Shell U.K. Limited

BRENT FIELD DECOMMISSIONING COMPARATIVE ASSESSMENT PROCEDURE

A supporting document to the Brent Field Decommissioning Programmes

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Contents

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1 THE OWNERS OF THE BRENT FIELD

This Procedure has been prepared by Shell U.K. Limited (Shell) the Operator of the Brent Field, on behalf of itself and Esso Exploration and Production UK Limited (Esso), who are the owners in equal shares of the Brent Field. Throughout this document therefore, the terms 'owners', 'we', 'us', and 'our' refer to 'Shell and Esso'.

Under the Petroleum Act 1998 and the Section 29 Notices that have been served on the owners (for the Brent Delta topside, the other platforms, and the Brent pipelines), Shell U.K. Limited and Esso Exploration and Production UK Limited have joint and several liability for the decommissioning of the Brent Field. A letter in the Brent Field Decommissioning Programme confirms that Esso fully supports and endorses the proposed Decommissioning Programmes.

2 BRENT FIELD DECOMMISSIONING DOCUMENTATION

The Brent Field comprises four platforms, 28 pipelines and four subsea structures with a total mass of approximately 1.9 million tonnes. In various ways all the platforms are linked to each other or to third party assets, and in our initial planning we carefully considered the chronological sequence of decommissioning and the implications for other producing platforms and systems. We started planning this complex decommissioning programme in 2006, and as a result of the extensive period of study, evaluation and assessment there is a substantial body of work which:

- Describes the facilities and their environmental settings
- Provides information on the technical and engineering aspects of a range of decommissioning options, and the ways in which those options could be undertaken
- Examines the advantages and disadvantages of technically feasible decommissioning options

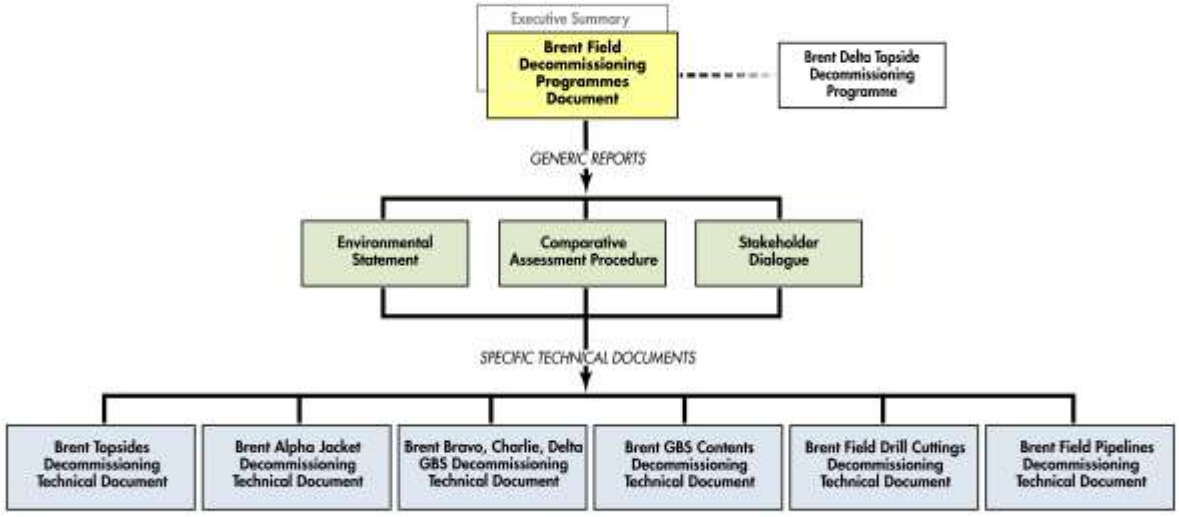
In agreement with the Department for Business, Energy and Industrial Strategy (BEIS)[1] we have chosen to present essential, detailed, descriptive and factual information, and where necessary full Comparative Assessments (CA), in six separate Technical Documents (TD) which support and inform the *Brent Field Decommissioning Programme* (DP) [1]. The DP itself therefore focuses on describing the:

- Process we followed to identify technically feasible options
- Safety, technical, environmental, economic and societal implications of different options
- Important differences between options
- Recommended options for each of the facilities
- Proposed programme of work for decommissioning the Brent Field
- Continuing responsibilities that we will have for any assets or material remaining in the Brent Field
- Monitoring programme that we would undertake to assess the condition and environmental impacts of any assets or material left in the Brent Field
- Any necessary maintenance programme we would undertake on any assets or material left in the Brent Field

Figure 1 shows the suite of documentation for the DP. The TDs are designed to be read after the DP, supplementing it and providing detail to the facts, assessments and conclusions presented in the DP. The full title of all references is given when first cited, and thereafter by the document's number in brackets [ ] as listed in Section 8.

[1] In July 2016 DECC was replaced by BEIS (Department for Business, Energy and Industrial Strategy) and any further reference to DECC should be taken as BEIS.

Figure 1 Brent Field Decommissioning Programme and Supporting Documentation.



3 EXECUTIVE SUMMARY

The Brent Decommissioning Project (BDP) has developed a standard CA procedure for use in all the CAs that are presented in the Brent Field DP [1].

Under *OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations* [2] CAs are required for the Brent Alpha steel jacket and the three concrete Gravity Based Structures (GBS) Bravo, Charlie and Delta. Under the *DECC Guidance Notes: Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998* [3] CAs are required for all of the Brent Field pipelines, and under *OSPAR Recommendation 2006/5 on a Management Regime for Offshore Cuttings Piles* [4] CAs are required for historic drill cuttings piles that exceed either of the thresholds stipulated in this Recommendation. As CAs are also an appropriate method for carrying out assessments of Best Environmental Practice (BEP), Best Available Technique (BAT) or Best Available Technology Not Entailing Excessive Cost (BATNEC), we have used our CA procedure to assess options for the management of the contents of the GBS oil storage cells, the potential disturbance of historic drill cuttings piles and of the materials in the bases of the drilling legs and in the minicell annuli on Brent Bravo and Brent Delta.

Oil and Gas UK has published *Guidelines for Comparative Assessment in Decommissioning Programmes* [5] which present three possible approaches to CAs – qualitative, semi-quantitative and quantitative. Because of the size and complexity of the BDP we have chosen to develop a quantitative CA method in line with these Guidelines, which can be applied uniformly and consistently across all our facilities, to provide a set of decommissioning recommendations that treats Brent Field decommissioning as a holistic, integrated programme of decisions and work.

DECC Guidance Notes [3] and the framework for CAs presented in OSPAR 98/3 [2] indicate that CAs should assess options in terms of safety, environmental, societal, technical and cost considerations, and, as necessary, other 'matters to be considered'. Accordingly, we took the DECC Five Main Criteria and further divided them into a set of 12 sub-criteria to examine the performances of options more accurately. By means of external and internal studies we generated quantitative and qualitative data on the performance of each option for each facility in each sub-criterion. These values then formed the basis of 12 scales of raw data, on which every option for each facility was placed.

In line with accepted methodology from Multi-criteria Decision Analysis (MCDA) all the different measures of raw data and their scales (for example, measures of fatality, gigajoules of energy, or cost in pounds) were then arithmetically transformed into 'global scales' ranging from 0 to 1. Each option was thus accorded a score in each sub-criterion ranging from 0 to 1. This was easily accomplished for all the quantitative sub-criteria. For the qualitative data, we held plenary workshops to ensure that all the facilities were placed correctly in relation to the top and bottom of the scale and in relation to each other.

After examining the relative magnitudes of the raw data scales, and taking into consideration our understanding of the views and concerns of our stakeholders, we then applied a weighting to each sub-criterion. A weighted score was then obtained in each sub-criterion by multiplying the option's score by the weighting, and a 'total weighted score' for each option was obtained by summing the weighted scores of all the sub-criteria. The option with the highest total weighted score was identified as the 'CA-recommended option'.

We weighted the DECC Five Main Criteria equally, and their sub-criteria (if any) equally pro rata, in a set of weightings we called the 'standard weighting'. To test the robustness of the CA-recommended option, we prepared several 'sensitivity' scenarios, in which the weightings of each of the DECC Five Main Criteria were increased in turn, and another scenario in which the criterion 'economic' was excluded. The purpose of these analyses was to determine if the order of the options changed when weightings were changed, and to identify which sub-criteria had the greatest influence on the overall performances of the options.

In each CA we examined the total weighted scores and the CA-recommended option under the standard weighting and the sensitivity scenarios. This resulted in the identification of an 'Emerging recommendation' for each facility. The option was then further evaluated by examining the real data in each sub-criterion, and a narrative was prepared describing the performance of the option and presenting the reasons for presenting the option as the 'recommended option'. It was this data-derived 'recommended option' which was shared and discussed with Stakeholders to understand their views before taking this forward into Public Consultation.

During the course of this Project, we had extensive discussions with a particular group of stakeholders, the Cell Management Stakeholder Task Group (CMSTG), who determined their own criteria and weightings in order to examine options for the management of the GBS cell contents. In addition, our Independent Review Group (IRG) suggested that we should examine other methods of creating weightings, and we selected an objective method in which the weightings of all sub-criteria were derived by expressing all the raw data scales in monetary terms. Some comparisons of CA results derived using these alternative weightings are presented in this procedure.

4 INTRODUCTION

This document describes the procedure that we used to prepare all the CAs required in support of the Brent Decommissioning Programmes. CAs are required to determine the recommended decommissioning option in the following circumstances:

- In support of a request for derogation from the requirement for full removal under OSPAR 98/3 [2] for:
  - All or part of the footings of a steel installation weighing more than 10,000 tonnes in air, placed in the maritime area before 9 February 1999
  - A gravity based concrete installation, a floating concrete installation or a concrete anchor base
  - Any other disused offshore installation to be dumped or left wholly or partly in place by reason of exceptional or unforeseen circumstances such as structural damage or deterioration or some other cause
- For all pipelines on the UKCS
- For concrete mattresses which the licensees propose to leave in situ
- To determine BAT/BEP for a drill cuttings pile that qualifies for Stage 2 assessment under OSPAR Recommendation 2006/5 [4]

The purpose of our CA procedure is to ensure that:

- Any CA completed for the BDP is in accordance with the requirements of the DECC Guidance Notes [3], the Petroleum Act 1998 as amended by the Energy Act 2008 [6], and OSPAR Decision 98/3 [2]
- Any CA completed for the BDP is consistent across all the facilities
- Any decisions or statements made in the CA sections of the TDs are based on appropriate supporting evidence

Accordingly, we have used this procedure to perform CAs of options for the following Brent facilities:

- The Brent Alpha jacket footings
- The three Brent GBSs, Bravo, Charlie and Delta
- The contents of the GBS oil storage cells[2]
- The material in the bases of the drilling legs on Bravo and Delta
- The material in the minicell annuli on Bravo and Delta
- All the pipelines and umbilicals which the BDP has identified as requiring 'quantitative' assessment
- Exposed concrete mattresses proposed to be left in situ

[2] On the assumption that all the attic oil and interphase material (if present) had already been removed.

- The Brent Alpha seabed drill cuttings pile[3]
- The cell-top drill cuttings piles on Bravo[4], Charlie[5] and Delta[6]

The DECC Guidance Notes [3] state that CAs are required for all pipelines. The Notes provide generic advice that small diameter and flexible pipelines that have been neither trenched nor buried would normally be expected to be removed completely. The CA for such pipelines may not have to be as complex as that for larger diameter rigid lines and the requirement for a CA may be satisfied by a 'narrative' assessment. In the BDP these assessments are referred to as 'qualitative CAs'. For such pipelines, the CA narrative describes and assesses the recommended option as identified by following the DECC Guidance Notes, and compares it with any other feasible options.

[3] All the seabed drill cuttings piles in the Brent Field fall below OSPAR Recommendation 2006/5 thresholds and therefore the recommended management option under this Recommendation is to leave the undisturbed piles *in situ*. In order to assess the option of full removal of the Brent Alpha jacket, however, the disturbance of the Alpha seabed cuttings has to be considered. Accordingly, we performed a CA of the management options for this cuttings pile.

[4] In order to facilitate any future access to the Brent Bravo GBS storage cells (e.g. for the removal of attic oil), drill cuttings on tops of the GBS cells may have to be disturbed. Accordingly, we performed a precautionary CA of options for the partial or complete removal of this cell top drill cuttings pile.

[5] Our modelling has shown that the oil loss rate from the Brent Charlie cell-top cuttings pile exceeds the OSPAR 2006/5 threshold. As required by Stage 2 of OSPAR 2006/5 we therefore performed a CA on options for the management of this pile.

[6] In order to facilitate any future access to the Brent Delta GBS storage cells (e.g. for the removal of attic oil), drill cuttings on tops of the GBS cells may have to be disturbed. Accordingly, we performed a precautionary CA of options for the partial or complete removal of this cell top drill cuttings pile.

5 OVERVIEW OF THE COMPARATIVE ASSESSMENT PROCEDURE

The BDP CA procedure comprises the following steps:

1. Identify an agreed suite of sub-criteria within the DECC Five Main Criteria that can be applied to the facilities subject to CA.
2. For all of the facilities subject to CA in the BDP, derive or acquire raw data on the performances of the relevant options in each of the sub-criteria.
3. From these data, identify maximum and minimum values in each sub-criterion from all BDP facilities subject to CA; these define the end points of the data scale for each sub-criterion.
4. Transform the sub-criteria data onto linear 0 to 1 'global scales', to obtain a score for each option for each facility in each sub-criterion.
5. Apply a 'standard' weighting to these values to derive a weighted score for each option's performance in each sub-criterion.
6. Sum the weighted scores to obtain the total weighted score for each option. The option with the highest score is the CA-recommended option.
7. Perform a sensitivity analysis by applying five weighting scenarios to the transformed data, to identify an 'emerging recommendation'.
8. Describe the outcome of the sensitivity analysis in a narrative, and present the evidence and reasoning of the key differentiating factors for the Recommended Option, linking this back to the raw data.

6 DESCRIPTION OF THE BDP COMPARATIVE ASSESSMENT PROCEDURE

6.1 Comparative Assessment Criteria and Sub-criteria

Technically feasible options were assessed using the DECC Five Main Criteria which are:

- Safety
- Environmental
- Technical
- Societal
- Economic

We used the advice provided in the Guidance Notes which lists those matters which are to be considered during a CA of feasible decommissioning options. These include but are not restricted to:

- Technical and engineering aspects
- Timing
- Safety
- Impacts on the marine environment
- Impacts on other environmental compartments
- Consumption of natural resources and energy (and climate change)
- Other consequences to the physical environment
- Impacts on amenities and the activities of communities
- Economic aspects

In line with this guidance, therefore, we assessed each option's performance by dividing that criterion into more specific sub-criteria. For example, the main criterion 'Environment' encompasses both the potential environmental impacts arising during the work programme (which is likely to be on a timescale of a few months) and the potential environmental impact arising from the long-term presence of the cuttings piles (which are likely to be on a timescale of years). By evaluating these different impacts as separate sub-criteria we were able to properly assess the performance of options in these two measures and examine how the environmental impacts changed with different options.

After examining all the feasible options for all the facilities subject to CA, the BDP identified 12 sub-criteria (Table 1) within the DECC Five Main Criteria that are complete and requisite for assessing the performances of all the BDP options. We decided that Safety should be assessed using three sub-criteria, Environmental using four sub-criteria and Societal using three sub-criteria; the criteria Technical and Economic were each assessed by one sub-criterion (Table 1). Full definitions of the main criteria and the sub-criteria are given in Appendix 1.

Table 1 The DECC Five Main Criteria and the Selected Sub-criteria used in all Brent CAs.

DECC Main Criterion	Sub-criterion	Description
Safety	Safety risk to offshore project personnel	An estimate of the safety risk to offshore personnel as a result of completing the proposed offshore programme of work
	Safety risk to other users of the sea	An estimate of the safety risk to other users of the sea from the long-term legacy of the structure after completion of the proposed programme of work
	Safety risk to onshore project personnel	An estimate of the safety risk to onshore personnel as a result of completing the proposed offshore programme of work
Environmental	Operational environmental impacts	An assessment of the environmental impacts that could arise as a result of the planned operations offshore and onshore
	Legacy environmental impacts	An assessment of the environmental impacts that could arise as a result of the long-term legacy effects of the structure or facility after completion of the proposed programme of work
	Energy use	An estimate of the total net energy use of the proposed programme of work, including an allowance for energy saved by recycling and energy used in the manufacture of new material to replace otherwise recyclable material left at sea
	Gaseous emissions	An estimate of the total net emissions of CO_2 from the proposed programme of work, including an allowance for emissions from the manufacture of new material to replace otherwise recyclable material left at sea
Technical	Technical feasibility	An assessment of the technical feasibility of being able to complete the proposed programme of work as planned
Societal	Effects on commercial fisheries	An estimate of the financial gain or loss compared with the current situation that might be experienced by commercial fishermen as a result of the successful completion of the planned programme of work
	Employment	An estimate of the man-years of employment that might be supported or created by the option
	Impact on communities	An assessment of the effects of the option on communities and onshore infrastructure
Economic	Cost	An estimate of the total likely cost of the option, including an allowance for long-term monitoring and maintenance

6.2 Applicability of Sub-criteria

The BDP has examined the full range of technically feasible options for all the facilities subject to CA and determined that the sub-criteria selected in Section 6.1 are complete and requisite for application in all the CAs.

We have determined, however, that not all sub-criteria are applicable to all the facilities, and in the relevant CA we have provided an explanation as to why the sub-criterion is not applicable. In such circumstances, where one or more sub-criterion is not applicable:

- The weighting for that sub-criterion is still applied (to maintain internal consistency across all the CAs)
- The options are accorded a score of 'nil' in this sub-criterion (not '0'); this ensures that the sub-criterion has no effect on the total weighted score of an option

Table 2 lists the 12 sub-criteria and shows which sub-criteria apply to each of the BDP CAs. For those facilities where a particular sub-criterion does not apply, an entry of 'NA' has been made.

Table 2 Sub-criteria Applicable to each of the BDP Comparative Assessments.

DECC Criterion	Sub-criterion	Pipelines	Brent Alpha Jacket	GBS Cell Contents	GBS Legs	Cell Top Drill Cuttings	Brent Alpha Seabed Drill Cuttings	Drilling Leg	Minicell	Mattresses
Safety	Offshore project personnel	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Other users of the sea	✓	✓	NA	✓	NA	✓	NA	NA	✓
	Onshore project personnel	✓	✓	✓	✓	✓	✓	✓	✓	✓
Environmental	Environmental impacts operations	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Legacy environmental impacts	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Gaseous emissions (CO_2)	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Energy use	✓	✓	✓	✓	✓	✓	✓	✓	✓
Technical	Technical feasibility	✓	✓	✓	✓	✓	✓	✓	✓	✓
Societal	Effects on commercial fisheries	✓	✓	NA	✓	NA	NA	NA	NA	✓
	Employment	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Communities	✓	✓	✓	✓	✓	✓	✓	✓	✓
Economic	Cost	✓	✓	✓	✓	✓	✓	✓	✓	✓

6.3 Comparative Assessment Data

We elected to use a method of assessment that uses 'global scales' as a way of (i) providing a unit-less scale on which to compare different sub-criteria (e.g. safety risk, the environmental impact of operations) and (ii) providing a way to compare the performance of the options across all of facilities within the BDP. This requires the production of quantitative data and qualitative information on the performance of each option in each sub-criterion.

These data were obtained from independent reports, internal technical studies, or external or internal subject-matter experts, and constituted the scientific supporting evidence required by BEIS. For eight sub-criteria, the studies provided quantitative data on performance (e.g. measured in units of gigajoules or man-years employment). For the remaining four sub-criteria the studies provided a narrative and an expert score of performance. Table 3 shows the sources and types of information that we obtained for the 12 sub-criteria.

It is important to note that the data for each option, for each facility and for each sub-criterion was generated using the same method of calculation within a sub-criterion. For example, if the cost estimate for a Brent Alpha jacket option had been generated using current vessel day rate estimates and ignoring any effect of inflation that might be expected to occur between now and the execution of the work, then the cost of an option for a GBS was calculated using these same assumptions.

Table 3 The Source and Type of Data used to Assess the Performance in each Sub-criterion.

Sub-criterion	Source of Information	Type of Data	Unit
Safety risk to offshore project personnel	Internal study by Shell	Numerical	PLL
Safety risk to other users of the sea	Studies by Anatec	Numerical	PLL
Safety risk to onshore project personnel	Internal study by Shell	Numerical	PLL
Operational environmental impacts	Score provided by DNV GL	Score	
Legacy environmental impacts	Score provided by DNV GL	Score	
Energy use	Environmental Statement	Numerical	Gigajoules
Emissions	Environmental Statement	Numerical	Tonnes
Technical feasibility	Score provided by Shell	Narrative and score	
Effects on commercial fisheries	Study by Mackay Consultants	Numerical	GBP
Employment	Study by Mackay Consultants	Numerical	Man-years
Impact on communities	Score provided by DNV GL	Score	
Cost	Internal study by Shell	Numerical	GBP

6.4 Global Scales

For each sub-criterion, the raw data values from every option and every facility were then placed on a 'data scale'. Considering each sub-criterion in turn, the 'best' and 'worst' data were then used to fix the top and bottom of the scale. For example, the option with the highest PLL is the *least desirable* and therefore determines the bottom of the scale, and the option with the lowest PLL is the *most desirable* and therefore determines the top of the scale. For each sub-criterion this resulted in a data scale spanning the whole range of data for that sub-criterion.

These raw data scales were then transformed into 'global scales', each spanning the range 0 to 1. The best or most desirable option on the raw data scale was accorded a score of '1' and the least desirable a score of '0'. Taking the example of safety risk again, the option with the highest PLL is the least desirable and therefore marks the bottom of the global scale and is accorded a score of '0', and the option with the lowest PLL is the most desirable and is therefore accorded a score of '1'. For each sub-criterion this resulted in a global scale spanning the whole data range for that sub-criterion.

We then arithmetically transformed the data for all the options and all the facilities onto these global scales. Thus, a single global scale for each sub-criterion could be used and applied consistently in all of the CAs for all of the facilities. This process of transformation converted the different sub-criteria into a common measure which then allowed us more easily and robustly to examine and compare the overall performances of the options.

As highlighted by the description above of how the raw data for safety risk was transformed onto the global scale, some of the scales were 'inverted' because in some sub-criteria large values (e.g. PLL, CO_2 emissions, cost) are not desirable. Table 4 shows how the raw data were transformed.

Table 4 Rules for the Transformation of Raw Data.

Sub-criterion	Measure	The Most Desirable Data Value
Safety risk offshore project personnel	Raw value PLL	Lowest value
Safety risk onshore project personnel	Raw value PLL	Lowest value
Safety risk to other users of the sea	Raw value PLL	Lowest value
Environmental impacts of operations	Score; high score = least impact	Highest score
Legacy environmental impacts	Score; high score = least impact	Highest score
Communities	Score; high score = least impact	Highest score
Gaseous emissions (CO_2)	Raw value tonnes CO_2	Lowest value
Energy use (GJ)	Raw value gigajoules	Lowest value
Effects on commercial fisheries	Raw value pounds sterling	Highest positive value
Employment	Raw value years employment	Highest value
Technical feasibility	Score; high score = most feasible	Highest score
Cost	Raw value pounds sterling	Lowest value

For eight of the sub-criteria listed in Table 3 we generated numerical data, such as estimates of the risk of Potential Loss of Life (PLL), energy use (gigajoules, GJ) and cost (£). The remaining four sub-criteria, however, 'operational environmental impacts', 'legacy environmental impacts', 'technical feasibility' and 'impact on communities', required the use of expert judgements on the performance of the options and therefore had no fixed numerical scale against which to score the options. Following advice from the independent consultancy Catalyze, who are MCDA experts, we established a methodology for ensuring that the scores provided by the experts could be used to create a global scale that maintained the mathematical accuracy of the performances of the options relative to each other on the global scale.

For the sub-criterion 'technical feasibility', Shell engineers attended a series of facility-based workshops to discuss and score each of the options under consideration. An aid to scoring was developed which listed factors which would affect the likelihood of successfully executing the option and included considerations such as the novelty of the equipment required and the susceptibility of the workscope to unplanned events. Each workshop resulted in a score on a 'local scale' (which was out of 45) for each of the options for that facility and an understanding of the reasons for each score. The Shell engineers then assessed whether these initial scores gave a realistic and justifiable measure of the relative technical feasibility of the options for that facility and ranked the options from best to worst. The Shell engineers then examined the differences between each of the scores to satisfy themselves that the relative position of each option was consistent and justifiable. For example, if Option A scored 30, Option B scored 15 and Option C scored 45 then the technical feasibility of Option B was half that of Option A and the difference in technical feasibility between Option B and Option C was twice that of the difference between Option A and Option B. The Shell engineers discussed and agreed any adjustments to the scores that were deemed necessary to ensure that the scores of the options on the local scale were correct relative to each other and the reasons for any adjustments were recorded.

A plenary Technical Feasibility workshop was then held at which the technical feasibilities of the options for all of the facilities were discussed and compared, with the objective of agreeing an assessment for each option which was relative to and consistent with all options across all facilities. This plenary workshop was facilitated by Catalyze and witnessed by the IRG. In summary, using the judgement of the Plenary Technical Feasibility Team, the best option in terms of technical feasibility across all of the BDP facilities was defined as '1' on the global scale. Similarly, the worst option for TF across all the facilities was defined as '0' on the global scale. The best and worst options for each facility were then placed on the global scale, referring to the record of the facility-based workshops as necessary. The intermediate options (those between 'best' and 'worst') were placed onto the global scale using a simple arithmetic mapping from the local scale position for each facility onto the global scale using the 'best; and 'worst' options for each facility as reference points. The resulting option placements on the global scale were then reviewed and any further changes documented.

DNV GL has assessed the potential impacts that could arise from each of the options under consideration in the CAs as part of their work to produce the *Brent Field Decommissioning Environmental Statement* (ES) for the BDP [7]. We therefore asked DNV GL to provide their expert judgement for the scoring of the sub-criteria 'impacts of operations', 'legacy environmental impacts' and 'impact on communities'.
As an initial step, DNV GL reviewed the type and degree of impact for each of the options under consideration. They then discounted any impact which duplicated any other sub-criterion that had been separately assessed for the purpose of the CAs. For example, the impact under the EIA aspect 'Fisheries' was removed because the commercial effect on fisheries was the subject of a separate sub-criterion in the CAs. This resulted in a judgement of the overall impacts arising from the execution and successful completion of the different options and the reasons for each judgement, similar to the technical feasibility scores produced from the facility-based workshops held by Shell. The DNV GL scores for each option were therefore informed by the EIA but do not necessarily directly correspond to the impact assessments presented in the EIA document, because the EIA assessments consider each facility in turn and do not assess the magnitude of impacts across the different facilities.

DNV GL then attended a plenary workshop, again facilitated by Catalyze and witnessed by both the IRG and Shell representatives. In this workshop, the same process as described for technical feasibility was followed for operational environmental impacts, legacy environmental impacts and impacts on communities, producing scores on a global scale for each of these three sub-criteria which reflected each option's relative performance.

Ultimately the work described here resulted in a suite of data appropriate for use in the BDP CAs and a set of raw data scales and global scales for each sub-criterion (Table 5).

Table 5 Raw Data Scales for each Sub-criterion used in Brent Decommissioning CAs.

Sub-criterion and Score on Global Scale	Units	Best Value	Worst Value
Safety risk to offshore project personnel	PLL	0.0000	0.2640
Score on this sub-criterion's global scale		1	0
Safety risk to other users of the sea	PLL	0.0000	0.2640
Score on this sub-criterion's global scale		1	0
Safety risk to onshore project personnel	PLL	0.0000	0.2640
Score on this sub-criterion's global scale		1	0
Operational environmental impacts (Note)	Score	1.00	0.00
Score on this sub-criterion's global scale		1	0
Legacy environmental impacts (Note)	Score	1.00	0.00
Score on this sub-criterion's global scale		1	0
Energy use (GJ)	GJ	0	1,738,959
Score on this sub-criterion's global scale		1	0
Emissions (CO_2)	Tonnes	1	156,726
Score on this sub-criterion's global scale		1	0
Technical feasibility (Note)	Score	1.00	0.00
Score on this sub-criterion's global scale		1	0
Effects on commercial fisheries	GBP	2,318,040	0.00
Score on this sub-criterion's global scale		1	0
Employment	Man-years	2,128	0.00
Score on this sub-criterion's global scale		1	0
Communities (Note)	Score	1.00	0.00
Score on this sub-criterion's global scale		1	0
Cost	GBP (million)	0.00	534.14
Score on this sub-criterion global scale		1	0

Note: The maximum possible score for these sub-criteria is 1.0.

6.5 Weighting the Global Scales

Weighting is a method used in MCDA to reflect the views of the decision-makers on the relative importance of the differences or range of raw data between different sub-criteria. After examining the full range of raw data on each of the data scales for each of the sub-criteria, the BDP decided that the initial assessment should be performed by applying a 'standard' set of weights to the DECC Five Main Criteria in which they were each assigned a weight of 20%. Within each main criterion, the sub-criteria were assigned a weight which was a strict pro rata division of the main criterion weight between the relevant sub-criteria. This resulted in the standard weighting shown in Table 6. The DECC Five Main Criteria are given equal weighting (left column) and their sub-criteria equal pro rata weighting (right column).

Table 6 Standard Weighting of Main DECC Criteria and Sub-criteria.

Weighting	Main DECC Criterion	Sub-criterion	Sub-criterion Weighting
20%	Safety	Safety risk to offshore project personnel	6.7%
		Safety risk to other users of the sea	6.7%
		Safety risk to onshore project personnel	6.7%
20%	Environmental	Environmental impacts of operations	5.0%
		Legacy environmental impacts	5.0%
		Gaseous emissions (CO_2)	5.0%
		Energy use (GJ)	5.0%
20%	Technical	Technical feasibility	20.0%
20%	Societal	Effects on commercial fisheries	6.7%
		Employment	6.7%
		Communities	6.7%
20%	Economic	Cost	20.0%

6.6 Identifying the CA-preferred Option

The weighted score for any sub-criterion was calculated by multiplying the score from the global scale by the standard weight for that sub-criterion. The total weighted score for any option was then obtained by summing the weighted scores of all the sub-criteria.

The results of this process were presented in tables and in bar charts, such as the examples shown in Figure 2 and Figure 3. These show the relative contributions of each of the sub-criteria (Figure 2) and the DECC Five Main Criteria (Figure 3) to the overall performance of the option. In both of these figures, the larger the coloured segment, the greater the contribution that sub-criterion has made to the overall 'good' performance of the option. If a criterion or sub-criterion does not appear on such a chart, it does not mean that is has not been assessed but simply that its performance is 'poor' and it has not contributed significantly to the overall good performance of the option. The option that had the highest total weighted score was then identified as the CA-recommended option.

Figure 2 Example of a Bar Chart showing the Total Weighted Scores of Three Options and the Contributions of Sub-criteria.

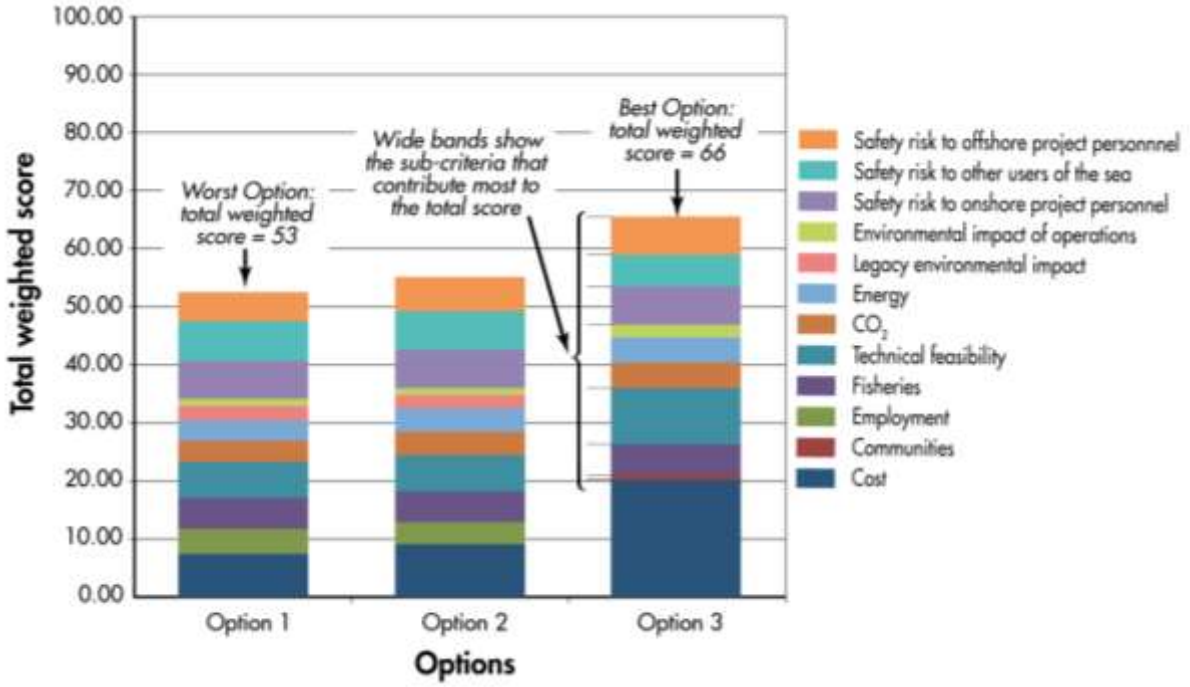
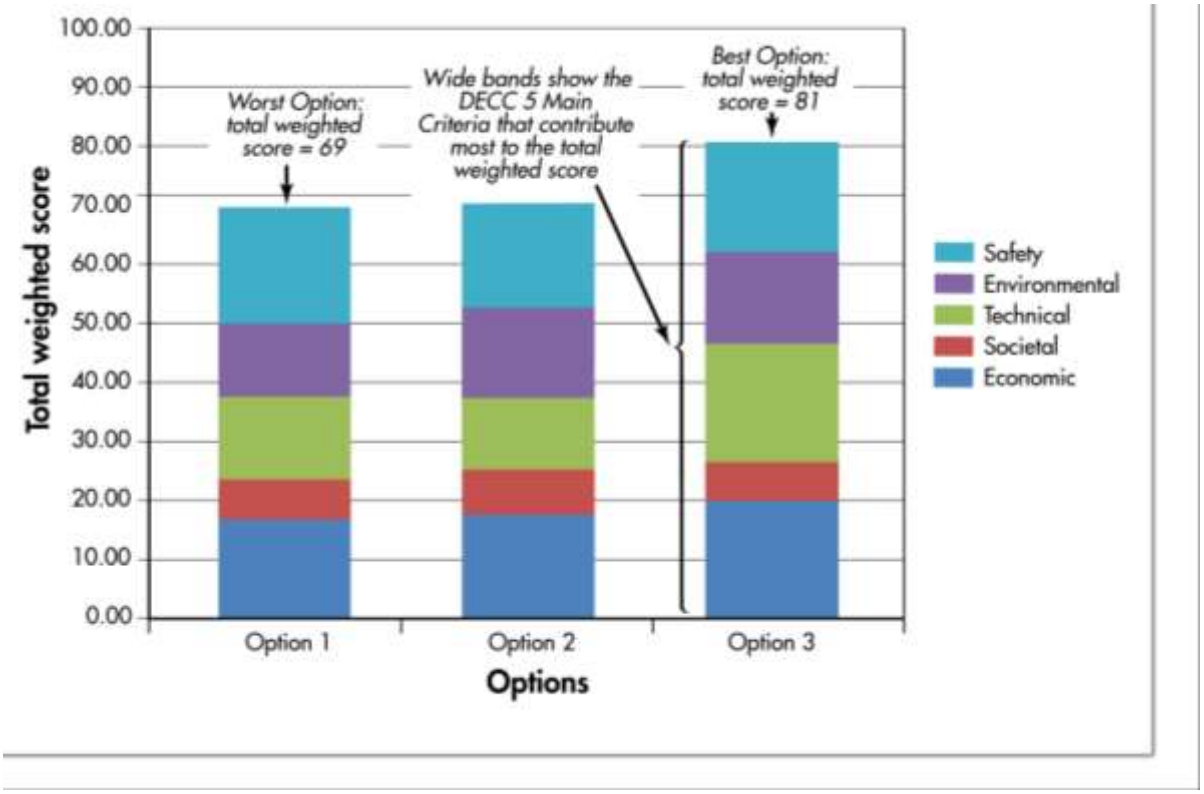


Figure 3 Example of a Bar Chart showing the Total Weighted Scores of Three Options and the Contributions of DECC Five Main Criteria.



6.7 Examining the Sensitivity of the CA-preferred Option

The OSPAR Framework for CAs states that the CA shall be *'sufficiently comprehensive to enable a reasoned judgement on the practicability of each disposal option'*, and that *'the conclusion shall be based on scientific principles…….and linked back to the supporting evidence and arguments'* [2]. DECC Guidance Notes also state *'it is unlikely that cost will be accepted as the main driver unless all other matters show no significant difference'* [3].

To examine the sensitivity of the CA-preferred option, therefore, we applied five 'selected weighting scenarios' to the scores, to generate new total weighted scores for each option. The selected weighting scenarios were confirmed after a consideration of the relative values in the global scales, and reflect our view, informed by feedback from meetings and dialogue, of the importance of the various criteria and sub-criteria to all our Stakeholders. Table 7 lists the five scenarios we used and Table 8 lists the resultant weights for each of the sub-criteria in each of the selected weighting scenarios as well as the 'standard weights'.

We then examined the total weighted scores in each scenario and assessed how the scores changed, and determined if the order of the options changed in some scenarios. This resulted in the identification of the option that was the Emerging recommendation. It should be noted that this option may have been so identified because, although not necessarily always the best option in every scenario, overall it performed well in a number of the scenarios.

Table 7 The Five Weighting Scenarios used to Assess the Sensitivity of the CA-preferred Decommissioning Option.

Scenario	Description
2	Weighted for Safety: DECC criterion Safety weighted 40%
3	Weighted for Environment: DECC criterion Environmental weighted 40%
4	Weighted for Technical: DECC criterion Technical Feasibility weighted 40%
5	Weighted for Societal: DECC criterion Societal weighted 40%
6	DECC Five Main Criteria without Economic

Table 8 Weighting Applied to Sub-criteria in Pre-determined Weighting Scenarios.

Sub-criteria	Weighting Scenario					
	1	2	3	4	5	6
Safety risk to offshore project personnel	6.7%	13.3%	5.0%	5.0%	5.0%	6.7%
Safety risk to fishermen	6.7%	13.3%	5.0%	5.0%	5.0%	6.7%
Safety risk to onshore project personnel	6.7%	13.3%	5.0%	5.0%	5.0%	6.7%
Operational environmental impacts	5.0%	3.8%	10.0%	3.8%	3.8%	5.0%
Legacy environmental impacts	5.0%	3.8%	10.0%	3.8%	3.8%	5.0%
Energy use (GJ)	5.0%	3.8%	10.0%	3.8%	3.8%	5.0%
Gaseous emissions (CO_2)	5.0%	3.8%	10.0%	3.8%	3.8%	5.0%
Technical feasibility	20%	15.0%	15.0%	40.0%	15.0%	20.0%
Effects on commercial fisheries	6.7%	5.0%	5.0%	5.0%	13.3%	6.7%
Employment	6.7%	5.0%	5.0%	5.0%	13.3%	6.7%
Communities	6.7%	5.0%	5.0%	5.0%	13.3%	6.7%
Cost	20%	5.0%	15.0%	15.0%	15.0%	20.0% (Note)

Note: On elimination of sub-criterion 'cost'. In this weighting scenario, to preserve the spread of the weightings across the other sub-criteria, the sub-criterion 'cost' retains a weighting of 20% but all the options are accorded a cost of 'nil'; this means that cost does not contribute to the overall weighted score of an option.

Key to Weighting Scenarios

Scenario	Description
1	Standard weighting; equal weight to the DECC Five Main Criteria
2	Weighted to Safety
3	Weighted to Environmental
4	Weighted to Technical
5	Weighted to Societal
6	DECC Five Main Criteria without Economic (Note)

6.8 Identifying the Recommended Option

We used the above assessments and sensitivity analyses, and wider business and corporate considerations, to compare and contrast the performances of the options in order to identify our 'recommended option'.

The assessment of the performances of options began by considering the performance of the option that provides the best performing 'clean seas' solution, and comparing that option against the next best option (identified by having the next highest total weighted score). If the 'clean seas' option did not provide the best outcome, the comparison was made between the 'clean seas' option and the option with the highest total weighted score. By means of this assessment we determined if there were any significant reasons why an option other than full removal should be proposed.

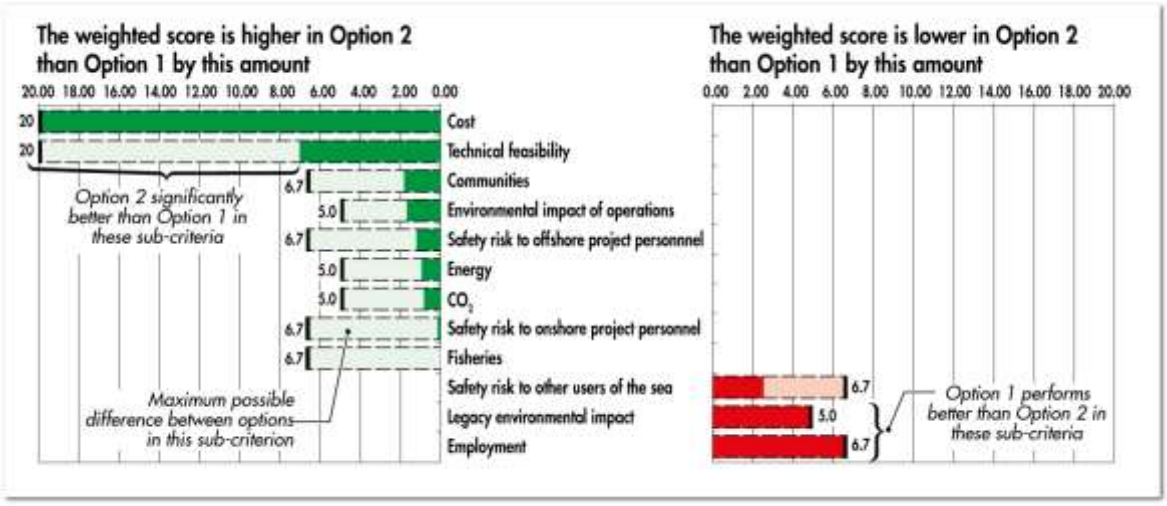
The results of our comparison and the reasons for our recommendations were then presented in a narrative in which we sought to describe clearly:

1. If there were significant differences in the overall performance of the options.
2. Which sub-criteria were responsible for or contributed significantly to those differences.
3. Whether the overall performances of the options changed significantly under the different weighting scenarios, and why.
4. Whether the order of preference of the options changed under different weighting scenarios.
5. The reasons why the BDP had identified the particular 'recommended option' for a facility.

The narratives and recommendations were supported by, and illustrated in, two types of diagram, the vertical bar charts such as that in Figure 2 and Figure 3 showing the contributions of the sub-criteria and a 'difference chart' such as that shown in Figure 4.

We prepared these difference charts to aid our examination of the important sub-criteria (the 'drivers') and enable our assessment of the trade-offs between sub-criteria. The bars show the difference in the total weighted score between the options in each of the sub-criteria; the longer the bar, the greater the difference. In this example, the bars on the left show where Option 2 is better than Option 1, and the bars on the right show where Option 1 is better than Option 2.

Figure 4 Example of a Difference Chart showing the Difference between Two Options in each of the Sub-criteria.



7 THE IMPORTANCE OF WEIGHTING

7.1 Introduction

Weighting is an essential part of the MCDA-type CAs that we have elected to perform. It reflects the value or preference that a decision-maker places on the relative sizes of the different raw data scales. It is not an expression of the 'importance' of one criterion over another, but rather of the 'exchange rate' between the range of one raw data scale and another. Such an assessment is informed by the raw data but is ultimately a subjective evaluation and different decision-makers, or groups of decision-makers, or stakeholders may have different views of the weightings that they would wish to be applied to the same set of raw data scales. As described in Section 6.7 we acknowledged this by creating a number of weighting scenarios to test the effects of applying different weightings to each of the DECC Five Main Criteria, including the exclusion of the criterion 'Economic'.

When considering weightings, stakeholders and decision-makers take into account the objective data and their own views and values. This is exemplified by the weightings that the Cell Management Stakeholder Task Group (CMSTG) applied to the MCDA model they constructed to examine the options for the management of the GBS cell contents, reported in Brent GBS Cell Contents Decommissioning Technical Document [8]. The CMSTG model comprised a total of 33 criteria that they considered necessary or valuable to compare options specifically for the management of the sediments in the former oil storage cells of the GBSs. Their weighting exercise was conducted in 2012 using the data and estimates available at that time and was reconfirmed in 2015 once we had obtained the results of the analysis of samples from the Brent Delta cells [8].

The MCDA model constructed by the CMSTG (facilitated by Catalyze) was not intended to be used in CAs for any other facility. Nonetheless it gives a valuable insight into the views of our stakeholders on some of the criteria that are also taken into consideration in our own CAs, for the cell sediment and the other Brent facilities.

Accordingly, Section 7.2 presents a brief analysis of the CMSTG weighting and compares it with the weightings that we have used, and presents the results of a CA run with the CMSTG weightings and our raw data for the GBS cell contents. Finally, Section 7.3 presents a form of swing weighting accomplished by converting all our raw data scales into monetary values, and compares this weighting with that used in our CAs.

7.2 Examination of BDP CAs using the CMSTG Weightings

We reviewed the 33 sub-criteria used by the CMSTG to prepare their MCDA model of options of the management of the GBS cell sediments. By inspection, we allocated each one to one of the 12 sub-criteria used in our CAs. By this method, we allocated 24 of the CMSTG criteria, accounting for a total of 73% of the criteria and 80.4% of the total CMSTG weights. Table 9 shows the CMSTG sub-criteria and their weights, with the yellow-highlighted sub-criteria being the ones that we felt able to allocate to one of our 12 sub-criteria. The remaining weights were applied pro rata between our sub-criteria, and this resulted in a 'CMSTG weighting' for our sub-criteria as shown in Table 10.

Table 9 CMSTG Sub-criteria and Weights.

No.	CMSTG Sub-criteria	CMSTG Weight
1	Marine environment end-point impacts	15.6
2	Natural resources use after decommissioning	3.1
3	Natural resources use during planned operations	2.1
4	Public reaction risk	6.4
5	Knowledge of cell contents	7.8
6	Technology readiness	3
7	Knowledge of technology	5.8
8	Marine environmental impact of operations to the seabed	7.8
9	Health and safety risks for personnel during operations	4.5
10	Risk of impact to marine environment	19.5
11	UK supply chain	1.6
12	Marine environmental impact of operations to the surface and above water	6.2
13	Risk to the onshore environment	5.8
14	Total cost	3.9
15	Marine environmental impact of operations to the water column	3.1
16	Amenity attributes	0.8
17	Execution complexity	1.2
18	Presumption to remove	0
19	Sediment volume	0.4
20	Sediment mobility	0.4
21	Regulatory risk	0.6
22	Fiscal regulation risk	0.6
23	Work resource availability	0.2
24	Health and safety risk for personnel in the long-term	0.4
25	Health and safety risks for sea users	0.2
26	Health and safety risks for road transport	0.2
27	Risk of unplanned air emissions	0.2
28	Risk of using unplanned resources	0.2
29	Fishing industry reaction risk	0.2
30	Sediment composition	0
31	Air emissions from operations	0
32	UK tax revenues impact	0
33	Health and safety risks for the local community	0
Total weight		101.8

Table 10 The BDP CA Sub-criteria Weights Derived from the CMTSG Weightings.

BDP CA Sub-criteria	Derived from CMSTG Work			BDP DECC Five Standard Weighting
	Weight from CMSTG Weights	Expressed as DECC Five Main Criteria		
Safety offshore pers	5.5	Safety	6.5	20
Safety onshore pers	0.2	Environmental	77.6	20
Safety others users	0.7	Societal	3.2	20
Impacts of operations	54.3	Technical	7.3	20
Legacy impacts	22.8	Cost	5.5	20
Gaseous emissions	0.2	**Total**	100.0	100
Energy use	0.2			
Employment	2.0			
Amenities	1.0			
Commercial Fishing	0.2			
Technical Feasibility	7.3			
Cost	5.5			
Total	100.0			

We then applied these weightings to our scores for the assessment of options for the management of the Brent Delta GBS cell material, and the results are shown in Figure 5. For comparison we also applied these weights to the BA footings plus cuttings (Figure 6) and the Brent Delta GBS (Figure 7), with the caveat that the CMSTG derived their weights from an inspection of the data ranges for the options for the cell sediments only, not all the installations and facilities.

In all these examples, the order of the options remained the same as in the CAs we performed using the 'standard weighting', and the 'CA-recommended' option remained unchanged.

Figure 5 Results of CA of Options for Management of the Brent Delta GBS Cell Contents using the CMSTG-derived Weights.

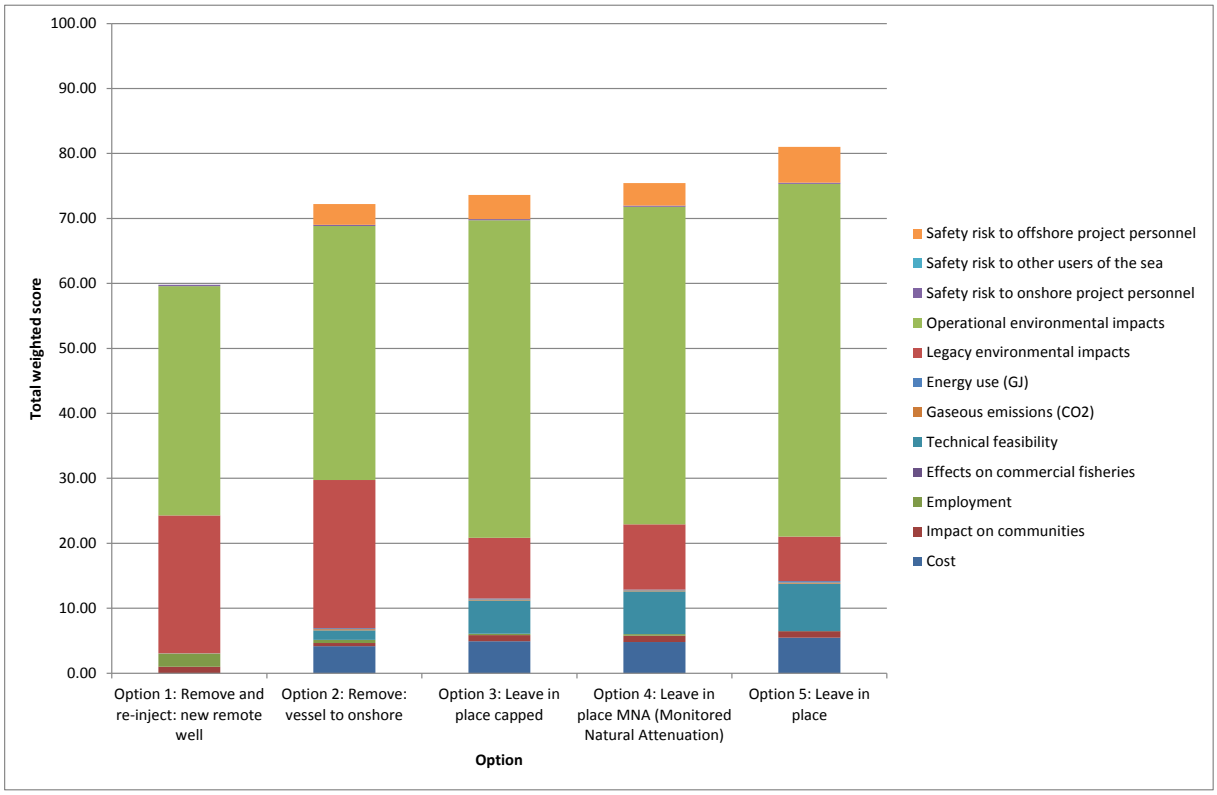


Figure 6 Results of CA of Options for the Brent Alpha Footings using the CMSTG-derived Weights.

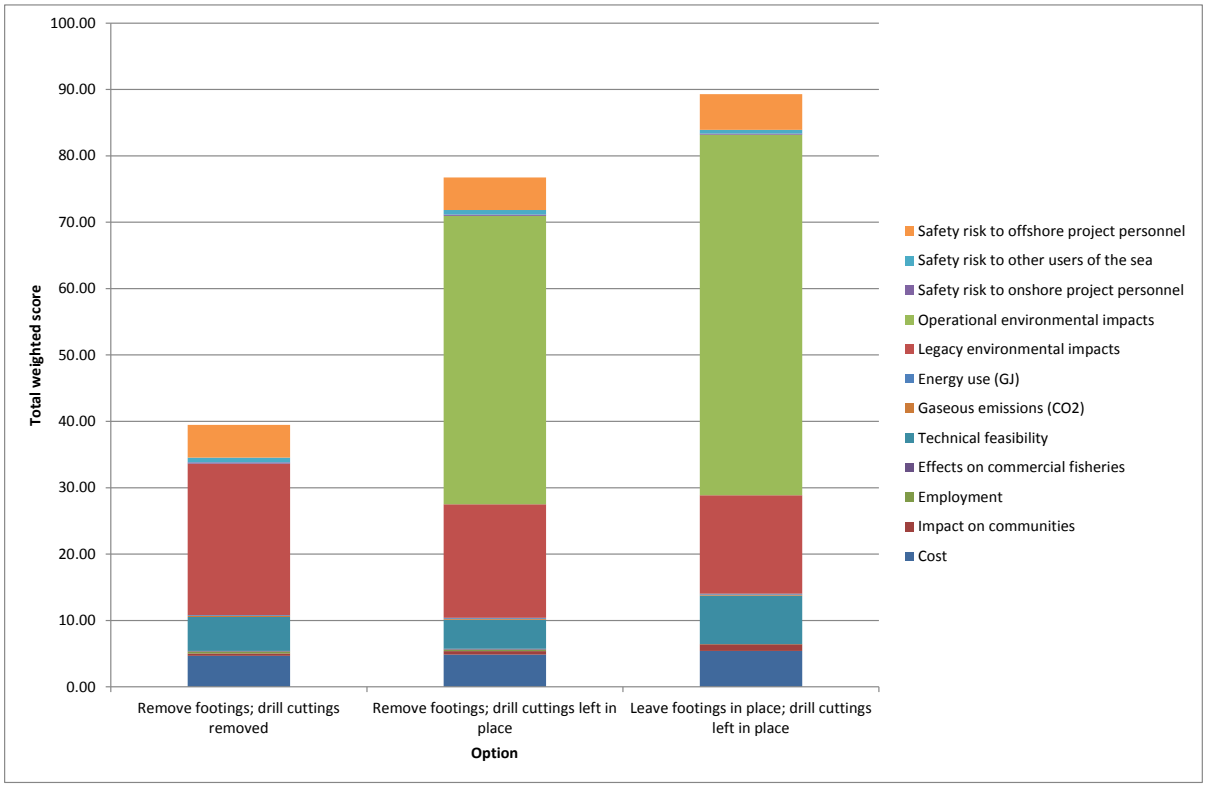
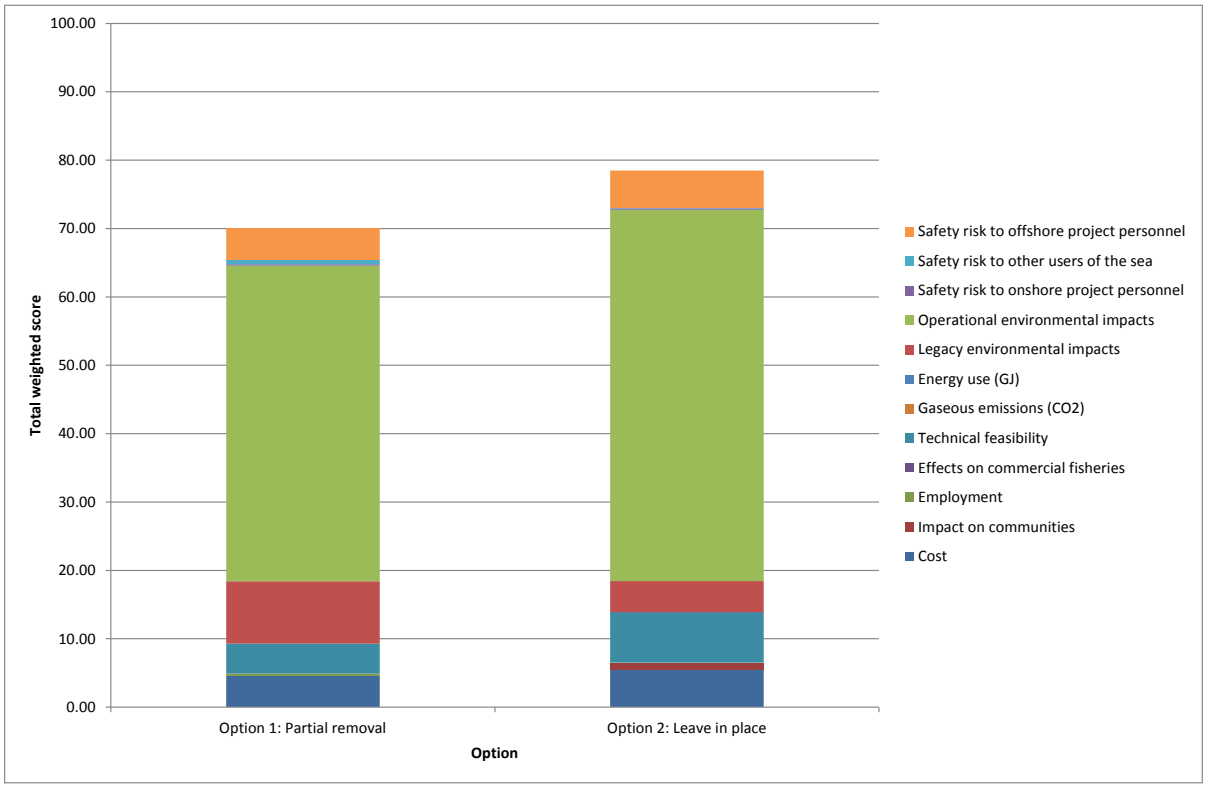


Figure 7 Results of CA of Options for the Brent Delta GBS using the CMSTG-derived Weights.



7.3 Weighting using Monetised Scales

As a result of dialogue with our IRG we also carried out further examination of the relative magnitudes of our raw data scales by attempting to convert all the raw data scales to a single monetary scale (with all the caveats associated with assigning a monetary value to the environment, human lives or societal well-being). This is not to say the monetisation is the best or only way of comparing or weighting the CA scales, but it does provide a point of reference.

We performed this exercise in several stages. Firstly, we used published data to generate a monetary value for the scale of the raw data in each sub-criterion. Uncertainties concerning the accuracy of the 'value' or 'unit cost' of each of the measures in the scales[7] were taken into account by selecting a high or conservative value from any range of published values. We then expressed each monetary value as a percentage of the total value of all the sub-criteria scales, including cost. This percentage was used as the initial weighting for each scale.

The monetised data scales were then adjusted to try to take into account uncertainty concerning the accuracy of, or confidence in, our original assessment of the sizes of the effects and thus the magnitudes of the scales. For all the sub-criteria except 'cost' these adjustments (if performed) always resulted in an increase in the monetary value of the scale. By increasing the monetary value of certain sub-criteria, we increased the percentage contribution of those sub-criteria to the overall value, and thus increased their weighting. This exercise resulted in an 'adjusted' set of weights for the criteria.

[7] Or confidence in this value, or acceptance in the literature of this value.

At the same time, we decided to reduce our estimate of the size of the 'cost' raw data scale by 1/3. This was not because we thought our estimates of cost were wrong or in any way inaccurate, but because it is reasonable to assume that a reduction in cost might be obtained through tendering and changes in the rates and prices that contractors might offer. The size of the cost scale was therefore reduced by 1/3 to £356 million and the percentages of the other monetised scales were recalculated against the new total value of all the sub-criteria scales.

Table 11 shows the resulting adjusted weights for each sub-criterion, and the resultant weights for the DECC Five Main Criteria, and compares these against the 'standard weighting' that we used in our CAs.

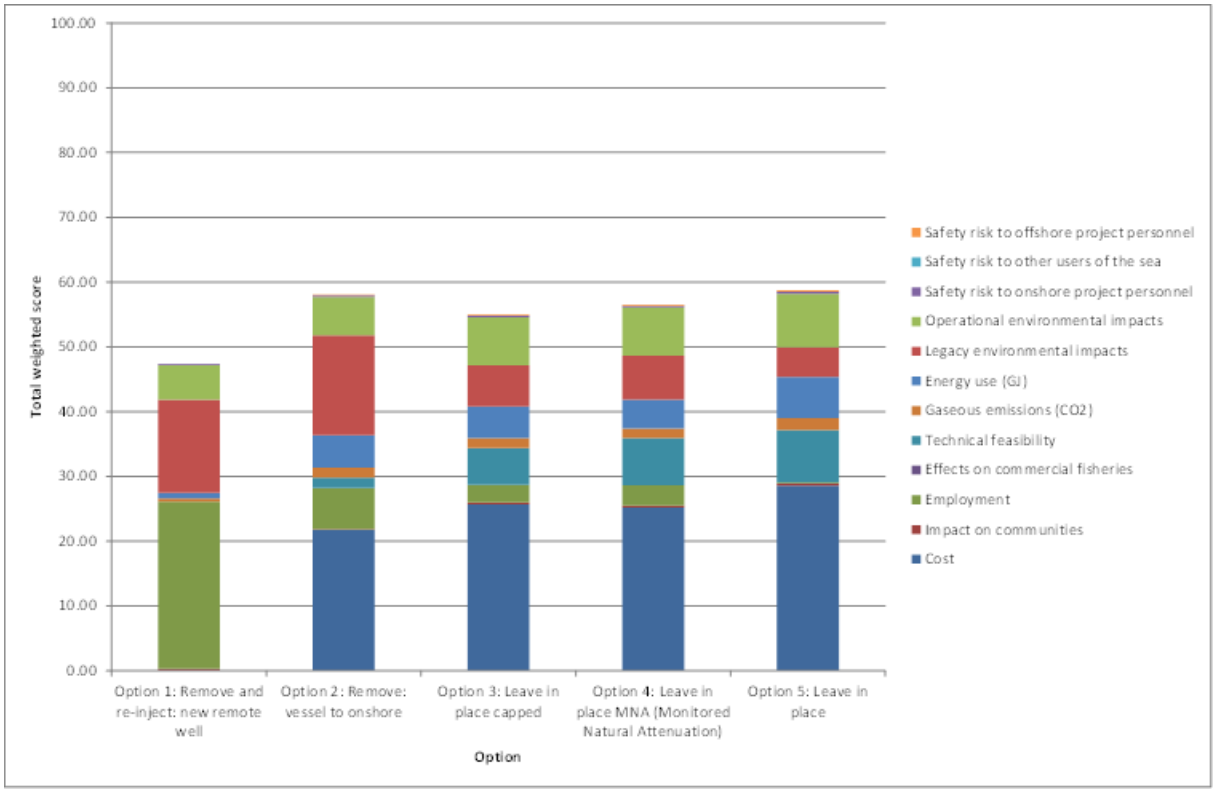
On the basis of this assessment and the adjustments to the raw data scales, it would appear that, in the standard weighting scenario, we have under-weighted the sub-criteria 'environmental impacts of operations', 'legacy environmental impacts', 'energy use' and 'employment' and under-weighted the criterion 'cost'. Conversely, it appears that we have placed significant or very significant emphasis on the sub-criteria, 'safety risk to offshore project personnel', 'safety risk to onshore project personnel', 'safety risk to other users of the sea', 'gaseous emissions', 'impacts on communities', 'impacts on commercial fisheries, and significant emphasis on the criterion 'technical feasibility'.

Table 11 Summary Comparison of Adjusted Monetised Weights and Shell Standard Weights for each Sub-criterion.

Sub-criteria	Derived from Monetised Weights			Shell Weightings		
	% of Total	DECC Main Criterion	Weight	% of Total	DECC Main Criterion	Weight
Safety risk offshore personnel	0.26	Safety	3.07	6.65	Safety	20
Safety risk onshore personnel	0.26		3.07	6.65		20
Safety risk other users of the sea	2.56		3.07	6.70		20
Environmental impacts of operations	8.25	Environment	31.97	5.00	Environment	20
Legacy environmental impacts	15.40		31.97	5.00		
Energy use	6.40		31.97	5.00		
Gaseous emissions	1.92		31.97	5.00		
Impacts on communities	0.32	Societal	28.13	6.65	Societal	20
Employment	25.78		28.13	6.65		
Impacts on commercial fisheries	2.03		28.13	6.70		
Technical feasibility	8.08	Technical	8.08	20	Technical	20
Cost	28.75	Cost	28.75	20	Cost	20
Total	**100**	**Total**	**100**	**100**	**Total**	**100**

To complete this assessment, we then performed a CA of the options for the management of the Brent Delta GBS cell contents using the above weightings derived from the monetisation of the raw data scales. The results are presented in Figure 8, and show that using a weighting derived from the monetisation of the data scales, the order or preference of the options for the Brent Delta GBS cell contents remains the same, and the CA-recommended option remains Option 5 'Leave in Place'.

Figure 8 Results of CA of Options for Management of the Brent Delta GBS Cell Contents using the Weights Derived from Monetisation.



8 SUPPORTING MATERIAL

[1] Shell (2017) Brent Field Decommissioning Programmes, BDE-F-GEN-AA-5880-00015.

[2] OSPAR (1998) OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations.

[3] DECC (2011) Guidance Notes: Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998. Version V6.

[4] OSPAR (2006) Recommendation 2006/5 on a Management Regime for Offshore Cuttings Piles.

[5] OGUK (2015) Guidelines for Comparative Assessment in Decommissioning Programmes.

[6] Energy Act, 2008.

[7] DNV GL (2017) Brent Field Decommissioning Environmental Statement, published by Det Norske Veritas, document number BDE-F-GEN-HE-0702-00006.

[8] Shell (2017) Brent GBS Cell Contents Decommissioning Technical Document, BDE-F-GBS-BA-5801-00002.

[9] Anatec Limited (2011) Assessment of safety risks to mariners from derogated Brent installations, BDE-F-GBS-HX-0708-00008.

[10] Anatec Limited (2011) Assessment of the safety risk to fishermen from derogated footings of the Brent Alpha steel jacket, BDE-A-JKT-HX-0709-00003.

[11] Anatec Limited (2011) Assessment of safety risks to fishermen from decommissioned pipelines in the Brent Field, BDE-F-PIP-HX-0709-00002.

[12] DNV GL (2017) Energy and Emissions Report for the Shell Brent Decommissioning EIA, BDE-F-GEN-HE-0702-0001.

[13] Mackay (2014) Brent Decommissioning Assessment of Socio-Economic Effects on Commercial Fisheries, BDE-F-GEN-HE-0702-00003.

[14] Mackay (2014) Assessment of Potential Economic and Employment Impacts, BDE-F-GEN-HX-0780-00002.

9 ACRONYMS AND GLOSSARY

ALARP	As Low As Reasonably Practicable
ASP	Able Seaton Port
BAT	Best Available Technique
BA	Brent Alpha
BB	Brent Bravo
BC	Brent Charlie
BD	Brent Delta
BDP	Brent Decommissioning Project
BEIS	Department of Business, Energy and Industrial Strategy
BEP	Best Environmental Practice
CA	Comparative Assessment
CAPEX	Capital Expenditure
CA-recommended Option	The option with the highest total weighted score from the CA procedure under the standard weighting scenario
CO_2	Carbon Dioxide (gas)
Criteria	The five main categories of 'matters to be taken into consideration' presented in the DECC Guidance Notes for use in CAs
DECC	Department of Energy and Climate Change
DNV-GL	Det Norske Veritas Germanischer Lloyd
DP	Decommissioning Programme
EIA	Environmental Impact Assessment
ESHIA	Environmental, Social, Health Impact Assessment
E&P	Exploration and Production
Emerging Recommendation	The option that on balance appears to be the most attractive following analysis of the data and CA results across the various weighting scenarios
FAR	Fatal Accident Rate
GBP	Pounds Sterling
GBS	Gravity Based Structure
GJ	Giga Joule
HSE	Health and Safety Executive
HSSE	Health, Security, Safety and Environment
ICES	International Council for the Exploration of the Sea
IoP	Institute of Petroleum
LWIV	Light Well Intervention Vessel
MCDA	Multi-criteria Decision Analysis
MWh	MegaWatt Hour
OGUK	Oil and Gas UK
OPEX	Operational Expenditure
OSPAR	Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic
Performance	The ability of an option to provide or result in a desirable outcome in any sub-criterion.
PLL	Potential Loss of Life
Raw Data	A term covering all the types of data (both quantitative and qualitative) obtained from internal or external studies, including technical data and expert judgement, to quantify the performance of an option in a sub-criterion
Recommended Option	The option recommended by the BDP after detailed consideration of the performances of the options including an examination of the sensitivity of the results, and taking into account any other factors not captured in the CA model, such as reputational concerns

Sensitivity	An expression of the likelihood that the relative performance of the options changes under the different weighting scenarios. Changes in the order of preference indicate that the CA outcome is sensitive to different weightings
Score	The numerical value generated when any type of data is transformed onto the global scale for a sub-criterion
Sub-criteria	One or more of the specific matters to be considered, as suggested in [3], which serve to give more detail or granularity to the assessment of a Criterion
TD	Technical Document
Total Weighted Score	The number obtained when the weighted scores of all the sub-criteria are summed
UKCS	United Kingdom Continental Shelf
Weighting Scenario	A set of weights that reflects the relative importance of the sub-criteria from a particular perspective. The standard weighting scenario is defined by the Brent Decommissioning Project (BDP). The other scenarios weight the criteria or sub-criteria in line with stakeholder or project concerns. These weighting scenarios are intended to examine the sensitivity of an option to changes in the weights of the criteria or sub-criteria
Weighted Score	The number obtained when a score in any sub-criterion is multiplied by the agreed weighting for that sub-criterion

APPENDIX 1 DEFINITIONS AND DESCRIPTIONS OF THE MAIN CRITERIA AND THE SUB-CRITERIA USED IN THE BRENT DECOMMISSIONING PROGRAMMES COMPARATIVE ASSESSMENTS

Safety

Three sub-criteria were used in the assessment of the DECC main criterion 'Safety'.

Definition of 'Safety' criteria: An assessment of the potential safety risk to people directly or indirectly involved in the programme of work offshore and onshore, or who may be exposed to risk as a result of the successful completion of the option. Safety risk was assessed using three specific sub-criteria.

Sub-criteria:

1. The safety risk for project personnel who would be engaged in performing decommissioning activities offshore.
2. The residual risk to other users of the sea on successful completion of the option.
3. The safety risk for project personnel who would be engaged in performing decommissioning activities onshore.

Assessment of criteria: In all three criteria safety risk was assessed using estimates of Potential Loss of Life (PLL).

PLL is one of the prime outputs of a Quantitative Risk Assessment (QRA). It provides a measure of cumulative risk which is directly dependent on the number of people exposed to the risk and the duration of the activity. In this context it therefore provides a simple measure of the relative safety risk between project personnel who may be engaged in operations to complete an option, and third-parties who may be exposed to the long-term risk from the planned end-point of the option. PLLs can and are therefore used in the overall decision-making process (such as in a CA) along with considerations of the environmental impacts, costs and other criteria.

There are absolute values of risk tolerability used by authorities, such as the HSE; for example, risks between 1×10^{-1} and 1×10^{-3} are considered intolerable and risks between 1×10^{-3} and 1×10^{-6} are in the region where it has to be shown that the risks are tolerable and are as As Low As Reasonably Practicable (ALARP). Within a decision-making process such as a CA, however, it should be stressed that PLL figures should not be used as an absolute measure of risk because the total PLLs here represent the cumulative predicted risk for different groups of people and activities, and there is no analysis of the options to determine the effects of any risk-reduction measures that would or could be applied. Such detailed analysis occurs once an option has been selected, and it is at this point that the specific PLLs for a given activity could be compared with the HSE thresholds above.

For personnel directly engaged in decommissioning activities, both offshore and onshore, the PLL estimate is based on the historical incidence of fatalities for each activity type undertaken and the amount of effort required to complete each activity. The PLL is a function of the Fatal Accident Rate (FAR) for the activity being undertaken, the expected duration of the activity and the number of project personnel involved. For the onshore decommissioning activities the risk is directly proportional to the amount of material recovered to shore and processed. The PLL is an estimate of the average level of safety risk for undertaking each activity and does not take into account either project-specific hazards that could increase the actual risk exposure or project-specific mitigation measures that would reduce the actual risk exposure.

For the potential residual risk to other users of the sea the PLL estimate is a function of the expected fishing activity or commercial shipping activity in the area, the likelihood of fatal accidents from such interactions, and the number of person on board the vessels, as presented by Anatec in their reports Assessment of safety risks to mariners from derogated Brent installations [9], Assessment of the safety risk to fishermen from derogated footings of the Brent Alpha steel jacket [10] and Assessment of safety risks to fishermen from decommissioned pipelines in the Brent Field [11]. With respect to collisions specifically, the risk to personnel on all types of vessel is a function on the level of shipping activity in the area (including fishing vessels), the likelihood of a fatal collision and the number of personnel on the vessel. For fishermen the risk from snagging is a function of the expected level and type of fishing activity in the area, the likelihood of interaction with a facility in various configurations, and the incidence of fatal accidents from such interactions. For both types of risk the PLL estimate is necessarily based on recent historical data for shipping activity in the area and collision statistics, and on fishing intensity and the propensity for current fishing fleet vessels to be involved in a fatal snagging event. The PLL is first calculated as an annual risk and that annual risk is then projected across the degradation lifetime of the facility. Given that levels of shipping activity, sizes of fish-stocks, fishing practices and fishing operations technology – to name but a few variables – may change considerably over time, this projection of estimated PLL to the very long-term (many hundreds of years) needs to be treated with great caution. The PLL for other users of the sea is therefore subject to great uncertainty.

The values resulting from these calculations represent the total PLL for the onshore and offshore project personnel for the whole of the proposed decommissioning programme of work, and the total PLL for other users of the sea for the whole lifetime of any decommissioned remains that are left in the sea.

Environmental

Four sub-criteria were used in the assessment of the DECC main criterion 'Environmental'.

Definition of two 'impacts' criteria: An assessment of the significance of the risks to any environmental receptor as a result of ***operations*** (the activities that would be undertaken to complete the option) or the ***legacy*** (the final state of the facilities, material or environment as a result of successfully completing the option).

Sub-criteria:

1. The severity of environmental risk to the marine and terrestrial environments from 'operations'.
2. The severity of environmental risks to the marine and terrestrial environments from 'legacy'.

Assessment of criteria: The nature and scale of both these impacts were assessed by DNV and reported in the ES [7]. Using these assessments as a basis, DNV prepared separate scores for the impacts of operations and legacy environmental impacts, which were presented in the plenary environmental workshop.

Definition of 'gaseous emissions' sub-criterion: The total emissions of CO_2 from the proposed offshore and onshore activities associated with the complete programme of work for each option. This includes all the 'direct' emissions from vessel use and the transportation, treatment, recycling and disposal of any recovered materials or waste. It also includes an estimate of the emissions that would arise during the new manufacture of material that would theoretically be required to replace otherwise recyclable materials that were deliberately not recovered or recycled.

Assessment of criterion: This criterion was assessed quantitatively as tonnes of CO_2, using the estimates presented in the DNV GL *Energy and Emissions Report for the Shell Brent Decommissioning EIA* [12], written in support of the ES [7].

Definition of 'energy use' sub-criterion: The total predicted energy use required to complete the proposed offshore and onshore activities to complete the programme of work for each option. This includes all the 'direct' energy use from vessel use and the transportation, treatment, recycling and disposal of any recovered materials or waste. It also includes an estimate of the energy that would theoretically be required for the new manufacture of material to replace otherwise recyclable materials that were deliberately not recovered or recycled.

Assessment of criterion: This criterion was assessed quantitatively as gigajoules (GJ) of energy, using the estimates presented in the DNV GL Energy and Emissions Report [12], written in support of the ES [7].

Technical

One sub-criterion was used in the assessment of the DECC main criterion 'Technical'.

Definition: The likelihood that the option will fail as a result of issues relating to equipment, or structural or environmental conditions, or project preparation and execution.

In this definition *failure* was defined as 'not being able to complete the proposed option as planned and having to go back to BEIS to seek approval to perform another (completely different) option'.

Sub-criterion: Technical was assessed using one sub-criterion – technical feasibility – which itself was determined by considering nine aspects of each option (Table A.1.1) namely:

1. Degree of planning and preparation.
2. Complexity of option.
3. Novelty of procedure.
4. Novelty of equipment.
5. Reliability of equipment.
6. Vulnerability to weather issues.
7. Vulnerability to facility condition issues.
8. Availability of spare equipment.
9. Use of alternative types of equipment and/or procedure.

Assessment of criterion: This criterion was assessed qualitatively, using the expert judgement of the engineering team informed by the assessments and results contained in internal and external engineering studies. At a number of Technical Feasibility Workshops, our engineers assessed the performance of options against each of these aspects, assigned each option to one of five defined categories, each of which carried a score of 1 to 5. The total score of each option was then calculated. All the scores for all the options for all the facilities were then collated and discussed at the plenary Technical Feasibility workshop and placed on the Global scale for Technical Feasibility. Table A.1.1 shows the table that was created to generate the technical feasibility scores of options for the Brent GBSs. With modification this was applied to all other facilities.

Table A.1.1 The Scoring Methodology for Assessing Technical Feasibility.

ISSUE	DESCRIPTION	CATEGORY	SCORE
Planning	**1.Degree of planning and preparation**	Very large amount of planning & prep	1
	How much planning , preparation and trialling would be required?	Large amount of planning & prep	2
		Moderate amount of planning & prep	3
		Small amount of planning & prep	4
		Very small amount of planning & prep	5
Execution	**2.Complexity of option**	Very highly complex option	1
	How complex is the option, how many interfaces and/or different contractors will be used?	Highly complex option	2
		Moderately complex option	3
		Small degree of complexity option	4
		Very small degree of complexity option	5
	3.Novelty of procedure	Very highly novel *Procedure*	1
	How novel is the procedure? Experimental? Trial? Sometimes used? Routinely used?	Highly novel *Procedure*	2
		Moderately novel *Procedure*	3
		Small degree of novelty in *Procedure*	4
		Very small degree of novelty in *Procedure*	5
	4.Novelty of equipment	Very highly novel *equipment*	1
	How novel is the equipment? Trial? Prototype? Tried & Tested?	Highly novel *equipment*	2
		Moderately novel *equipment*	3
		Small degree of novelty in *equipment*	4
		Very small degree of novelty in *equipment*	5
	5.Reliability of equipment	Very unreliable equipment	1
	How reliable is the equipment? How likely to fail/break-down, & thus e.g. miss weather window	Worse than average reliability of equipment	2
		Average reliability of equipment	3
		Better than average reliability of equipment	4
		Very reliable equipment	5
	6.Vulnerability to weather issues	Very highly vulnerable to weather	1
	How vulnerable is the option/procedure to weather conditions and/or deterioration in the weather?	Highly vulnerable to weather	2
		Moderately vulnerable to weather	3
		Quite immune to weather	4
		Not affected / hardly affected be weather	5
	7.Vulnerability to facility condition issues	Very highly vulnerable to structure's condition	1
	How vulnerable is the option/procedure to unknown condition(s) of the facility?	Highly vulnerable to structure's condition	2
		Moderately vulnerable to structure's condition	3
		Small degree of vulnerability to structure's condition	4
		Very small / no vulnerability to structure's condition	5
Fall-back / Recovery	**8.Availability of spare equipment**	Very poor availability of spare equipment	1
	Is spare equipment readily available, if the original equipment breaks down?	Poor availability of spare equipment	2
		Moderate availability of spare equipment	3
		Readily available of spare equipment	4
		Very readily available spare equipment	5
	9.Use of alternative types of equioment and/or procedure	Very difficult / impossible to achieve with alternative equipment and / or procedure	1
	How easy would it be to use other **different** types of equipment to complete the option?	Difficult to achieve with alternative equipment and / or procedure	2
		Moderately easy to achieve with alternative equipment and / or procedure	3
		Quite easy to achieve with alternative equipment and / or procedure	4
		Very easy to achieve with alternative equipment and / or procedure	5
The highest possible TF value is 45 (the *most* feasible) and the lowest value is 9 (the *least* feasible).			

Societal

Three sub-criteria were used in the assessment of the DECC main criterion 'Societal'.

Definition: The effects of any of the operations or legacy on the standard of living or the commercial activity of individuals, organisations or companies, or local or national infrastructure or amenities. Societal impacts were assessed using three specific sub-criteria.

Sub-criteria:

1. The effects on the commercial interests of fishermen (i.e. excluding safety risks).
2. The effects on local employment and commercial activity onshore.
3. The effects on the local onshore communities, amenities or infrastructure.

Assessment of criteria: The commercial effects on fishermen and the effects on local employment onshore were assessed quantitatively using the results from the reports by Mackay Consultants *Brent Decommissioning Assessment of Socio-Economic Effects on Commercial Fisheries on effects on commercial fisheries* [13] and *Assessment of Potential Economic and Employment Impacts* [14].

Effects on onshore communities and infrastructure were assessed qualitatively, using the assessments and results presented in the ES [7].

Economic

One sub-criterion was used in the assessment of the DECC main criterion 'Economic'.

Definition: The total net cost specifically attributable to the execution of the proposed decommissioning programme and allowing for the proper recycling, treatment and disposal of wastes, and a assumed programme of post-decommissioning monitoring and maintenance where required. Cost was assessed using one sub-criterion.

Sub-criterion:

1. The estimated total cost of the complete programme of work, including offshore and onshore operations, waste treatment and disposal, and future monitoring.

Assessment of criteria: This criterion was assessed quantitatively by Shell, using data from internal and external studies.

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APPENDIX 2 PRE-SELECTED WEIGHTING SCENARIOS

The following tables present the weightings applied to the sub-criteria and DECC main criteria in each of the five pre-selected weighting scenarios used to test the robustness of the CA-preferred option, resulting in the Emerging recommendation.

Safety Weighting Scenario

Total Weighting		Sub-criteria	Weighting
40%	Safety	Safety risk to offshore project personnel	13.3%
		Safety risk to other users of the sea	13.3%
		Safety risk to onshore project personnel	13.3%
15%	Environmental	Environmental impacts of operations	3.8%
		Legacy environmental impacts	3.8%
		Gaseous emissions (CO_2)	3.8%
		Energy use (GJ)	3.8%
15%	Technical	Technical feasibility	15.0%
15%	Societal	Effects on commercial fisheries	5.0%
		Employment	5.0%
		Communities	5.0%
15%	Economic	Cost	15.0%

Environmental Weighting Scenario

Total Weighting		Sub-criteria	Weighting
15%	Safety	Safety risk to offshore project personnel	5.0%
		Safety risk to other users of the sea	5.0%
		Safety risk to onshore project personnel	5.0%
40%	Environmental	Environmental impacts of operations	10.0%
		Legacy environmental impacts	10.0%
		Gaseous emissions (CO_2)	10.0%
		Energy use (GJ)	10.0%
15%	Technical	Technical feasibility	15.0%
15%	Societal	Effects on commercial fisheries	5.0%
		Employment	5.0%
		Communities	5.0%
15%	Economic	Cost	15.0%

Technical Weighting Scenario

Total Weighting		Sub-criteria	Weighting
15%	Safety	Safety risk to offshore project personnel	5.0%
		Safety risk to other users of the sea	5.0%
		Safety risk to onshore project personnel	5.0%
15%	Environmental	Environmental impacts of operations	3.8%
		Legacy environmental impacts	3.8%
		Gaseous emissions (CO_2)	3.8%
		Energy use (GJ)	3.8%
40%	Technical	Technical feasibility	40.0%
15%	Societal	Effects on commercial fisheries	5.0%
		Employment	5.0%
		Communities	5.0%
15%	Economic	Cost	15.0%

Societal Weighting Scenario

Total Weighting		Sub-criteria	Weighting
15%	Safety	Safety risk to offshore project personnel	5.0%
		Safety risk to other users of the sea	5.0%
		Safety risk to onshore project personnel	5.0%
15%	Environmental	Environmental impacts of operations	3.8%
		Legacy environmental impacts	3.8%
		Gaseous emissions (CO_2)	3.8%
		Energy use (GJ)	3.8%
15%	Technical	Technical feasibility	15.0%
40%	Societal	Effects on commercial fisheries	13.3%
		Employment	13.3%
		Communities	13.3%
15%	Economic	Cost	15.0%

Excluding Economic from the DECC Five Main Criteria Weighting Scenario

Total weighting		Sub-criteria	Weighting
20%	Safety	Safety risk to offshore project personnel	6.7%
		Safety risk to other users of the sea	6.7%
		Safety risk to onshore project personnel	6.7%
20%	Environmental	Environmental impacts of operations	5.0%
		Legacy environmental impacts	5.0%
		Gaseous emissions (CO2)	5.0%
		Energy use (GJ)	5.0%
20%	Technical	Technical feasibility	20.0%
20%	Societal	Effects on commercial fisheries	6.7%
		Employment	6.7%
		Communities	6.7%
20%	Economic (Note)	Cost	20%

Note: To eliminate 'cost' for this scenario, the criterion cost is still accorded a weight of 20% (to preserve the relative weights of the criteria and sub-criteria,) but all the options were accorded a score of 'nil'.

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