Additional material (rock) is needed for this option to rock dump the ends. It is considered a minimal amount (i.e. around 5m area).
		Summary	Whilst Option 1 includes potential for recycling, option 1 still requires around 10 times the fuel consumption of option 2, which is the dominant factor. Overall option 1 is assessed as Very Much Weaker than option 2 from an Environment - Consumption perspective.	
	2.4 Disturbance	This sub-criterion relates to both direct and indirect seabed disturbance. Both short and long term impacts are considered.	Large amount of seabed disturbance due to removing (de-burying) the pipeline over approx. 4 km.	Minimal disturbance to seabed, around 5m. Some rock placement will be required at the end if unable to cut the pipeline in the trench.
		Summary	Despite the long distance of pipeline deburial, the permanent nature of the (albeit limited) rock dump associated with option 2 makes option 1 assessed as	
	2.5 Protections	This sub-criterion relates to the impact of the options on any protected sites and species. It also covers potential legacy environmental impacts to the marine environment.	No impact on protected sites or species associated with this option.	No impact on protected sites or species associated with this option.
		Summary	There is no impact associated with either of the options from an Environment - Protections perspective. Overall option 1 is assessed as Neutral to option 2.	
3. Technical	3.1 Technical Risk	This sub-criterion relates to the various technical risks that could result in a major project failure. Concepts such as: Technical Novelty and Potential for Showstoppers can be captured along with impact on the schedule due to overruns from technical issues such as operations being interrupted by the weather. Technical Feasibility and Technical Maturity is also considered.	The ability to perform deburial, subsea cutting and removal of pipeline are all routine and well proven activities technically.	The ability to subsea cutting and removal of pipeline end and associated rock dump are all routine and well proven activities technically.
		Summary	Both activities are routine, well proven activities, using off the shelf, proven technology. Option 1 is assessed as being Neutral to option 2 from a Technical Risk	

Project Differentiator Attributes

Differentiator	Sub-Criteria	Description	1. Full Removal	2. Leave in Situ - cut & remove ends - rock dump if less than 0,6m
4. Societal	4.1 Fishing	This sub-criterion addresses the impact of the option on commercial fishing operations. It includes consideration of impacts from both the decommissioning activities any residual impacts post decommissioning such as reinstatement of access to area.	Little impact on fishing industry associated with this option.	Little impact on fishing industry associated with this option.
		Summary	No change from current situation in terms of fishing operations for either option. Option 1 is assessed as Neutral to option 2 from a Societal - Fishing perspective.	
	4.2 Other Users	This sub-criterion addresses any socio-economic impacts on other users both onshore where the impact may be from dismantling, transporting, treating, recycling and land filling activities relating to the option and offshore. Issues such as impact on the health, well-being, standard of living, structure or coherence of communities or amenities are considered here e.g. business or jobs creation, increase in noise, dust or odour pollution during the process which has a negative impact on communities, increased traffic disruption due to extra-large transport loads, etc.	Negative - disturbance to local population due to onshore disposal associated with returning 4km of steel pipeline to shore. Positive - job creation due to greater work scope. Benefit from the significant increase in recycling associated with 4km of steel pipeline.	Negative - limited job creation due to smaller work scope. Positive - less disturbance for local population as limited onshore disposal - limited recycling.
		Summary	Neither job creation nor disruption is significant for the volume of work associated with either option - deemed not significant enough to differentiate between the two options. However, recycling benefit associated with option 1 means this has been assessed as Stronger than option 2 from a Societal - Other Users perspective.	
5. Economic	5.1 Short-term Costs	This sub-criterion addresses the cost of delivering the option as described. No long-term cost element is considered here. Cost uncertainty (a function of activity maturity) is also recorded.	Costs expected to be 10 to 20 times higher than option 2. Cost risk is higher than option 2 as may have to do more work to back fill trench if profile is not acceptable post pipeline removal. This option also has a greater risk to weather impacts / delays.	Cost expected to be 10 to 20 times lower than option 1 and has very low cost risk.
	5.2 Long-term Costs	This sub-criterion addresses the costs associated with any long-term liabilities such as on-going monitoring and any potential future remediation costs.	No long term costs associated with this option.	Long-term costs related to monitoring and remediation campaigns, although these are estimated to be no higher than the cost of the initial operations.
		Summary	Total costs associated with option 1 are between 5 and 10 times higher than option 2. Option 1 also carries more cost risk. Overall, option 1 is assessed as being	

Project Differentiator Attributes

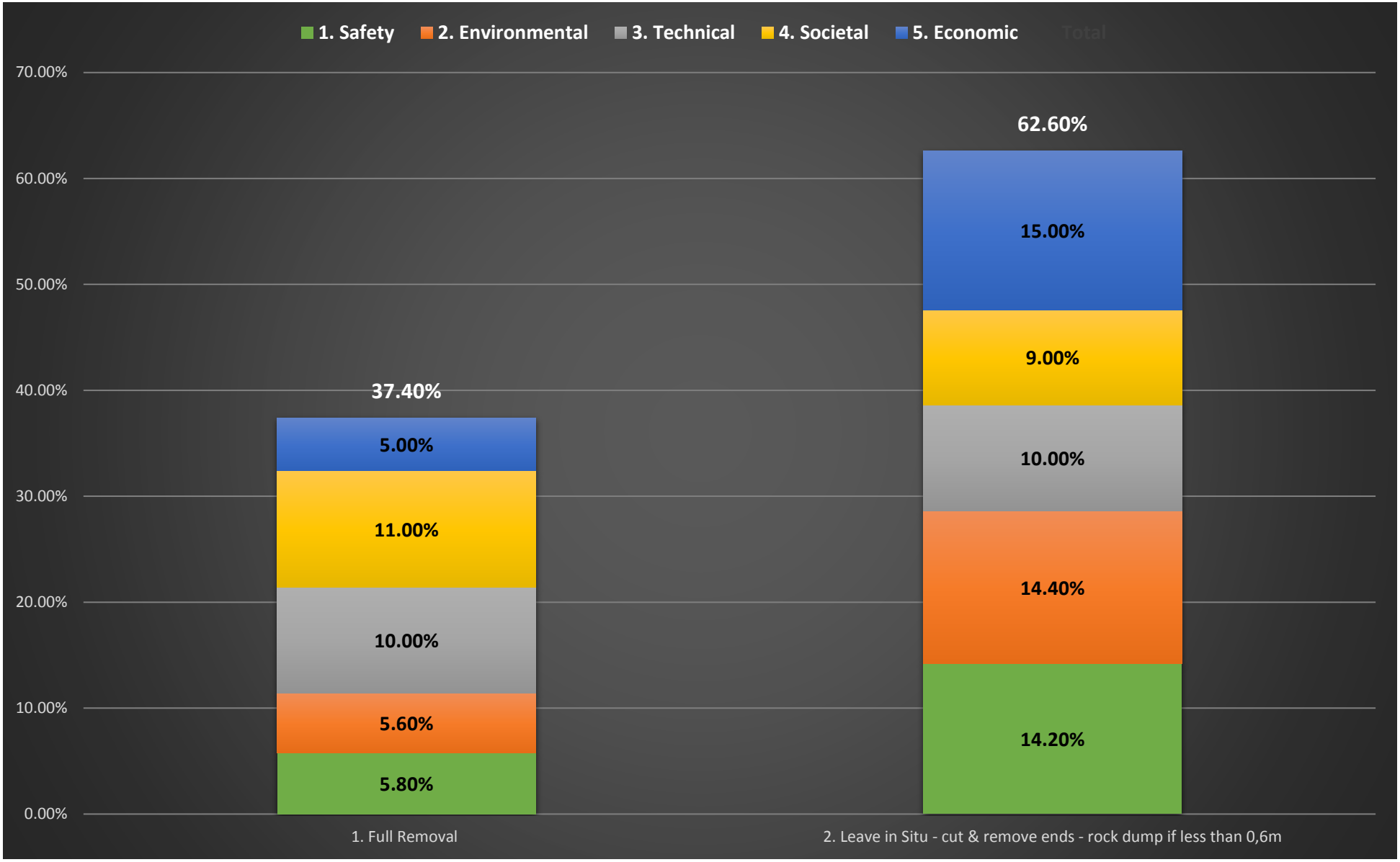
Differentiator	Sub-Criteria	Description	1. Full Removal	2. Leave in Situ - cut & remove ends	3. Leave in Situ - rock placement to increase depth of burial
1. Safety	1.1 Personnel Offshore	This sub-criterion considers elements that impact risk to offshore personnel and includes, project team, project vessel crew, diving teams, supply boat crew, and survey vessel crew. It should be noted that crew changes are performed via port calls.	Will need to reel in 4,5 (or 9) km of umbilical as part of the removal process resulting in: - more operations under water with ROV - more operations from seabed to deck - Extensive material handling of umbilical on boat deck (reels) and possibly below deck - more exposure to weather while working on deck - trench filling operations, potentially Note: Reverse reeling would be performed from REV end rather than Armada end.	Minimum of work offshore since only end of umbilical is cut & removed to vessel, minimum number of lifts. Minimum number of people exposed. Rock dumping will be required to cover umbilical where not trenched at Armada junction box end.	Similar to option 2 with a minimum work offshore since only end of umbilical is cut & removed to vessel, minimum number of lifts. Minimum number of people exposed. Additional rock placement compared to option 2.
		Summary	The personnel safety - offshore is proportional to the duration of the operations associated with each option. Option 1 has more safety exposure for offshore personnel than option 2 but is significantly better than option 3 due to the speed by which reverse reeling operations can be completed versus the rock placement operations. Overall, from a Safety - Personnel Offshore perspective, option 1 is assessed as Weaker than option 2 and Stronger than option 3. Option 2 is assessed as Much Stronger than option 2.		
	1.2 Personnel Onshore	This sub-criterion considers elements that impact risk to onshore personnel. Factors such as any requirement for dismantling, disposal operations, material transfer and onshore handling may impact onshore personnel.	Higher risk than option 2 due to following: - transfer of much larger quantity of umbilical to quayside - more work onshore required to dispose of waste materials - potentially more exposure to chemicals/fluids	Minimal work onshore since only end of umbilical returned to onshore for disposal.	Similar to option 2. Minimal work onshore since only end of umbilical returned to onshore for disposal. Minor additional exposure from at-shore work activity loading rock to vessel
		Summary	Option 2 and option 3 carry similar amounts of onshore worker exposure. Both have significantly less exposure than option 1. Overall, from a Safety - Personnel Onshore perspective, option 1 is assessed as Much Weaker than option 2 and option 3. Option 2 is assessed as Neutral to option 3.		
	1.3 Other Users	This sub-criterion covers the impact associated with the risk to other users. Considers elements such as collision impact whilst performing activities. Users such as fishing vessels, commercial transport vessels and military vessels are considered.	Due to a longer period of offshore activity over 4,5 (or 9) km there is a greater potential for collisions with other marine vessels. Greater duration of the work with increased exposure. In addition there is work within 500m zone of Armada therefore risk of collision with vessels, for example standby, supply vessel, etc.	Shorter duration of exposure. Cutting of umbilical and removal within 500m zone of Armada has therefore a risk of collision with vessels, for example supply vessel.	Similar to option 2. Shorter duration of exposure. Cutting of umbilical and removal within 500m zone of Armada has therefore a risk of collision with vessels, for example supply vessel. Additional requirement for rock placement operations outside 500 m zone with similar risk of vessel collision.
		Summary	In terms of durations of exposure, option 1 is estimates as 2-3 days, option 2 is around a single day and option 3 is 3-5 days. Overall, from a Safety - Other Users perspective, option 1 is assessed as Much Weaker than option 2 and Stronger than option 3. Option 2 is assessed as Much Stronger than option 3.		
	1.4 High Consequence Events	This sub-criterion relates to any inherent potential for high consequence events i.e. major accident hazard, major environmental hazard type events. It applies to all onshore and offshore personnel involved in the project. Considerations such as dropped object concerns, support vessel risks, are considered.	Possible collision with platform by vessel. Potential for 'snap back' event when reverse reeling.	Possible collision with platform by vessel. The type of work in 500m zone is different to option 1 but as the marine operation duration is the same a similar exposure can be expected.	Possible collision with platform by vessel. The type of work in 500m zone is different to option 1 but as the marine operation duration is the same a similar exposure can be expected. The rock placement activities are outside the 500m zone so probability of collision with platform during this operation is considered very low.
		Summary	The potential for high consequence events is slightly higher for option 1 due to the reverse reeling operations. Overall, from a Safety - High Consequence Events perspective, option 1 is assessed as Weaker than option 2 and option 3. Option 2 is assessed as Neutral to option 3.		
	1.5 Residual Risk	This sub-criterion addresses and residual risk to other sea users i.e. fishermen, military vessel crews, commercial vessel crews and passengers, other sea users, that is provided by the option. Issues such as residual snag risk, collision risk, etc. may be considered.	Full removal option so no long-term monitoring required beyond 2 off mandatory post decommissioning activity surveys. No long term risk to fisheries as fully removed - would have an overtrawlable survey preformed post removal.	Highest risk if umbilical is exposed or has limited coverage in the trench there is a chance of trawl snagging the umbilical or the trench. Would also require periodic monitoring and potential for remediation on an on-going basis.	Residual risk in terms of snag hazard to fishing industry likely to be equal or better than current as burial depth increased, assuming monitored and remediated accordingly Would also require periodic monitoring and potential for remediation on an on-going basis.
		Summary	The residual risk is highest for option 2 due to the remaining potential for snag hazard to fishing and the requirement for on-going monitoring and potential remediation. This is followed by option 3 as, whilst the snag hazard is managed, there is a requirement for on-going monitoring and potential remediation. Option 1 is the most favourable from a residual risk perspectives as it is the full removal option. It should be noted that the umbilical has been in its trench with limited cover since installation in 2009 and no snag incidents have been recorded. Overall, from a Safety - Residual Risk perspective, option 1 is assessed as Much Stronger than option 2 and Stronger than option 3. Option 2 is assessed as Weaker than option 3.		

Project Differentiator Attributes

Differentiator	Sub-Criteria	Description	1. Full Removal	2. Leave in Situ - cut & remove ends	3. Leave in Situ - rock placement to increase depth of burial
2. Environmental	2.1 Marine Impacts	This sub-criterion covers elements such as noise generated by vessels, cutting operations, explosives etc. It also covers any damaging discharges to sea from vessels and / or activities performed.	Longer duration of vessels / operations will result in greater noise impacts. Should be noted that reverse reel operations are not particularly noisy. Additional potential for marine impact from short-duration hydraulic fluid release (assuming unable to flush prior to removal).	Shortest time with vessel and with less handling time on the vessel resulting in lowest noise impact. Some small scale rock dump - noisy but not excessively so. Equal Marine impact perspective.	Similar to option 2 with short time with vessel and less handling time on the vessel resulting in a lower noise impact. However have additional noise generated by the additional rock placement operations.
		Summary	Marine noise impact is largely proportional to the duration / type of activities involved. Additional impact from potential for hydraulic fluid release from unflushed umbilical. Overall, from an Environment - Marine Impact perspective, option 1 is assessed as Neutral to option 2 and Stronger than option 3. Option 2 is assessed as Stronger than option3.		
	2.2 Emissions	This sub-criterion relates to the amount of damaging atmospheric emissions associated with a particular option.	Atmospheric emissions (CO_2 / NO_x) are proportional to the estimated 3 days of vessel time associated with this option. Should there be a need for backfilling operations, these durations and hence emission will increase. Note: Edda Freya size vessel required for reeling.	Atmospheric emissions (CO_2 / NO_x) are proportional to the estimated 1 day of vessel time associated with this option. Likely to be a smaller vessel than required under option 1. Also, requires less transits all leading to lower atmospheric emissions.	Atmospheric emissions (CO_2 / NO_x) are proportional to the estimated 3-5 days of vessel time associated with this option. Likely to be a smaller vessel than required under option 1 for the umbilical recovery operations. Additional vessel required for rock dump activities (as more extensive than option 2).
		Summary	The environmental impact of emissions are proportional to the vessels and duration of activities. Overall, from an Environment - Emissions perspective, option 1 is assessed as Weaker than option 2 and Stronger than option 3. Option 2 is assessed as Much Stronger than option 3.		
	2.3 Consumption	This sub-criterion relates to the amount of Energy / Resource consumption such as fuel use, recycling of materials, use of quarried rock, production of replacement materials.	Fuel consumption is proportional to the 3 days of vessel duration associated with this option. No other materials required.	Fuel consumption is proportional to the 1 day of vessel duration associated with this option. Do need additional material for rock placement however this is very minimal.	Fuel consumption is proportional to the 3-5 days of vessel duration associated with this option. Do need highest amount of additional material for rock placement.
		Summary	The most attractive option from a consumption perspective is option 2 as it will use the lowest amount of fuel and only a small amount of rock placement. This is followed by option 1 where there is an increase in the amount of fuel used. Finally, option 3 uses more fuel again and will use the largest amount of new material for rock placement. Overall, from an Environment - Consumption perspective, option 1 is assessed as Weaker than option 2 and Stronger than option 3. Option 2 is assessed as Much Stronger than option3.		
	2.4 Disturbance	This sub-criterion relates to both direct and indirect seabed disturbance. Both short and long term impacts are considered.	Potential for large amount of seabed disturbance due removing the umbilical. Distance covered 4,5 km but in a narrow corridor and is temporary disturbance.	Very limited area of seabed disturbance, c. 5m.	Greatest area of seabed disturbance than options 1 and 2, due to additional rock placement operations.
		Summary	Whilst the area of disturbance associated with option is the highest, this is considered to have lower impact as it is temporary in nature when compared to option 2 and 3. Overall, from an Environment - Disturbance perspective, option 1 is assessed as Stronger than option 2 and Very Much Stronger than option 3. Option 2 is assessed as Much Stronger than option3.		
	2.5 Protections	This sub-criterion relates to the impact of the options on any protected sites and species. It also covers potential legacy environmental impacts to the marine environment.	No impact on protected sites or species associated with this option.	No impact on protected sites or species associated with this option.	No impact on protected sites or species associated with this option.
		Summary	There is no impact associated with the options from an Environment - Protections perspective. Overall, rom an Environment - Protections perspective, all options are assessed as Neutral to each other.		
3. Technical	3.1 Technical Risk	This sub-criterion relates to the various technical risks that could result in a major project failure. Concepts such as: Technical Novelty and Potential for Showstoppers can be captured along with impact on the schedule due to overruns from technical issues such as operations being interrupted by the weather. Technical Feasibility and Technical Maturity is also considered.	No technical risks identified that could be considered major project failure. Reeling in the riser is a proven technical solution.	No technical risks identified that could be considered major project failure. Proven technical solution.	No technical risks identified that could be considered major project failure. Proven technical solution.
		Summary	All options consist of routine, well proven activities, using off the shelf, proven technology. Overall, from a Technical Risk perspective, all options are assessed as Neutral to each other.		
4. Societal	4.1 Fishing	This sub-criterion addresses the impact of the option on commercial fishing operations. It includes consideration of impacts from both the decommissioning activities any residual impacts post decommissioning such as reinstatement of access to area.	This full removal option is more attractive from fishing perspective as it removes the potential for a snag hazard that could lead to loss of fishing nets.	Marginally higher impact on fishing industry than other options as not fully buried to beyond 0.6m depth.	More attractive from a fishing perspective than option 2 as full buried to 0.6m but not as attractive as option 1 as not fully removed.
		Summary	Overall, from a Societal - Fishing perspective, option 1 is assessed as Much Stronger than option 1 and Stronger than option3. Option 2 assessed as Weaker than option 3.		
	4.2 Other Users	This sub-criterion addresses any socio-economic impacts on other users both onshore where the impact may be from dismantling, transporting, treating, recycling and land filling activities relating to the option and offshore. Issues such as impact on the health, well-being, standard of living,	Negative - will be highest level onshore landfill disposal required. Negative - greatest disturbance for local population from noise and odours. Positive - minor job creation due to disposal work scope.	Positive - will be lowest onshore landfill requirements and lowest disturbance for local population from noise and odours.	Positive - will be lowest onshore landfill requirements and lowest disturbance for local population from noise and odours.
		Summary	Overall not much to differentiate the options from a societal perspective. The likely inability to recycle much of the umbilical means option 1 is assessed as Weaker than option 2 and 3 (which are neutral to each other).		
5. Economic	5.1 Short-term Costs	This sub-criterion addresses the cost of delivering the option as described. No long-term cost element is considered here. Cost uncertainty (a function of activity maturity) is also recorded.	Cost estimate is proportional to duration of operations - estimated to be 3 days. It should be noted that the Reverse Reeling vessel is likely to be more expensive than the vessels used in other operations so likely to be similar in operations cost as option 3.	Cost estimate is proportional to duration of operations - estimated to be 1 day.	Cost estimate is proportional to duration of operations - estimated to be 3-5 days. There will also be additional costs for the greater amount of rock placement material.
	5.2 Long-term Costs	This sub-criterion addresses the costs associated with any long-term liabilities such as on-going monitoring and any potential future remediation costs.	No long term costs associated with this option.	Periodic surveys and potential remediation will be required. Cost for this yet to be defined.	Periodic surveys and potential remediation will be required. Cost for this yet to be defined.
		Summary	Whilst durations are lower, overall cost profile for option 1 short-term operations is likely to be similar to option 3 due to the higher cost associated with the reverse reeling vessel. Option 2 short-term costs will be lower than both option 1 and option 3 due to the short duration of the activities. Once long-term costs are factored in, from an Economic perspective, option 1 is assessed as Neutral to option 2 and Stronger than option 3. Option 2 is assessed as Neutral to option 3.		

Appendix D Decision Output Charts

Pipeline - Attributes - RevB



Umbilical - RevB