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1.0 Executive Summary

Twenty sites have been selected from 579 for further due diligence. Key features of the Select Inventory are:

- *Significant overall capacity target of 6.8GT.*
- *Strong balance between saline formations and depleted hydrocarbon fields with good geographic diversity.*
- *Strong compliance with IEAGHG screening guidelines and the Project BoD qualifications.*
- *Proximal sites to 5/42 and Goldeneye.*
- *Strong technical diversity of sites.*
- *Deselection of sites with high risk high confidence containment issues.*

This Energy Technologies Institute (ETI) Strategic UK CCS Storage Appraisal project has been commissioned on behalf of the Department of Energy and Climate Change. The project brings together existing storage appraisal initiatives, accelerates the development of strategically important storage capacity and leverages further investment in the building this capacity to meet UK needs.

The primary objective of the overall project is to down-select and materially progress the appraisal of five potential CO_2 storage sites on their path towards final investment decision (FID) readiness from an initial site inventory of over 500. The desired outcome is the delivery of a mature set of high quality CO_2 storage options for the developers of major power and industrial CCS project developers to access in the future. The work will add significantly to the de-risking of these stores and be transferable to storage developers to complete the more capital intensive parts of storage development.

This is the report for Work Package 3 (WP3) of the project. The objective of WP3 was to deliver a Select Inventory of 20 potential CO_2 Storage sites from an Initial Inventory of over 500 sites. In addition a Reserve Inventory of 5 sites was identified as a potential backup. The Initial Inventory was developed primarily from the CO2Stored database (Energy Technologies Institute, 2010). It was augmented with further hydrocarbon fields for which DECC hold production records (DECC - UK Government, 2015). Whilst there were over 207 oil and gas fields in the DECC list which were not in CO2Stored, these are almost entirely small satellite fields which had little potential CO_2 storage capacity to offer. Five fields of some significance were added to an Initial Inventory which totalled 579 sites. Any oil and gas fields with cessation of production dates estimated by Wood Mackenzie (Appendix 1) to be before 2031 and therefore potentially available were considered by this project. Whilst oil and gas fields were considered as CO_2 storage sites, their use for enhanced oil recovery (EOR) is outside the scope of this project. Fields with significant EOR potential as identified by recent studies (Element Energy Ltd, 2012) are considered likely to be “unavailable” to CO_2 storage developers.

The methodology used to extract 20 sites from the Initial Inventory was outlined in WP1 and was deployed here with only minor refinements after input from a Stakeholder meeting on 2nd July 2015 (Appendix 2). The methodology involved an initial qualification step to ensure that the site met both the requirements of the project screening basis of design (WP1) and also global best practice guidance where it exists. The qualification step delivered a “Qualification Inventory” which was then subjected to a ranking step to deliver the “Select Inventory” of 20 sites together with the Reserve Inventory of 5 backups.

Whilst the screening basis of design has several components of the kind of storage sites that are required to meet these study objectives, The Project qualification criteria were limited at this stage to a minimum theoretical capacity threshold of 50MT and a maximum distance to the nearest ETI Scenarios beachhead of 450km (Energy Technologies Institute, 2015).

The key document used for best practice guidance was DNV recommended Practice 203 (Det Norsk Veritas, 2012). This referred to the IEAGHG document on screening CO_2 Storage sites (IEA Greenhouse Gas R&D Programme, 2009) which itself was based largely on the work of Chadwick et al (Chadwick, et al., 2008).

The Project Requirements qualification had the overall effect of removing 68% of the Initial Inventory eliminating a large number of sites with low individual capacities. Site numbers reduced from 579 to 186; total theoretical capacity reduced from 78,142MT to 77,051MT.

- Removed 68% of Initial Inventory sites.
- Removed 1.4% of Initial Inventory capacity.

The IEAGHG Qualification step resulted in the removal of a large number of potential sites which did not meet the minimum cautionary key attribute metrics for a potential CO_2 storage site. Some of these sites carried large-to-very large capacities, but did not meet other key criteria.

- Site numbers reduced from 186 to 37; total theoretical capacity reduced from 77,051MT to 8,295MT.
- Removed 80% of project qualified sites.
- Removed 89% of project qualified capacity.

Neither of the storage sites being considered for UK CCS Phase 1 projects reached the qualification inventory. Goldeneye did not meet the capacity requirement being limited to significantly less than 50MT as currently specified. 5/42 could not be included simply because this project could only access 3D over a part of the full structure. Both sites also failed on “Availability” as they are both anticipated to be fully licensed to their operators and be unavailable to other storage developers. It should be highlighted that whilst these sites are considered to be strong CO_2 storage candidates for Phase 1 CCS projects, they do not meet the requirements of this project.

The qualification step delivered a Qualified Inventory of 37 potential sites. Both 5/42 and Goldeneye were added to this inventory to provide useful benchmarks in the screening process.

Ranking was performed using a Multiple Attribute Decision Making process called TOPSIS (Yoon & Hwang, 1995). Six attributes were selected from the CO2Stored database. These were either database values such as the P50 Theoretical Capacity, simple calculations such as injectivity (permeability x thickness) or quantification of qualitative assessments such as containment risk. The six attributes were:

- P50 Theoretical Capacity in MT
- Injectivity in mDm
- Engineered Containment Risk Factor in wells/km2
- Georisk Factor (dimensionless)
- Development Cost factor (dimensionless)
- Upside Potential (in MT)

The TOPSIS process required that these criteria be independent of one another and linearly distributed. Each attribute was weighted to capture the relative significance of each and sensitivities to this weighting from Stakeholder input were also used in the final selection. The process performed well and was verified against two simple ranking processes. There was agreement from all approaches on the "progress or drop" position of 75% of the Qualified Inventory. The destiny of the final 25% was finalised by expert judgement and Stakeholder input.

The recommended "Select Inventory" comprised 10 depleted hydrocarbon fields and 10 saline aquifers. 15 of the sites were discrete structural closures with 5 being in open formations. Sites are located throughout the geological column and include sites in the East Irish Sea, the Southern North Sea and the Central North Sea.

Code	Capacity MT	Unit Designation	Site Description	Nearest Beachhead
226.011	1691.0	Saline Aquifer	Bunter Closure 9	Barmston
372.000	1388.0	Saline Aquifer	Forties 5	St Fergus
248.005	776.0	Gas	South Morecambe gas field	Connah's Quay
227.007	409.0	Saline Aquifer	Bunter Closure 3	Barmston
266.001	243.0	Gas	Hewett gas field	Barmston
139.016	232.0	Saline Aquifer	Bunter Closure 36	Barmston
303.001	205.0	Gas	Hewett gas field (Bunter)	Barmston
248.004	175.0	Gas	North Morecambe gas field	Connah's Quay
336.000	175.0	Saline Aquifer	Grid Sandstone Member	St Fergus
361.000	174.0	Saline Aquifer	Mey 1	St Fergus
366.000	162.0	Saline Aquifer	Maureen 1	St Fergus
218.000	156.0	Saline Aquifer	Captain_013_17	St Fergus
133.001	211.0	Gas Condensate	Bruce Gas Condensate Field	St Fergus
248.002	120.0	Gas	Hamilton gas field	Connah's Quay
217.000	81.0	Saline Aquifer	Coracle_012_20	St Fergus
218.001	97.0	Oil & Gas	Captain Oil Field	St Fergus
139.020	84.0	Saline Aquifer	Bunter Closure 40	Barmston
141.035	271.0	Gas	Viking gas field	Barmston
141.002	120.0	Gas	Barque gas field	Barmston
252.001	76.0	Oil & Gas	Harding Central oil field	St Fergus

Table 1 - The Recommended Select Inventory

Had 5/42 reached the "Qualified Inventory" then it would have been ranked around 5th overall. Had Goldeneye reached the "Qualified Inventory" then it would have been ranked around 25 out of 37. This reflects the importance of capacity in the ranking process.

Key features of the Top Twenty Select Inventory are:

- Significant overall capacity target of 6.8GT.
- Strong balance between saline formations and depleted hydrocarbon fields.
- Deselection of sites with high risk high confidence containment issues.
- Strong compliance with IEAGHG screening guidelines and the Project BoD qualifications.
- A strong portfolio with a broad geographic spread:
    - SNS, CNS and EIS.
    - Proximal sites to 5/42 and Goldeneye.
    - Strong technical diversity of sites.

The results have been shared and tested with a broad group of Stakeholders at an event in London on 2nd July. The authors of the report appreciated the constructive engagement from all those involved.

2.0 Objectives

The primary objectives for this project are to identify and materially progress the appraisal of five high potential CO_2 Storage sites on their path towards FID readiness. The desired outcome is the delivery of a mature set of high quality CO_2 Storage options for the developers of major power and industrial CCS projects to access in the future. The work will add significantly to the de-risking of these five stores and will be available to storage developers as a basis for them to commission the more capital intensive parts of storage site appraisal.

The focus of this Work Package 3 (WP3) is to select a pool of twenty storage sites with five reserves on the UKCS from which the project requirements can be met. This "Many to Twenty" down-selection follows a screening process, based on both physical character and geographic location, designed to generate a portfolio of five sites with the greatest potential for safe, material and long term storage of CO_2. The workflow for selection complies appropriately with the requirements of the EU Directive 2009/31/EC (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,, 2009) on the Geological Storage of Carbon Dioxide and other key recommended practice guidelines such as DNV-RP-J203 Geological Storage of Carbon Dioxide. (Det Norsk Veritas, 2012) *and IEAGHG Recommended Practice* (IEA Greenhouse Gas R&D Programme, 2009).

Further details of the overall methodology and approach to this challenge are described in the WP1 report. Minor aspects of this approach have been modified following a detailed review of the site inventory available via the CO2Stored database and Stakeholder review but the general method remains the same. Methodology refinements are included in this report.

The scope of work for this WP3 has been divided into the following 4 tasks:

1. Procure screening data and build the Initial Inventory of potential storage sites.
2. Deliver a "Select Inventory" of twenty sites with five reserves.
3. Document the screening results and develop a presentation.
4. Present the results to Stakeholders and gain approval of the Select Inventory.

This report documents the process and results of this WP3 down select. The report is organised into a series of sections which mirror the work flow for this stage of the project as presented in WP1.

3.0 Methodology

Approach

A five step work flow for the WP3 "Many to Twenty" site selection was presented in WP1 and is shown here in Figure 1.

The planned approach generally fitted well to the data available at this stage and was retained in full. Some further refinements of the details of the methodology for qualification and ranking are described in Sections 5.0 and 6.0 of this report.

The “Screening Basis” is a common set of requirements against which all potential storage sites will be assessed. Specifically this defines the requirements to be fulfilled during the project screening in order to be able to

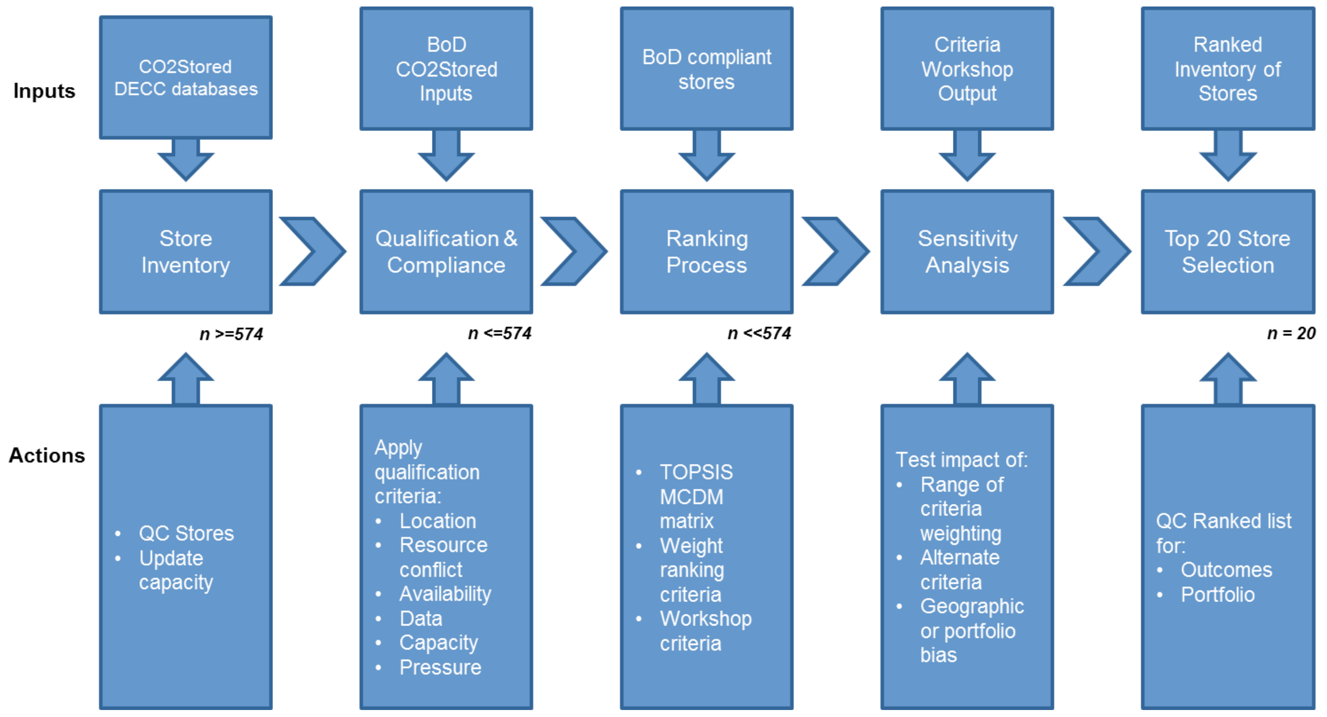

Figure 1 - Workflow for WP3

regard a storage site as both prospective and qualified for considered appraisal. Here, the two key elements of the "Screening Basis" are:-

1. Qualification and Compliance – Here the Initial Inventory was subject to two tests to check whether the site could meet basic project requirements outlined in a preliminary basis of design and then meet basic International Energy Agency Greenhouse Gas (IEAGHG) guidance for CO2 storage sites. The output of this was a "Qualified Inventory".
2. The second step involved ranking the "Qualified Inventory" against a series of attributes that reflected the interests of the project as a whole. The output from this was a "Select Inventory".

Finally – some key sensitivities were run to check the robustness of the proposed selection.

The approach applied in the work package is primarily based upon information held within the CO2Stored database, focusing on the technical attributes of each potential site (location, capacity, injectivity and containment), plus a "Development Cost Factor" and a view of proximal upside potential.

Prior to deploying the data in the CO2Stored dataset, the UKSAP report (Energy Technologies Institue, 2011) was reviewed to develop a good understanding of the database contents and methods used to derive both the capacity estimates and qualify other aspects such as risk factors. This was augmented by helpful discussions with the database authors at BGS. The available data files were downloaded as excel files and a 'master' excel dataset created. Using the guidance in the UKSAP report and Appendices, the capacity calculations were repeated to ensure the data could be matched.

Capacity Estimates

Several capacity estimates are present in the CO2Stored database. Following a review of the reports and data, and a brief discussion with the BGS, the P50 'theoretical capacity' values, available for both saline aquifers and hydrocarbon fields, were selected as these are the best representation of the site capacity, albeit still a value with high degree of uncertainty attached to it, especially with regard to the saline aquifers.

Limitations of Methodology

A number of limitations and issues exist with the proposed methodology. These were highlighted in the WP1 report and are primarily related to establishing the Initial Inventory. Whilst CO2Stored represents the most comprehensive and consistent data package available in the public domain, there are, a number of limitations with both saline aquifer and hydrocarbon field data:

- The database values are sometimes based on limited information - average values e.g. for porosity, permeability or depth, are in some cases derived from a small number of wells but applied to a very large rock volume.
- As with all subsurface analysis, most of the data inputs are not direct measurements but are estimates derived from other data or correlations which are then extrapolated as averages across the full volume of the site.
- Key inputs for calculating saline aquifer pore volume are based on data for which a 'low' measure of confidence is sometimes assigned.
- With so many sites to assess, it was not feasible to use dynamic simulation models for each site to develop saline aquifer storage

efficiency factors (E). This also contributes significant uncertainty to the capacity estimates, although the use of dynamic model exemplars in UKSAP on some sites has helped to calibrate this.

- Capacity estimates for the hydrocarbon fields are based on the net volume of fluids produced from the reservoir for each field using cumulative production data made available by DECC. UKSAP used production data up to end-2010 and so the capacity estimates only represents the pore volume available for CO_2 storage based on historical production to that date. Further capacity would result from a further 4 years production data (to 2015). The assessment here suggests that this is generally a minor contributor to uncertainty at this point.
- The uncertainty range applied to some of the inputs to the saline aquifer data in CO2Stored have been set at +/-10% across the dataset. This implies an unrealistic consistency of uncertainty levels. In oil and gas, +/- 10% often does not even capture direct measurement error for some attributes and so it is possible that the uncertainty in capacity estimates may have been under estimated. This raises some concerns about the reliability of the P90 (too big?) and P10 (too small?) theoretical capacity estimates which arise from the Monte Carlo analysis.

Data Sources

Bearing these limitations in mind, CO2Stored is the best place from which to start this screening process given:

- UKSAP and the CO2Stored database were designed to develop a standardised methodology for CO_2 storage capacity estimation.
- No other extensive, internally-consistent dataset exists.
- CO2Stored is subject to update and refinement and improvement through a separate project.

CO2Stored will primarily be used for this “Many to Twenty” work package. Subsequent WP4 and WP5 will collect and apply site specific data. The qualifying and ranking criteria used in this work package attempt both to recognise these complex uncertainty limitations within the database and to limit the use of data which carry greatest uncertainty or lowest confidence.

Finally, it was decided not to deploy economic assessments from CO2Nomica at this stage in the project. It was considered that simple metrics very close to the database should be used to provide clarity and direct linkage with screening decisions. Furthermore it was considered that the deployment of the sophisticated modelling of CO2Nomica may enhance confidence in site outcomes where such confidence is not merited by the UKSAP assessment at this time. CO2Nomica will be considered within WP4.

4.0 Inventory and Data Sources

The backbone of the Initial Inventory is the CO2Stored database and its 574 identified offshore storage units around the UKCS derived from the ETI-funded UK Storage Appraisal Project (UKSAP) (Table 2). CO2Stored provides the first comprehensive, auditable and defensible estimates of CO_2 storage capacity in the UK using standardised methodologies for both depleted hydrocarbon fields and saline aquifers. As such it provides a source of recent and internally consistent data for use in this project (subject to the limitations discussed in the previous section).

Site numbers	Unit Designation				
Storage Unit Type	**Saline Aquifer**	**Oil & Gas**	**Gas Condensate**	**Gas**	**Total**
Fully confined (closed box)	228	3	1	8	**240**
Open, with identified structural/stratigraphic confinement	20	0	0	0	**20**
Open, no identified structural/stratigraphic confinement	62	0	0	0	**62**
Structural/Stratigraphic confinement	50	85	15	101	**251**
Uncategorised	1	0	0	0	**1**
Total	**361**	**88**	**16**	**109**	**574**

Table 2 - Summary of sites in the CO2Stored database.

This project does not consider (nor did the parent UKSAP) any storage options in the area West of Shetland due to the large distance to both a suitable beachhead and a significant source of CO_2. The uncategorized unit represents a site encompassing the extent of the Triassic Bunter Sandstone Formation and is an empty data entry.

Data Sources

The data sources used for WP3 did not change from the initial plan. These are detailed in the WP2 report. This was supplemented by up to date cumulative production figures to February 2015 from DECC and also 2015 estimates of Cessation of Production dates from Wood Mackenzie (discussed in more detail below). The assumptions behind these estimates are included as Appendix 1 to this report. Additional sources of information include Element Energy's report 'Economic Impacts of CO_2-EOR for Scotland, Final Report' (Element Energy Ltd, 2012) which was used as the most up-to-date source of information on oilfields considered to have strong EOR potential.

Update to Store Inventory

A full review and update of the CO2Stored database is neither required or within the scope of this project. However not all UK registered hydrocarbon fields are explicitly identified as potential CO_2 Storage units within the UKSAP study (Table 3). It is also clear that where such sites are included in the database they are not always well populated with information.

The following approach has been taken to ensure that these omissions did not impact upon the workflow and results here:

1. There were 213 hydrocarbon fields noted in CO2Stored. These are reservoir specific sites such that where one field has oil and gas at several different geological formations and structures, each formation is designated as a separate site. An example is Hewett where there a single integrated facility but many different sites.
2. An inventory of hydrocarbon fields was supplied by DECC. These included all sanctioned hydrocarbon fields and introduced an additional 207 specific potential offshore sites for consideration. After careful review of these, five sites with the largest cumulative production were added to the Initial Inventory. These represented the largest capacity sites using the UKSAP methodology.
3. A further inventory of hydrocarbon fields was provided by Wood Mackenzie to this study. These contain a range of producing, commercial and technical field sites and introduced a further 65 specific commercial sites and a further 60 potential offshore sites for consideration from the Wood Mackenzie – pre commercial "Technical" category. Since there was no production data from any these sites their capacity cannot be estimated using the UKSAP method. An inspection suggests that these are small satellite development projects and not significant here. No further consideration has been given to these at this time.

Hydrocarbon Field Inventory	Offshore
CO2Stored Database Hydrocarbon Sites	213
Additional Hydrocarbon Fields from DECC	207
Additional Commercial Fields from Wood Mackenzie	65
Additional Technical Fields from Wood Mackenzie	60
Total Hydrocarbon Field Inventory	545

Table 3 – Total Hydrocarbon Field Inventory

The vast majority of these additional potential sites represent small fields and reservoirs which have little CO_2 storage potential because of their size. However the following 12 fields are notable by their absence and have been considered as additions to the Initial Inventory (all but 5 were eliminated by the Qualification threshold metrics - Section 5.0).

Field	Reservoir Stratigraphy	Screening Result*
Alba	Tertiary	Include
Foinaven	Tertiary	Exclude - because of West of Shetland location
Schiehallion	Tertiary	Exclude - because of West of Shetland location
Elgin	Jurassic	Exclude - because of depth
Maureen	Palaeocene	Include
Mungo	Cretaceous	Exclude - because of complex chalk reservoir
Franklin	Jurassic	Exclude - because of depth
Bittern	Tertiary	Include
Braemar	Jurassic	Include
Gryphon	Tertiary	Include
Mariner	Tertiary	Exclude - because of 2055 Cessation of Production

Table 4 – Hydrocarbon fields considered for addition to Initial Inventory

Screening data for these potential sites including depth and area have been accessed from publically available papers such as the Millennium Volume. Where containment risk data was not available for hydrocarbon fields, the most frequently occurring risk assessments for hydrocarbon fields were used. In CO2Stored there are six important containment factors, each of which has been rated as low, medium or high risk with low, medium or high confidence. Three of these factors are seal related (Fracture pressure capacity, Seal chemical reactivity and Seal degradation) and three are fault related (Fault Density, Fault Throw and seal and Fault vertical extent). These were reviewed for oil and gas fields and the mode values assigned to fields where such data was missing. This was deemed appropriate at this stage since it is most unlikely that any hydrocarbon field would be eliminated on the grounds of containment risk at this early stage given the substantial containment demonstrated by their ability to trap and hold oil and gas over geological time.

The final Initial Inventory, therefore, contained the 574 possible storage units from CO2Stored together with the additional 5 hydrocarbon field sites making an Initial Inventory of 579. A full list is provided in Appendix 3.

Hydrocarbon Field Capacity Updates

Since the analysis for the UKSAP project was delivered in 2010, existing oil and gas fields have continued to produce. These values of cumulative production are important as the theoretical CO_2 storage capacity in CO2Stored is linked to the volumes of hydrocarbons produced. Whilst the production from small, new fields is not significant, continued additional production on the larger fields was checked to assess whether the capacity estimates required updating. This was approached as follows:

- Overall, oil fields that had produced over 100 mmstb of oil by the end of February 2015 had incremented recovered volumes by 5% since the end of 2010. Whilst this overall figure is insufficient to warrant a recalculation of CO_2 Storage capacities, there are individual fields where production growth has been much more significant. These include the Buzzard, Braemar and Captain fields.

- In gas fields that had produced over 200 bcf of gas by the end of February 2015, recovered volumes had incremented on average by 8% since the end of 2010. Again this overall figure is insufficient to warrant a recalculation of CO_2 storage capacities for all fields at this stage, there are individual fields where production growth has been much more significant. These include the Ketch, Saturn, Carrack and Sean fields.

After consideration of these factors and also the lowering of the qualification hurdle for capacity from 75MT to 50MT, it was concluded that a recalculation and refinement of capacity using the UKSAP process was no longer useful for this project as it would not change the fields under consideration.

5.0 Qualification

The Initial Inventory of potential sites stands at 579 (574 from CO2Stored together with an additional 5 hydrocarbon field sites). The initial qualification and compliance step seeks to ensure compliance with project needs and recommended screening practice whilst at the same time reducing the Initial Inventory to a more manageable size.

The final 'threshold' criteria were selected to meet two sets of requirements:

1. Project-specific qualification requirements which were selected to ensure compliance with both the project objectives and the Screening Basis of Design.
2. Established carbon storage screening protocols, in this case DNV-RP-J203 Screening Basis (Det Norsk Veritas, 2012); to ensure the screening and site selection processes are as rigorous as possible.

It should be noted that, to ensure that a strong population of sites survived the qualification step, the theoretical capacity threshold set by the Basis of Design for Screening was relaxed from 75MT to 50MT. This maintained a stronger inventory into the ranking process. It also helped to ensure that those sites or larger hydrocarbon fields which might have been eliminated through a marginal failure to meet a 75MT threshold with uncertain capacity estimates would not be eliminated too early in the process.

5.1 Qualification Criteria

Project Specific Qualification Criteria

The following Project-Specific qualification criteria are based upon the project objectives and Basis of Design (Table 5).

Qualification Criteria	Threshold	Description	Rationale	Data Source	Impact in the inventory
Distance to Beachhead	<450km	Sites must lie within 450km of one of the beachheads noted in the BoD.	This is a practical threshold to ensure Phase 2 sites do not cost escalate through the need for extended pipeline infrastructure.	Latitude / Longitude coordinates from CO2Stored. (Energy Technologies Institute, 2010)	14 sites failed this test, these are mostly located north of the Statfjord field in the Northern north sea.
Capacity	>50MT	The P50 estimate of Theoretical Capacity in CO2Stored must be at least 50MT.	The project is seeking to materially progress significant storage sites to meet Phase 2 and Phase 3 demand. These will require sites with capacities of at least 50MT and ideally over 100MT. Larger threshold values were considered (75MT), but higher values start to remove a very significant proportion of the total capacity inventory.	The P50 Theoretical capacity estimate in CO2Stored database. (Energy Technologies Institute, 2010)	387 sites failed this test. This represents over two thirds of the inventory and is the subject of further sensitivity analysis.
Reservoir Pressure	No Routine Pressure management through water production wells.	Phase 2 sites will not rely upon water production to create significant essential storage capacity. The sites need to be large and low cost.	The early requirement of pressure management wells to achieve basic capacity thresholds is considered to be a significant additional cost (potentially doubling the offshore development costs). Whilst it is envisaged that many sites will benefit from local pressure management to optimise the development, at this stage, water production from the start of injection to create essential voidage is not being considered.	Theoretical capacity estimates for Fully Confined units in CO2Stored database. (Energy Technologies Institute, 2010)	No sites were excluded by this criteria.
Store Type	All Unit Designations will be considered.	Saline aquifers, oil and gas fields, gas fields, gas condensate fields.	There was no exclusion of a site based simply upon its designation or storage type in order to try to preserve diversity within the Select Inventory.	Assigned 'Unit Designation' in CO2Stored database. (Energy Technologies Institute, 2010)	No sites were excluded by this criteria.

Qualification Criteria	Threshold	Description	Rationale	Data Source	Impact in the inventory
Reservoir Type	Complex dual porosity reservoir systems will not be considered.	Sites with good quality, primary pore systems will be considered.	A simplified play fairway consideration has indicated that there are several reservoir intervals whose complexity does not suggest them as ideal DECC 'Phase 2' sites. Examples include Chalk and Zechstein carbonate reservoirs and also fractured Devonian sandstones, both with complex dual porosity systems.	Geological description provided in CO2Stored database. (Energy Technologies Institute, 2010)	No sites were eliminated as a result of this criteria directly. Most complex reservoirs failing on many other criteria.

Table 5 - Project-Specific qualification criteria are based upon the project objectives and Basis of Design

Qualification Criteria from Recommended Guidelines

A second set of qualification criteria drawn from recommended guidelines and best practice was also used (Table 6).

These ensure that the Qualified Inventory only held sites which meet recognised minimum screening criteria (i.e. DNV RP 203 Screening Basis guidelines (Det Norsk Veritas, 2012)) in addition to the project requirements. The DNV RP-J203_2012-04 Recommended Practice cites the IEA GHG 2009 report (IEA Greenhouse Gas R&D Programme, 2009) with selection criteria recommended by (Chadwick, et al., 2008) for screening requirements for saline aquifers. It is recognised that many of these criteria are time dependent (e.g. availability, data availability) or are indications but not proof of unsuitability (e.g. fault throws) and therefore deselection knowing what we know today does not necessarily mean they will be deselected in the future.

Qualification Criteria	Threshold	Description	Rationale	Data Source	Impact on the Inventory
Availability	COP<2031 and no significant EOR potential. Not currently licensed for storage.	The site should have reasonable availability for use by a prospective developer in the 2015 to 2030 timeframe.	Some oilfields which have been identified by significant studies as having high potential for miscible CO_2-EOR projects were excluded on the basis that when CO_2 is flowing into the offshore area then they might reasonably be considered for CO_2 EOR by their license owners. As such they would be unavailable for CO_2 storage. Goldeneye and 5/42 are also assumed to be unavailable as it is assumed they will already be licensed. Finally some of the recent and larger hydrocarbon fields are forecast to continue operations past 2030 and these are considered unavailable for the purposes of this project.	Wood MacKenzie data (Appendix 1). Economic Impacts of CO_2-EOR for Scotland, Final Report (Element Energy Ltd, 2012)	14 sites failed this test, 9 through EOR potential, 3 through COP constraints and 2 through CO_2 Storage licensing.

Qualification Criteria	Threshold	Description	Rationale	Data Source	Impact on the Inventory
Data Availability	3D seismic plus >1 well	Must have good 3D seismic coverage and at least one well with good log data.	The authority is likely to require that 3D seismic data and geological information from drilling is available ahead of filing any storage development plan.	PGS dataset coverage. (PGS, 2015) Well count in CO2Stored. (Energy Technologies Institute, 2010)	25 sites failed this test because of lack of well data with a further 8 sites failed because of limited 3D seismic access by this project.
Centroid Depth	>800m and < 2500m	The saline aquifer formation centroid depth must be below 800m in depth and no more than 2500m in depth.	Positive indicators >1000m and <2500m, cautionary indicators <800m and >2500m - (Chadwick, et al., 2008). These limits are driven by CO_2 phase control at the shallow limit and reservoir quality degradation at the deeper limit.	CO2Stored database (centroid depth). (Energy Technologies Institute, 2010)	243 sites failed this test (42% of the initial inventory). 20 were less than 800m but 223 were between 2500m and 6000m. This criteria was not applied to oil & gas fields, 73 of which are below 2500m
Trans-national Migration Risk	High Risk elements	Sites given a 'High' risk which are located close (<1km) to median lines with a high trans-national migration risk are not considered further.	EU Directive 2009/31/EC on the Geological Storage of Carbon Dioxide. (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,, 2009) The Carbon Dioxide (Licensing etc.) Regulations 2010 (SI 2010/2221). (UK Government, 2010)	CO2Stored database. (Energy Technologies Institute, 2010) UKSAP Final Report Appendix A6.2. (Energy Technologies Institue, 2011)	91 sites failed this test being assessed as a high transnational migration risk in CO2Stored database.
Permeability	>50mD	The formations should have an average permeability in excess of 50mD.	Positive indicators >300mD, cautionary indicators <10-100mD - (Chadwick, et al., 2008)	CO2Stored database (saline aquifers). (Energy Technologies Institute, 2010) Published data (hydrocarbon fields). (DECC - UK Government, 2015)	188 sites failed this test (32% of the Initial Inventory). This was the subject of a further sensitivity study.

Qualification Criteria	Threshold	Description	Rationale	Data Source	Impact on the Inventory
Thickness	>20m	The formations should have an average net thickness in excess of 20m.	Positive indicators >50m, cautionary indicators <20m - (Chadwick, et al., 2008).	CO2Stored database (saline aquifers). (Energy Technologies Institute, 2010)	Only 9 sites failed to meet this test.
Porosity	>10%	The formations should have an average porosity in excess of 10%.	Positive indicators >20%, cautionary indicators <10% - (Chadwick, et al., 2008)	CO2Stored database (saline aquifers). (Energy Technologies Institute, 2010)	11 sites failed this test. They included tight Triassic and Devonian sandstones and some Permian limestones.
Salinity	>30,000mg/l	The formations should have a water salinity in excess of 30,000mg/l to avoid potable water sources.	Positive indicators >100,000mg/l, cautionary indicators < 30,000 mg/l - (Chadwick, et al., 2008)	CO2Stored database (saline aquifers). (Energy Technologies Institute, 2010)	31 sites failed this test and have fresher formation water than 30,000mg/l. These were all formations deeper than 2500m.
Geological Containment	High risk / High confidence containment risk elements.	A saline aquifer site with any containment element considered to be high risk and high confidence will not be considered further. Hydrocarbon fields are considered to meet this requirement.	Positive indicators: >100m thick unfaulted caprock, Cautionary indicators: lateral caprock variability with overburden faulting and thin seal formations <20m.	UKSAP (Energy Technologies Institue, 2011)& CO2Stored 'Security of Storage' analysis of saline aquifers. (Energy Technologies Institute, 2010)	147 sites failed this test on at least one of six containment factors. This represents 25% of the initial inventory.31 sites failed on 2 or more factors.

Table 6 - Qualification criteria drawn from recommended guidelines and best practice

	Positive Indicators	Cautionary Indicators
Storage Capacity		
Total storage capacity	Total capacity estimated to be much larger than the total amount produced form the CO_2 source.	Total capacity estimated to be similar to or less than the total amount produced from the CO_2 source.
Reservoir Properties		
Depth	Between 1000 and 2500 m	<800 m or >2500 m
Reservoir thickness	>50 m	<20 m
Porosity	>20%	<10%
Permeability	>300 mD	<10 – 100 mD
Salinity	>100,000 mg/l (ppm)	<30,000 mg/l (ppm)
Caprock Properties		
Lateral continuity	Unfaulted	Lateral variations, faulted
Thickness	>100 m	<20 m
Capillary entry pressure	Much greater than buoyancy force of maximum predicted height of CO_2 column.	Similar to the buoyancy force of maximum predicted height of CO_2 column.

Table 7 - Extract from IEAGHG guidelines for saline aquifer site selection (IEA Greenhouse Gas R&D Programme, 2009)

Availability

An initial check has been made to sites where there may be a conflicting use of the subsurface. These conflicts occur in three primary areas:-

1. Where a site is still in use for hydrocarbon extraction.
2. Where a site might have a reasonable chance of a positive response to CO_2 Enhanced Oil Recovery and therefore would not be available for simple CO_2 storage.
3. Where a site is likely to have already been licensed for CO_2 storage to a specific operator. Goldeneye and the whole of the 5/42 structure have been considered as not available in this regard.

Continued Hydrocarbon Extraction

For the purposes of this qualification step, Wood Mackenzie have provided for this project the results of an analysis of estimated Cessation of Production (COP) dates. Wood Mackenzie have taken a view of these dates based upon their understanding of the fields and the forward price forecast held in May 2015. More details of their forecast assumptions are included in Appendix 1.

At this stage it has been concluded that only hydrocarbon sites where the COP dates fall before 2031 will be considered as qualified. This threshold currently excludes the fields in Table 8.

Field	Type	Status	Estimated COP
MARINER	Oil	Commercial	2055
BENTLEY	Oil	Commercial	2051
BRESSAY	Oil	Commercial	2051
CLAIR	Oil	Commercial	2050
CAMBO	Oil	Technical	2043
LOCHNAGAR	Oil	Technical	2042
TORNADO	Gas	Technical	2040
KRAKEN	Oil	Commercial	2039
KRAKEN NORTH	Oil	Commercial	2039
ROSEBANK	Oil	Commercial	2039
BREAGH	Gas	Commercial	2037
CULZEAN	Gas	Commercial	2037
COURAGEOUS	Gas/condensate	Technical	2036
JACKDAW	Gas/condensate	Commercial	2036
LANCASTER	Oil	Technical	2036
LOYAL	Oil	Commercial	2035
SCHIEHALLION	Oil	Commercial	2035
ALLIGIN	Oil	Commercial	2035
J2	Oil	Technical	2035
PERTH	Oil	Commercial	2035
SUILVEN	Oil & Gas	Technical	2035
FRAM	Oil & Gas	Commercial	2034
JOCELYN	Oil & Gas	Technical	2034
ELGIN	Gas/condensate	Commercial	2033
FRANKLIN	Gas/condensate	Commercial	2033

Field	Type	Status	Estimated COP
APPLETON BETA	Oil	Technical	2033
CONQUERER	Gas	Technical	2033
GLENN (JURASSIC)	Oil	Technical	2033
KILDRUMMY	Oil	Technical	2033
SEAGULL	Oil	Technical	2033
SOLAN	Oil	Commercial	2033
WEST FRANKLIN	Gas/condensate	Commercial	2033
WHIRLWIND	Oil	Technical	2033
ARBROATH	Oil	Commercial	2032
ARKWRIGHT	Oil	Commercial	2032
MONTROSE	Oil	Commercial	2032
WOOD	Oil	Commercial	2032
CAYLEY	Gas	Commercial	2032
CRAWFORD	Oil	Technical	2032
MARCONI	Oil & Gas	Technical	2032
PEACH	Gas/condensate	Technical	2032
SHAW	Oil	Commercial	2032
TALBOT	Oil & Gas	Technical	2032
APPLETON	Oil & Gas	Technical	2031
CROSGAN	Gas	Technical	2031
FARADAY	Gas/condensate	Technical	2031
FULHAM	Gas	Technical	2031
PUFFIN	Gas/condensate	Technical	2031

Table 8 - List of Fields with COP dates beyond 2030 – Source Wood Mackenzie

CO_2-EOR Utilisation Potential

There have been many studies of the CO_2-EOR potential of the North Sea. Most recently these have included the "CO_2 storage and Enhanced Oil Recovery in the North Sea: Securing a low-carbon future for the UK" (SCCS July 2015) and also "Economic impacts of CO_2 Enhanced oil recovery for Scotland" (Element Energy Ltd, 2012). The latter reports on a specific range of named fields which are deemed to have significant EOR potential (Table 9). These sites were excluded from the qualified inventory on the basis that as soon as CO_2 becomes available offshore then these sites are likely to remain unavailable for simple CO_2 storage as EOR developments start. The Basis of Design excludes CO_2-EOR opportunities as primary storage candidates but includes them on a portfolio basis for upside potential. Their potential role in initiating a CCS industry as has happened in the onshore US is not considered here due to the complex challenges of financing and consenting two first of a kind projects at a major power plant and major oilfield at the same time.

Existing CO_2Storage Sites

It has been assumed for the purposes of the qualification step that both the proposed Goldeneye storage site and the proposed storage site at 5/42 will be developed by their current operators and will not be available for licensing by other third parties. Clearly both have upside capacity potential in excess of that required by the UK CCS commercialisation programme, but the future development of this additional potential will be for the owners of those storage licenses to progress. Both are therefore deemed unavailable at this stage.

Country	Field Name	Incremental oil recovered (mbbl)	Incremental CO_2 stored during EOR ($MTCO_2$)
UK	Alba	119	39
UK	Auk	53	11
UK	Beryl	232	82
UK	Brae	104	34
UK	Brent	502	154
UK	Buzzard	108	31
UK	Claymore	144	46
UK	Clyde	41	21
UK	Cormorant	157	45
UK	Dunlin	83	24
UK	Forties	420	80
UK	Fulmar	82	81
UK	Janice	129	87
UK	Miller	75	25
UK	Nelson	79	26
UK	Ninian	292	94
UK	Piper	140	20
UK	Scott	95	29
UK	Teal	82	55
UK	Thistle	82	22
UK/NO	Murchison	79	25
UK/NO	Statfjord	635	236

Table 9 - North Sea oilfields identified as having CO_2-EOR potential (Element Energy Ltd, 2012)

Data Availability

Appropriate data is an essential part of any appraisal programme. To this end it has been concluded that for qualification purposes, a site must have at least one well with data available and also good 3D seismic coverage available to the project. Of course a simple well count cannot fully describe the quality of the information available since one well with a good data acquisition programme purpose drilled for the task of appraising a CO_2 storage site will often have far more value than a site with several old wells which have drilled through the target storage reservoir on the way to a deeper hydrocarbon target with very little data acquisition focussed upon the potential storage interval. At this stage however a single well is required to qualify. Later on in WP4 the quality of the available data will be assessed.

Geological Containment

Whilst all the sites in the Initial Inventory possessed the basic attributes to be considered as a potential viable CO_2 storage site, the IEAGHG guidance rightly stresses the importance of containment risk in any selection process. Within the CO2Stored database, there are six geological containment attributes. Three are linked to the caprock system and three relate to the fault related structures in the caprock and overburden geology.

- Fracture Pressure Capacity
- Seal Chemical Reactivity
- Seal Degradation
- Fault Density
- Fault Throw and Fault Seal
- Fault Vertical Extent

The risk associated with each is estimated together with the confidence level for that estimation. For the purposes of qualification, if any of these factors were assessed as high risk of containment loss with a high confidence then the site was deselected. Altogether, 147 sites were deselected on the basis that available data showed potential weakness in at least one containment attribute (Table 10).

High Risk High Confidence Containment Risk	Number of Sites Deselected
1 out of 6 attributes	116
2 out of 6	21
3 out of 6	7
out of 6	3
Total	147

Table 10 - Containment Risk Failure Rate

Of these, the most frequently occurring high risk elements carrying a high degree of confidence are shown in (Table 11).

Containment Attribute	Number of Site Deslections
Fracture Pressure Capacity	88
Fault Density	67
Fault Vertical Extent	29
Seal Chemical Reactivity	27
Fault Throw and Fault Seal	25
Seal Degradation	0

Table 11 - Containment Attribute Failure Frequency

5.2 Recommended Practice

While the most important compliance process for CO_2 storage sites on the UKCS is with the EU Directive (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,, 2009) and UK Carbon Dioxide Regulations 2010 (UK Government, 2010), the project methodology also aims to comply with the broad set of recommended steps set out by Det Norske Veritas: Geological Storage of Carbon Dioxide: Recommended Practice (Det Norsk Veritas, 2012) which provides guidance on site selection and appraisal. At present, there is no regulatory requirement to comply with this Recommended Practice, however it represents both a useful reference and is close to being an accepted industry standard at this time. It is therefore considered useful to map the site selection work flows for this project onto RP-J203 to help ensure technical rigour and communicate the processes used.

The DNV Recommended Practice (RP) for geological storage sites (RP-J203) was developed to provide "a systemic approach to the selection, qualification and management…. of sites" (Det Norsk Veritas, 2012), specifying what DNV regard as the best industry practice. The RP (J203) is fairly broad-ranging however it contains one performance requirement and procedure pertinent to this work programme: the selection and qualification of geological storage sites for long-term storage of CO_2. Other RP requirements and procedures exist which, may be applied to later work programmes (WP4 and WP5) of this project.

The storage site screening process is rolled-up in the "Screening Basis", a "document that defines the requirements to be fulfilled during the project screening stage in order to be able to regard a storage site as prospective and thereby qualify for appraisal" (Det Norsk Veritas, 2012). This document is designed to be used at the key milestone, Site Selection, in the DNV life cycle for CO_2 geological storage. Table 12 summarises the RP-J203 Screening Basis requirements and context items and demonstrates how the screening and site appraisal methodologies for this project map to them.

DNV Screening Basis Requirement	Description	Rationale	UKSTORE Screening Basis Compliance
Quantitative requirement for minimum total **CAPACITY** (MT)			BoD: (minimum practical capacity >50MT) Project Requirements: portfolio leading to 1500MT capacity by 2030.
Quantitative requirement for minimum annual **INJECTION**(MT/annum)			BoD (3-15MT for a minimum of 15 years) Project Requirements: 50MT/yr by 2030 across five sites.
Positive indicators of long term **CONTAINMENT** (documented evidence)	Depth: CO_2 remains in dense phase condition (>300kg/m^3) under reservoir conditions.		Depth Qualification: threshold >800m and <2500m.
	Seal presence: presence of laterally-extensive seal above the injection zone.		UKSAP/CO2Stored qualification criteria for inclusion in the Initial Inventory.
	Well integrity: confidence that well integrity can be established and maintained.		High Well Density contributed to lower site ranking in WP3.
	Geological Faults.	Containment will not be jeopardized by natural tectonic activity	Georisk Qualification: high geological containment risk/high data confidence sites are excluded.
		Absence of existing fault-related flow paths penetrating storage complex.	Georisk Qualification: high geological containment risk/high data confidence sites are excluded.
Positive indicators of the potential to monitor and deploy risk treatment	Legal availability of the storage site over expected life cycle.		WP3-5 provide input for UK storage license and permit process.
	Physical accessibility to the storage site over expected life cycle.		Availability Qualification: CoP dates <= 2030.
Screening Basis Context	Location of source of CO_2.		BoD: Beachhead locations defined.
	Mass rates and composition of CO_2 steam(s) .		BoD: representative composition applied. ETI Scenarios used for mass flow rates.
	Expected rates of supply and lifetime of CO_2 sources.		BoD (3-15MT for a minimum of 15 years).

DNV Screening Basis Requirement	Description	Rationale	UKSTORE Screening Basis Compliance
	Natural environment interaction potential with storage complex or leakage.		
	Resource/activity conflict potential.		Availability Qualification criteria.
	Social and cultural context of storage site.		All sites are offshore.
	Legal and regulatory environment.		EU Directive 2009/31/EC. (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,, 2009) UK Carbon Dioxide Regulations (UK Government, 2010)
	Expectations of operator, regulators and stakeholders to screening process.		Project Design: stakeholder meetings and workshops. Project requirements: portfolio management & compliance with UK CCS 'development scenarios'. (Energy Technologies Institute, 2015)

Table 12 - RP-J203 Screening Basis - Mapping

RP-J203 also requires that the methodology and activities planned to achieve the Screening Basis are reported in a 'Screening Plan' ('to describe the scope of each screening step and the activities to be carried out'). Table 13 summarises the main requirements and maps the work packages in this project which will provide compliance.

DNV Screening Plan Requirement	UKSTORE Screening Plan Compliance
Data to be used for screening	WP2
How data will be obtained	WP2 / WP5
Application of data to identify potential storage sites	WP1 / WP3 / WP4 / WP5
Calculation of storage capacity methodology	WP3: CO2Stored database (UKSAP project results)
Identification and risk assessment of existing wells	WP3 (CO2Stored database) / WP4 / WP5
Identification and risk assessment of potential leakage risks	WP3 (CO2Stored high level screening) / WP5
Identification of resource/usage conflicts	WP3
Evaluation of source-site location	WP3
Identification of stakeholders for inclusion in project	N/A
Communication strategy and rationale with stakeholders	N/A
Assessment of legal and physical accessibility to storage sites	WP3 (CoP dates);

Table 13 - RP-J203 Requirements and applicable Work Packages

5.3 Results

Figure 2 summarises the results of the Qualification Screening process. From the starting Initial Inventory of 579 sites, a Qualified Inventory of 37 sites has been developed. This "Qualified Inventory" passes all of the threshold metrics for both the project Basis of Design and the established recommended guidelines for carbon storage.

Figure 3 summarises the effect of the same qualification process but on the total theoretical capacity of the inventory. Note that some deselection criteria are temporal and others based on indicative rather than conclusive properties, and so deselection now does not mean deselection in the future.

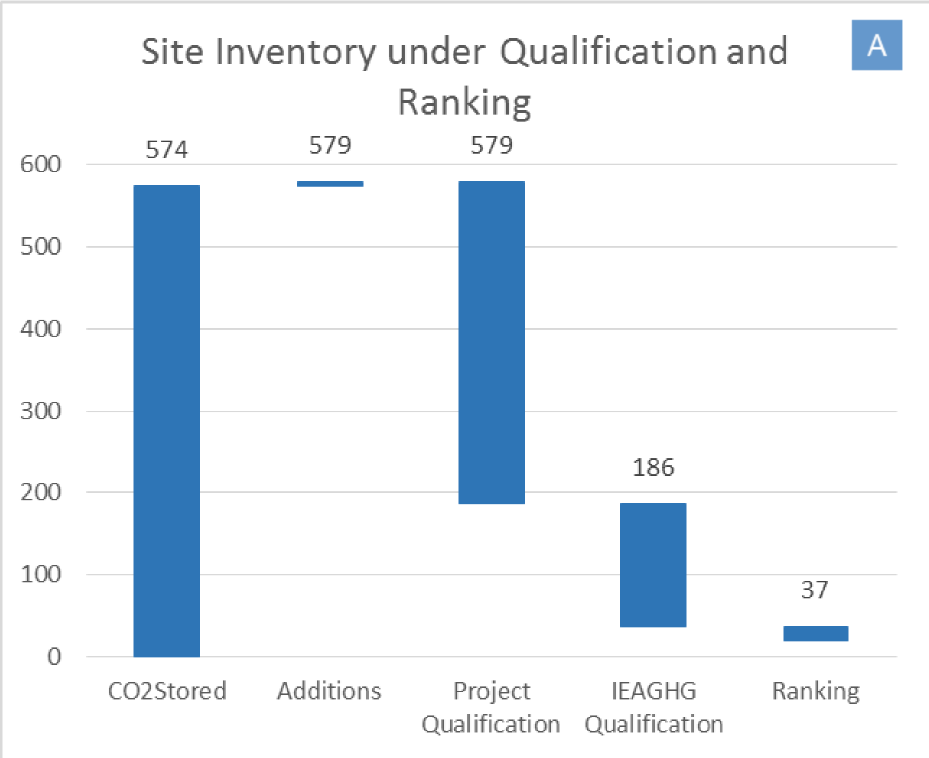

Figure 2 – Impact of Qualification on Site Numbers.

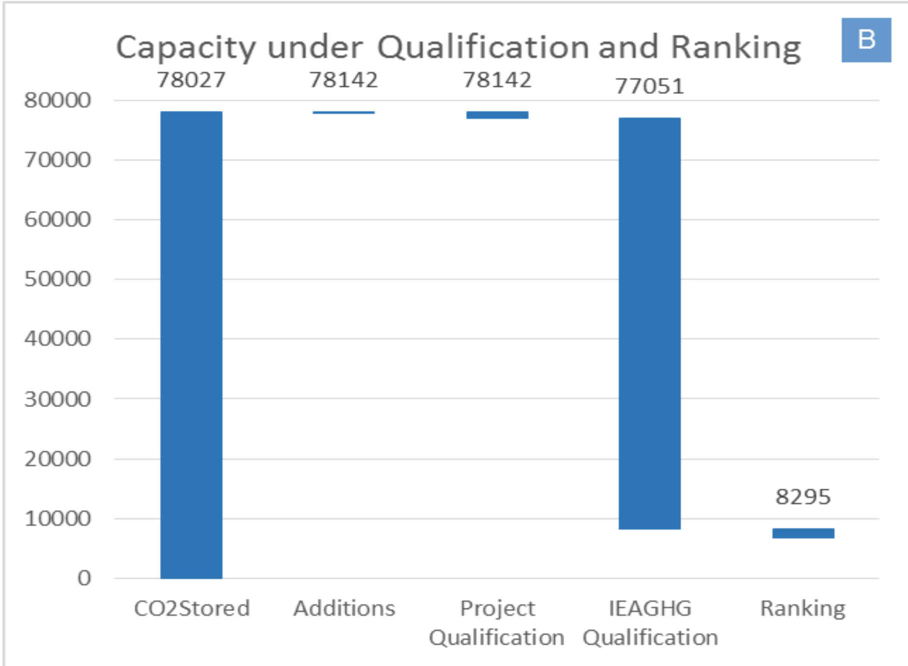

Figure 3 - Impact of Qualification on Theoretical Capacity.

In summary, the Project Requirement qualification step and the IEAGHG Qualification step combined to reduce an Initial Inventory of 579 sites down to 37. Each had a different impact:-

The Project Requirements qualification had the overall effect of removing 68% of the Initial Inventory eliminating a large number of sites with low individual capacities. Some of these sites, such as Goldeneye, are excellent storage locations for small volumes, but they do not meet the requirements of this project.

- Site numbers reduced from 579 to 186; total theoretical capacity reduced from 78,142MT to 77,051MT.
- Removed 68% of Initial Inventory sites.
- Removed 1.4% of Initial Inventory capacity.
- Removed Sites had an average theoretical P50 capacity of 3MT.

The IEAGHG Qualification step resulted in the removal of a large number of potential sites which did not meet the minimum cautionary key attribute metrics for a potential CO_2 storage site. Some of these sites carried large to very large capacities, but failed other key tests.

- Site numbers reduced from 186 to 37; total theoretical capacity reduced from 77,051MT to 8,295MT.
- Removed 80% of project qualified sites.
- Removed89% of project qualified capacity.
- Removed Sites had an average theoretical P50 capacity of 461 MT.

Figure 4 illustrates the impact of each individual criteria on the Initial Inventory and the total theoretical capacity, colour coded by store unit type. The image on the left shows the cumulative effect of each qualification criteria on the number of sites remaining in the inventory at each screening step. The image on the right shows the impact of site removal on the total theoretical capacity of the remaining sites.

The Capacity threshold (50MT) has the most significant impact on the inventory size cutting 64% (373) of sites from the initial inventory. Saline aquifer site numbers are cut by over 55% but the relative number of hydrocarbon fields removed is significantly greater at over 80%. The impact on the total theoretical capacity of the remaining inventory is, however, almost insignificant at 1.4%. The removal of the large number of low capacity sites has a limited effect (Figure 5).

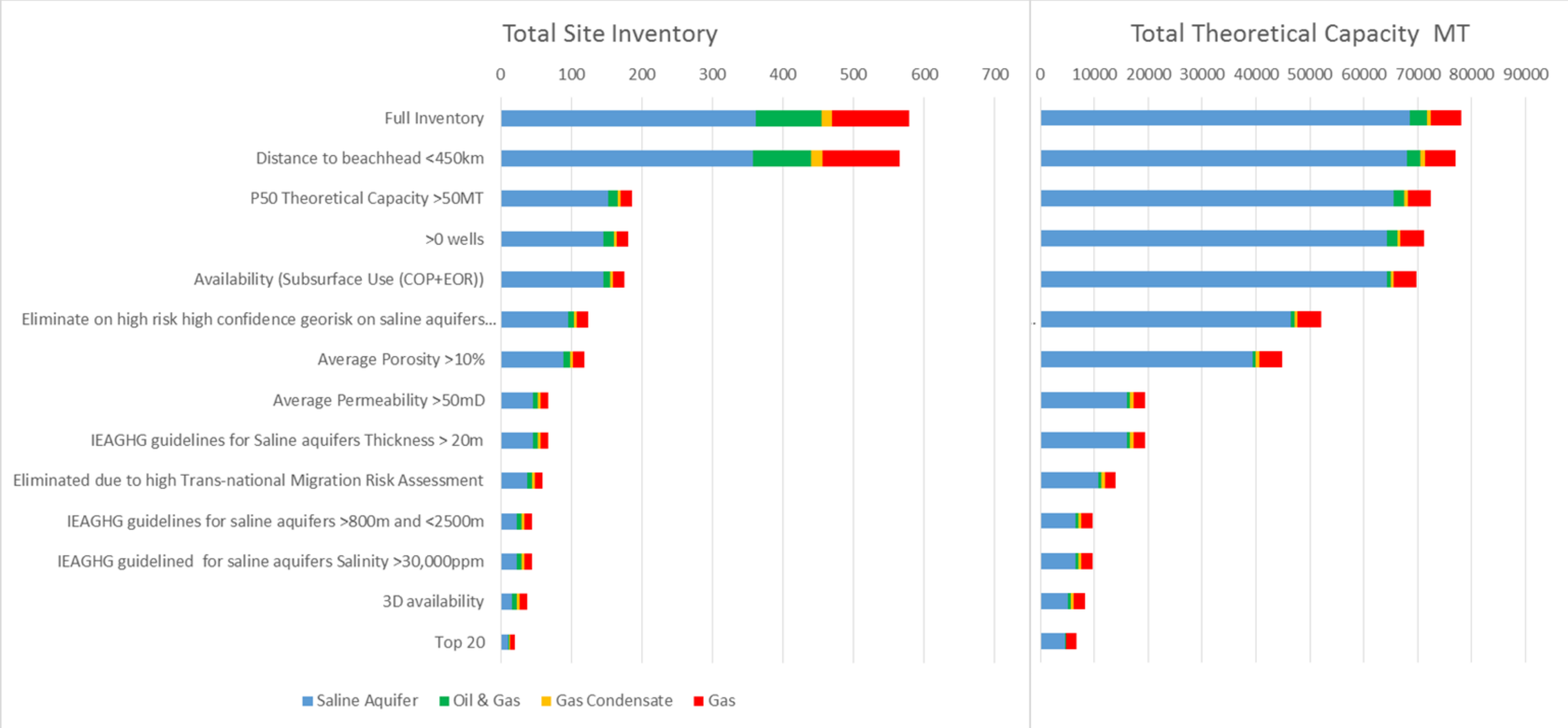

Figure 4 - Impact of individual qualification criteria on inventory number and total theoretical capacity, coded by store unit type.

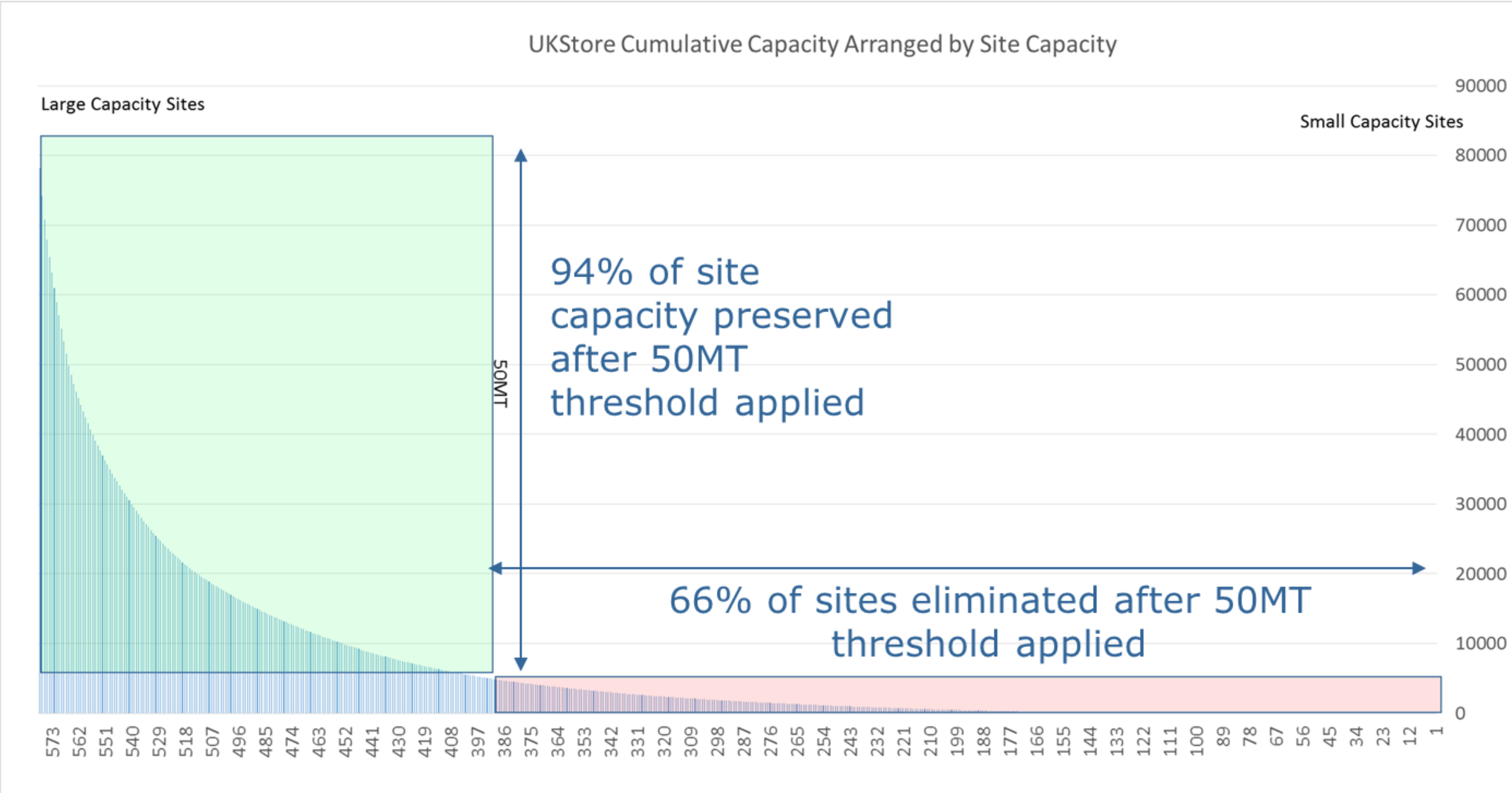

Figure 5 - Impact of the theoretical capacity (>50MT) qualification criteria on total capacity.

It is worth noting at this point that the P50 theoretical capacity estimate in CO2Stored does not equate to a true dynamic capacity of each site. As such, it is anticipated that the capacity values for each qualified site will change (most likely fall) as the site progresses further through evaluation and appraisal - experience indicates that capacity tends to decrease as knowledge increases. The 50MT threshold is very much a minimum cut-off value.

Figure 4 indicates that Georisk, or the geological risk to secure containment (as opposed to the engineered containment risk associated with existing and new-drill wells) was effective at cutting the saline aquifer site number by 51 which were considered to have both a high risk factor linked to secure, long term containment and high confidence in the data used to assign that risk. This was considered a key qualification criterion - there being little point in investing development money to investigate and derisk such stores when an abundance of less risky candidate stores are available.. Hydrocarbon sites were excluded from Georisk qualification at this stage and so show no impact to this cut.

The permeability cut-off (>50mD) was also selected to allow for the significant uncertainty associated with the values held within the CO2Stored database (Energy Technologies Institute, 2010) while also removing the 51 sites which are unlikely to support the required injection rate (as per the Basis of Design). The IEAGHG (2009) guidelines actually suggest >300mD is required for a site to have 'positive indicators' for carbon storage; a 10-100mD range is a cautionary indicator (IEA Greenhouse Gas R&D Programme, 2009). The selection of 50mD provides for the level of uncertainty associated with the permeability values reported. A sensitivity analysis suggests that of 118 sites remaining before the permeability cut off was applied just over 40% were lost with a 50mD threshold whilst only a further 10% were lost with a 100mD threshold (Figure 6). WP4 will begin to verify the permeability ranges where possible for each selected site.

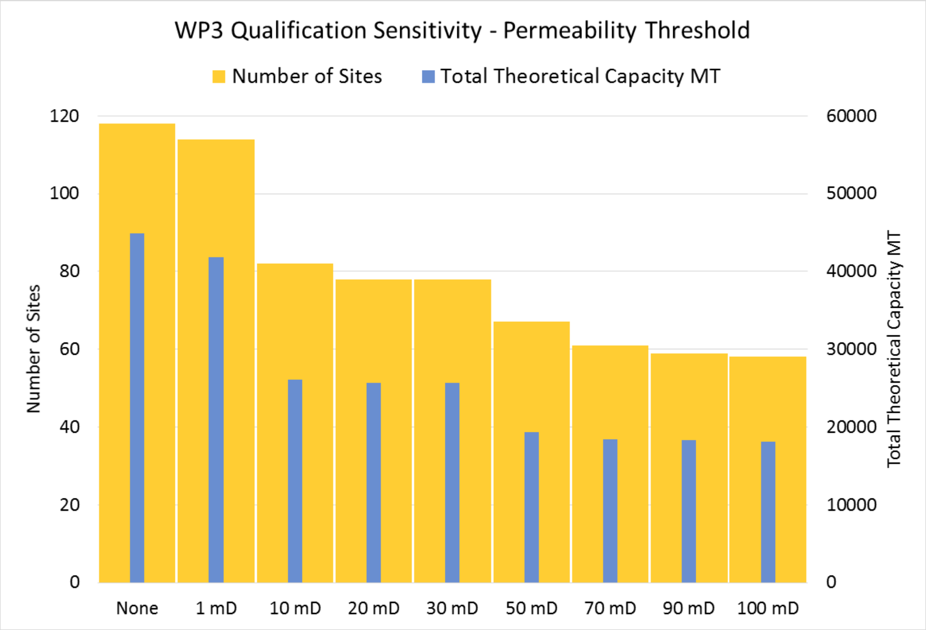

Figure 6 - Qualification Sensitivity to Permeability Threshold

The removal of the lower permeability sites also has a significant impact on the total inventory capacity, dropping from around 45000 MT by over 50% to 19350 MT. These losses arise from the elimination of 43 deep saline aquifers (average depth 2940m) and 6 large low permeability Leman Sandstone gas fields.

It is noted that permeability effects cost more than security, and cost is also correlated with other fundamentals (depth, water depth, distance from shore etc).

The Qualified Inventory

The final result of the Qualification screening process is a "Qualified Inventory" containing sites which carry the greatest potential for long term, secure storage and have good potential to meet the project objectives. The qualified inventory of 37 sites has a total theoretical capacity of 8295 MT held in a broad portfolio. Figure 14 illustrates the full Qualified Inventory plus two additional Benchmarking sites. Table 14 summarises the distribution of unit designations, store types and nearest Beachheads for the Qualified Inventory.

Unit Designation		Store Type		Nearest Beachhead	
Saline Aquifer	16	Structural / Stratigraphic Trap	27	Barmston	12
Gas Field	10	Fully Confined	4	St. Fergus	20
Oil & Gas Field	7	Open (no confinement)	4	Connah's Quay	4
Gas Condensate Field	4	Open (with confinement)	2	Redcar	
				Medway	1
Total	37	Total	37	Total	37

Table 14 – Qualified Inventory Characterisation

This Qualified Inventory was then progressed to the Ranking phase of this work programme to produce the final selection of the Top 20 sites to move into WP4 where each will be subject to detailed due diligence.

6.0 Ranking

Each of the sites in the Qualified Inventory now generally satisfies the requirements of both the project and also best practice guidance. The next step is to consider a ranking of these sites such that a "Select Inventory" of the 20 most favourable sites can be progressed to Work Package 4 ("Twenty to Five" site selection).

Ranking was carried out using 3 different techniques to ensure the best 20 sites were selected. Sensitivity analysis was also carried out using a set of different 'perspectives' to evaluate the impact on site ranking.

The ranking methodology was carried out as follows:

1. A set of 6 relatively independent factors or criteria important to a successful CO_2 storage site were chosen to evaluate each site. These included factors which described capacity, injectivity, containment (both georisk and engineering), development costs and upside potential.
2. The criteria for each site in the Qualified Inventory were then quantified from information held in CO2Stored database. These were either deployment of existing numeric values in the database (eg Capacity), simple calculation based upon numeric values in the database (eg Injectivity) or a quantification of a qualitative coding held in the database (eg Georisk).
3. A criteria weighting exercise was carried out by the project team members after input from a Stakeholder meeting.
4. The sites then underwent ranking using the TOPSIS methodology using the criteria weightings and a TOPSIS Score assigned to each site. These delivered a TOPSIS ranking of the Qualified Inventory.
5. A simple average rank for each site in the Qualified Inventory was also calculated across all criteria in order to validate and compare with the TOPSIS rank. This was completed assuming equal weighting for each criteria.
6. Step 5 was repeated but using the weightings assigned in step 3. An average weighted rank for each site was calculated across all criteria in order to further validate and compare with the TOPSIS rank.
7. The three ranking lists from steps 4, 5 and 6 were assembled and compared ahead of a development of a final single ranking which was performed manually.
8. In total, 4 scenarios were completed using different criteria weightings to assess their impact.
9. Results from each scenario were compared and a final "Select Inventory" of 20 sites was developed with input from Stakeholders. This Select Inventory was recommended to progress to WP4.

TOPSIS Analysis

TOPSIS, or Technique for Order Preference by Similarity to Ideal Solution (Yoon & Hwang, 1995) , was selected in WP1 as the tool to lead the site ranking process. The benefits of TOPSIS have been discussed in more detail in the WP1 report are summarised here:

- Multi-criteria decision-making analysis method.

- Alternatives (sites) are compared to pairs of positive (best of all worlds) and negative (worst of all worlds) ideal solutions hypothesised by decision maker.
- Ideal solutions derived from set of criteria, e.g. in a two criteria system, the highest capacity value and the highest injectivity value would together represent the positive ideal solution (even if these values came from different sites); the lowest capacity value and the lowest injectivity value would represent the negative ideal solution.
- The best alternative is the one with the shortest direct distance from the positive ideal solution and greatest distance from the negative ideal solution (Figure 7).
- Each alternative is assigned with a TOPSIS 'score' (the separation of the negative ideal solution divided by the sum of the separation from the positive and negative ideal solutions). This can then be used to rank every alternative in the inventory.
- Unlike the Qualification screening, TOPSIS is a compensatory process since sites are not cut out on the basis of a threshold value.
- Both qualitative and quantitative data can be handled. Qualitative data must be numerically coded in order to be used.

A key requirement of the TOPSIS method is that all criteria must be independent of each other and their data values must increase or decrease on a linear scale.

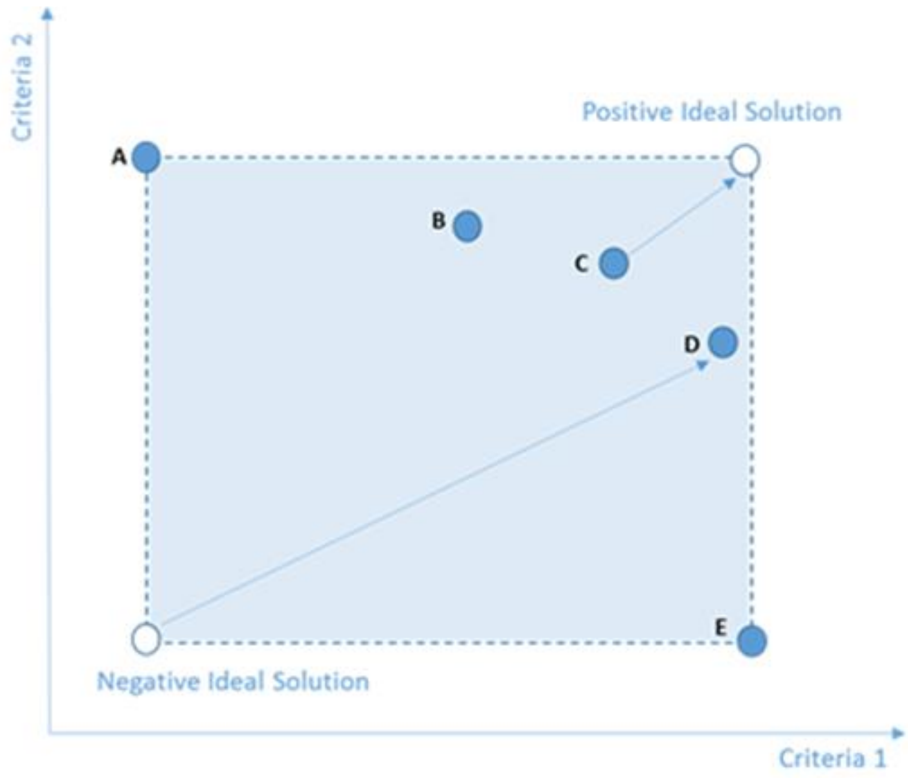

Figure 7 - Illustration of the TOPSIS method

6.1 Criteria

The six ranking criteria selected are described in Table 15 below. In a complex system such as a CO_2 storage site, it is very difficult to find totally independent parameters. For example, capacity and permeability are both related to porosity, injectivity is dependent upon permeability and even development cost is dependent upon depth which also controls pressure – a key element of capacity. As a result, each criterion has undergone careful consideration to ensure the set are relatively independent. This was tested later quantitatively through a correlation search.

	Ranking Criteria	Description	Data Source
1	**Theoretical capacity**	Database Value - P50 theoretical capacity in MT.	CO2Stored database. (Energy Technologies Institute, 2010)
2	**Injectivity**	Calculated Value - The product permeability and thickness mid case values as a proxy for injectivity index.	CO2Stored database. (Energy Technologies Institute, 2010)
3	**Containment: Engineered**	Calculated Value - The density of existing and legacy wells (number of wells/km^2).	CO2Stored database (area estimates and well count). (Energy Technologies Institute, 2010)
4	**Containment: Georisk**	Quantification Value - A quantification of the three caprock seal factors and three fault risk factors assigned to each site (Table 16).	CO2Stored database.
5	**Development Cost Factor**	Calculated Value – A proxy cost factor based on approximate pipeline and well cost for a standardised development of a store 5 wells based only on geographic location and reservoir depth. This approach is required to ensure that the cost factor is independent of all other factors (as required by TOPSIS) and in particular capacity and injectivity. In reality of course the development cost is dependent upon both capacity and injectivity as well as a range of other items. Estimating factors of £1.1m/ km of installed pipeline and £17m/km of well depth were used, these are derived from the Data Sources quoted. DCF(£m) = (distance to beachhead in km)*£1.1m/km + 5*(depth of well in metres)*£17m/km	CO2Stored site coordinates TVU report (pipeline). (Pale Blue Dot Energy Ltd, 2015) Aspen Conceptual Well Design Options (spd, 2012)
6	**Upside Potential**	Summation of all the P50 theoretical capacity estimates from the full Initial Inventory sites with centroid positions within 20 km radius of site in question.	CO2Stored database (full inventory minus specific site). (Energy Technologies Institute, 2010)

Table 15 - Ranking Criteria

While the majority of the criteria are quantitative, it was necessary to quantify a qualitative value for the Georisk Containment criteria. The information available in CO2Stored for containment is a consistent qualitative risk assessment ranked as high, medium or low. It was based on a methodology which had undergone a benchmarking process. Here these risk assessments were quantified by replacing the high, medium and low risks with scores of 3, 2 and 1 for each of the six containment factors and then summing these scores. The resulting Georisk factor ranges from a minimum of 6 to a maximum of 18 (Table 16).

	Seal Characterisation			Fault Characterisation			Georisk Factor
	Fracture pressure capacity	Seal chemical reactivity	Seal degradation	Fault Density	Throw and fault seal	Fault vertical extent	
Site A	low	high	medium	high	high	medium	14
Site B	low	low	low	low	low	low	6
Site C	medium	medium	medium	medium	medium	medium	12
Site D	high	high	high	high	high	high	18

low = 1 medium = 2 high = 3

Table 16 – Examples of Georisk Containment quantification.

Finally, to be confident that the criteria being used in the ranking process were independent of each other (a requirement of TOPSIS), a simple correlation search was completed. This was achieved by plotting the data for each of the 37 sites in the qualified inventory for each pair of criteria. Figure 8 shows a matrix of scatter plots each of which displays either poorly or completely uncorrelated clouds of points. This provides further confidence that the selected criteria are indeed largely independent of one another.

TOPSIS Ideal Solutions

The ideal positive and negative solutions for the TOPSIS analysis are shown in Table 17. For the ranking criteria selected, capacity, injectivity and upside potential are normal criteria while both containment criteria and the development cost factor are reverse criteria (lowest value is optimal).

Criteria	Criteria Label	Positive Ideal Solution	Negative Ideal Solution
1	Capacity	1691MT	50MT
2	Injectivity	1,286,651 mDm	2,743mDm
3	Containment (Engineered)	0.013 wells/km2	18.378 wells/km2
4	Containment (Georisk)	6 (dimensionless)	16 (dimensionless)
5	Development Cost Factor	116 (dimensionless)	751 (dimensionless)
6	Upside Potential	10016MT	421MT

Table 17 - Optimal positive and negative ideal solutions for each ranking criteria

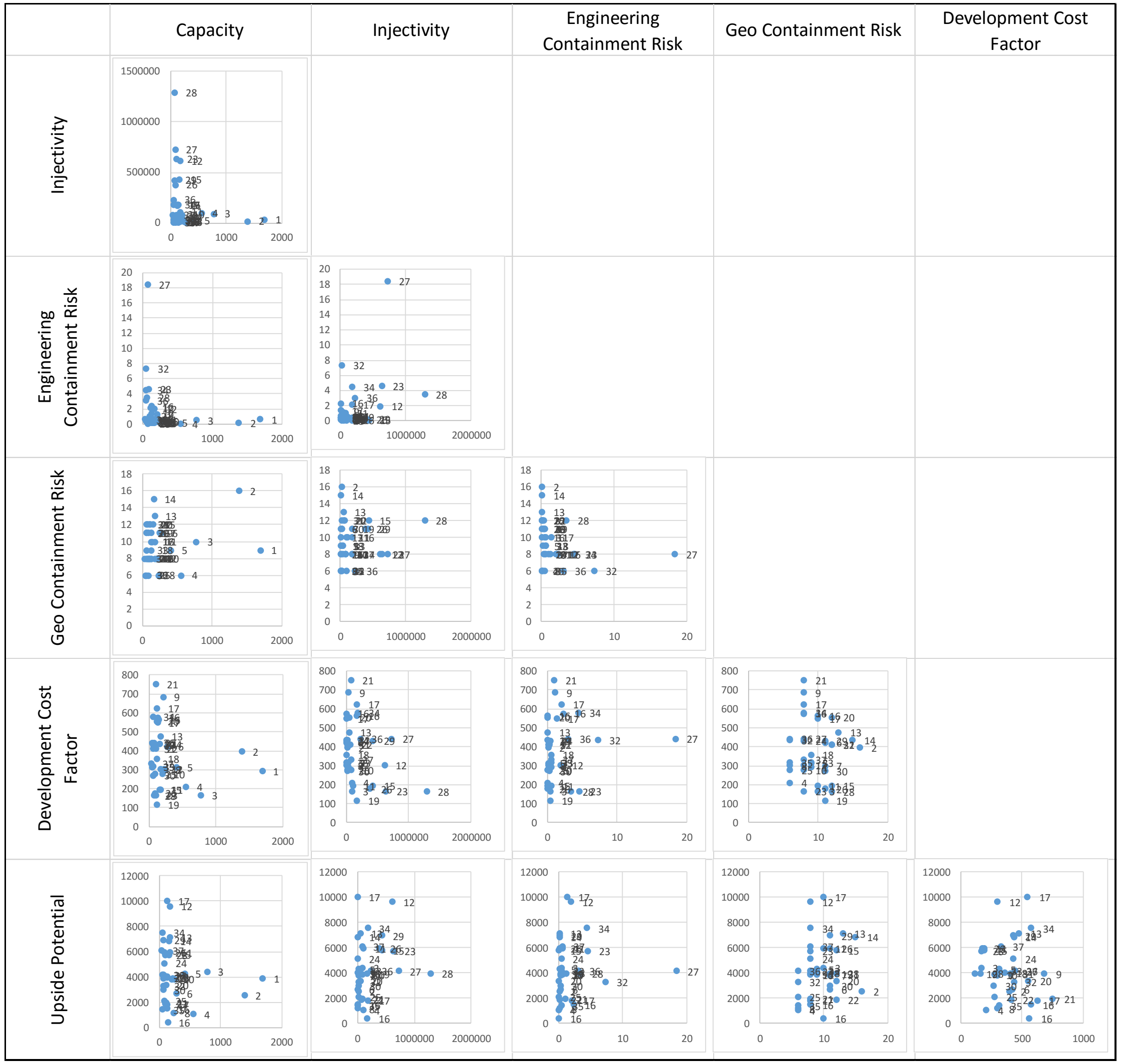

Figure 8 - Ranking Factor Independence Check

6.2 Criteria Weighting

Both the TOPSIS analytical process and the average ranking process allow each criteria to have a different weight or relative importance assigned to them. A base case set of criteria weights was developed using a pairwise consideration matrix. Here each criteria was compared to each other to consider their relative importance of each to the project objectives (safe, long term, economically-viable storage). The results are outlined in Figure 9. In the plot, Theoretical Capacity is considered to be moderately more important than injectivity with a score of 3 for example. A weight for each criterion was rolled up from the process with Georisk containment being the dominant criterion (46%) followed by theoretical capacity (21%). The input into the matrix was controlled by the project team using expert judgement and so is subjective in nature. The impact of the weightings on the site selections was tested further during the sensitivity analysis.

The Stakeholder Workshop on 2nd July 2015 included a session on criteria, weighting and ranking. The insights from the session were used to develop four alternative weighting scenarios. These were used to ensure robustness in the ranking process and are summarized below.

1. Rounded View – Uses all six criteria and initial weighting from a pairwise consideration matrix
2. Equal Weighting - Uses all six criteria with equal weighting
3. Container View – Uses the four subsurface characteristics (Capacity, Injectivity and 2x Containment) equally weighted
4. Simple View – Uses only capacity and development cost to focus on a “keep it simple” approach and taking advantage of all “qualified sites” having passed the IEAGHG site characterization guidelines (IEA Greenhouse Gas R&D Programme, 2009).

Pairwise comparison	Theoretical Capacity	Injectivity (Kh)	Containment (Engineered)	Containment (Georisk)	Development Cost Factor	Upside Potential	Weighting
Theoretical Capacity	1.00	3.00	5.00	0.20	3.00	3.00	21%
Injectivity (Kh)	0.33	1.00	3.00	0.20	1.00	3.00	11%
Containment (Engineered)	0.20	0.33	1.00	0.20	3.00	3.00	9%
Containment (Georisk)	5.00	5.00	5.00	1.00	5.00	5.00	46%
Development Cost Factor	0.33	1.00	0.33	0.20	1.00	3.00	8%
Upside Potential	0.33	0.33	0.33	0.20	0.33	1.00	4%

1	Equal Imortance	Options are equally important
3	Moderate importance	Experience and judgement slightly in favour of one Option over the other
5	Strong Importance	Experience and judgement strongly in favour of one Option over the other
7	Very Strong Importance	One Option is very strongly favoured over the other
9	Extreme Importance	One Option is favoured over the other to the highest order possible

Figure 9 - Development of Initial Ranking Criteria Weighting

6.3 Benchmarking

Following the ranking process, and feedback from stakeholders, it was concluded that it would be useful to benchmark the ranking using some of the well-known CO_2 storage targets in the UKCS which have been significantly invested in and matured through FEED programmes. The key benchmark sites for consideration included:-

1. 5/42 – Prospective Phase 1 storage site, a saline aquifer Triassic Bunter Formation structural trap in the Southern North Sea.
2. Goldeneye – Prospective Phase 1 storage site, a depleted Lower Cretaceous gas field in the Central North Sea.
3. Hewett – Prospective Demo1 FEED storage site, a depleted Bunter gas field in the Southern North Sea.

All of these sites were part of the Initial Inventory, however neither 5/42 nor Goldeneye were able to pass the qualification requirements for this project. 5/42 was eliminated because there was not enough 3D seismic coverage available to this project to consider it further. New 3D is available to the Operator over the whole structure, but access to this is commercially beyond the budget for this project. Goldeneye was eliminated because it did not meet the requirement to have a P50 theoretical capacity of at least 50MT. Furthermore it is assumed that both of these sites will be licensed long term to the respective CO_2 Storage operators and will therefore be unavailable to other prospective storage developers.

It is very important to stress that the absence of these two specific sites in the Qualified Inventory does not imply they are in any way technically unsuitable for CO_2 storage, but merely that they did not qualify under the metrics applied to this project.

The Hewett field is another potential storage site which has also undergone significant evaluation and early appraisal through projects which were partly publically funded. Hewett has made the Qualified Inventory by passing the threshold tests.

In addition to Hewett, both 5/42 and Goldeneye have been used as Benchmarks to provide useful reference points in the ranking process.

Stakeholder Input

Stakeholder input has been an important part of bringing the focus of a wide range of expertise from industry, policymakers and academic research together to help sense check and inform the process and outputs from the project to date. In the course of WP3 a workshop was completed around the detailed screening methodology and first pass results. A short workshop report is included as Appendix 2 to this report

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6.4 Results

The input data and the TOPSIS score for each site in the Qualified Inventory is illustrated in Figure 10. At this stage the site identity remains hidden to minimise any bias influence. Only three sites are identified. These are the benchmarks of 5/42, Goldeneye and Hewett. Of these only Hewett is actually a part of the Qualified Inventory. The sites are simply ordered by their P50 Theoretical Capacity. In the plot, the green bars denote normal criteria where larger numbers are favourable, and the red bars denote reverse criteria where smaller numbers are favourable.

The data set was then used to calculate a TOPSIS score with the base case criteria weights in place. This base case or Rounded View TOPSIS score is also shown in Figure 10. A key to the site number and identifiers is given at the end of the ranking and sensitivity analysis in Figure 14.

Two additional ranking methods were added as a result of Stakeholder feedback. These have been used to validate and sense check the TOPSIS approach. The first of these simply looked at the rank that each site achieved for each criteria (Capacity, Injectivity, Development Cost Factor etc) and then averaged this position. The second performed this same calculation again, but this time accounted for the relative weights assigned to each criteria. The results of these ranking methods are shown alongside the TOPSIS ranks in Figure 11. The ranks for all criteria & sites are colour-coded by whether they fall into the top 5 sites (green), the next 15 sites (white) or sites in the drop zone below position 20 to allow easy visual comparison of results.

Comparison of Results and Ranking Methods

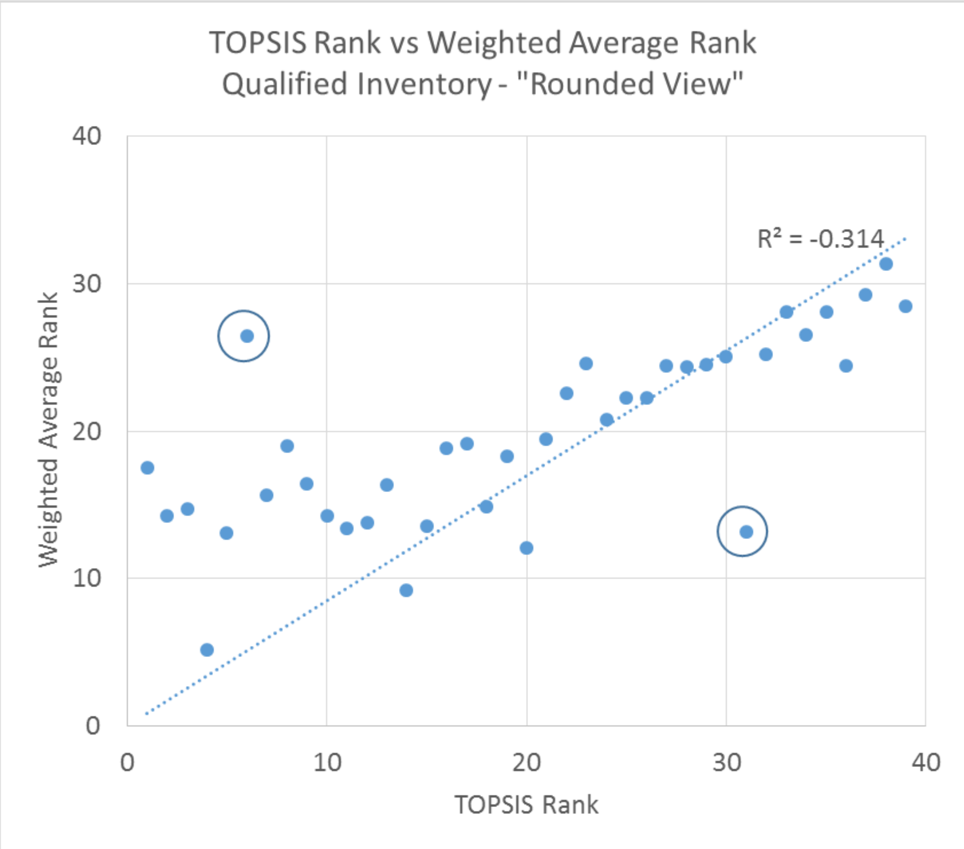
An initial review of the three ranking methods suggests strong agreement regarding the bulk of the Top 20 sites. At the site rank level, there is more variation, particularly amongst the Top 10 sites. The two plots shown in Figure 12 compare the TOPSIS site ranking with both the "Average Rank' and 'Weighted Average Rank'. As would be expected, the TOPSIS and Weighted Average Ranks (using the same criteria weighting values) are significantly better correlated. Two outliers are circled in Figure 12, representing sites 15 and 16. This highlights the importance of using expert judgement to ultimately decide whether to keep the site in the final selection or whether to place on-hold. Other than these outliers, the results provide confidence that TOPSIS performed well as a tool and the ranking process is both useful and comparable between methods and, as such, is ready for advancing to sensitivity analysis.

Basic Select Data	Capacity	Injectivity	Engineering Containment Risk	Geo Containment Risk	Development Cost Factor	Upside Potential	TOPSIS SCORE
Weight->	21	11	46	8	8	4	0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
Site 1	1691.0	33380.0	0.6	9.0	292.1	3898.0	1
Site 2	1388.0	19012.0	0.1	16.0	396.2	2534.0	2
Site 3	776.0	90753.0	0.4	10.0	167.1	4429.0	3
Bmk 5/42	554.0	98052.0	0.0	6.0	210.4	1057.0	4
Site 4	409.0	23926.0	0.2	9.0	313.7	4287.0	5
Site 5	271.0	8350.0	0.4	11.0	423.5	2711.0	6
Site 6 - Bmk Hewett	243.0	20500.0	0.3	11.0	299.5	3812.0	7
Site 7	232.0	11051.5	0.2	6.0	301.5	1179.0	8
Site 8	211.0	36540.0	1.2	8.0	685.2	3923.0	9
Site 9	205.0	82749.2	0.3	8.0	276.9	3856.0	10
Site 10	175.0	109728.0	0.6	10.0	193.8	5958.0	11
Site 11	175.0	612500.0	2.0	8.0	304.1	9624.1	12
Site 12	174.0	48906.0	0.1	13.0	476.6	7140.0	13
Site 13	162.0	10978.0	0.1	15.0	434.9	6868.0	14
Site 14	156.0	430010.0	0.1	12.0	194.8	5777.0	15
Site 15	137.0	177000.0	0.1	10.0	562.8	421.0	16
Site 16	130.0	4572.0	1.4	10.0	548.2	10016.1	17
Site 17	128.0	10500.0	2.3	8.0	576.0	1495.5	18
Site 18	122.0	178560.0	2.1	8.0	625.7	1825.5	19
Site 20	120.0	11430.0	0.6	9.0	359.4	4019.0	20
Site 19	120.0	175715.0	0.5	11.0	116.1	3946.0	21
Site 21	114.0	46288.0	0.1	12.0	555.4	3379.0	22
Site 22	104.0	81600.0	1.0	8.0	751.3	1947.0	23
Site 23	99.0	64860.0	0.2	12.0	412.1	1889.5	24
Site 24	97.0	630000.0	4.6	8.0	167.1	5746.0	25
Site 25	85.0	5720.0	0.4	8.0	432.7	5102.0	26
Site 26	84.0	22673.0	0.0	6.0	278.0	2127.0	27
Site 27	81.0	378585.0	0.1	11.0	177.5	5946.0	28
Site 28	76.0	723900.0	18.4	8.0	443.1	4139.6	29
Site 29	72.0	1286651.3	3.5	12.0	163.9	3982.0	30
Site 30	64.0	424080.0	0.2	11.0	432.0	6947.1	31
Site 31	63.0	19068.0	0.3	11.0	271.3	2978.0	32
Site 32	62.0	24888.4	0.3	12.0	410.9	3928.0	33
Site 33	60.0	27800.0	7.3	6.0	435.8	3285.5	34
Site 34	56.0	35476.0	0.5	9.0	317.5	4179.0	35
Site 35	53.0	182500.0	4.5	8.0	578.7	7543.0	36
Site 36	50.0	2743.0	0.4	6.0	315.7	1420.0	37
Site 37	50.0	228600.0	3.1	6.0	442.4	4165.6	38
Bmk GY	37.0	79000.0	0.6	8.0	331.4	6113.0	39

Figure 10 - Input to TOPSIS Score for Qualified Inventory

Site Rankings	Single Criteria Ranking Results						Multi Criteria Ranking Results			Recommendation for WP4
	Capacity	Injectivity	Engineering Containment Risk	Geo Containment Risk	Development Cost Factor	Upside Potential	*TOPSIS*	*Average Rank Excl TOPSIS*	*Weighted Average Rank Excl TOPSIS*	
Criteria Weightings - >	*21*	*11*	*46*	*8*	*8*	*4*				0 - Pass, 1 - Fail
Site 1	1	24	24	18	12	23	1	17	18	0
Site 2	2	31	9	39	21	30	2	22	14	0
Site 3	3	15	21	22	3	13	3	13	15	0
Bmk 5/42	4	14	1	1	8	38	4	11	5	1
Site 4	5	27	12	18	16	14	5	15	13	0
Site 5	6	36	18	26	24	29	8	23	19	0
Site 6 - Bmk Hewett	7	29	16	26	13	25	9	19	16	0
Site 7	8	33	13	1	14	37	10	18	14	0
Site 8	9	22	29	7	38	22	22	21	23	1
Site 9	10	16	16	7	10	24	12	14	14	0
Site 10	12	13	26	22	6	8	16	15	19	0
Site 11	12	4	31	7	15	2	21	12	19	0
Site 12	13	20	6	37	31	4	15	19	14	0
Site 13	14	34	7	38	27	6	7	21	16	0
Site 14	15	5	4	32	7	10	14	12	9	0
Site 15	16	11	5	22	34	39	31	21	13	1
Site 16	17	38	30	22	32	1	6	23	26	0
Site 17	18	35	33	7	35	35	33	27	28	1
Site 18	19	10	32	7	37	34	32	23	25	1
Site 20	21	32	27	18	20	18	23	23	25	0
Site 19	21	12	22	26	1	20	17	17	19	0
Site 21	22	21	3	32	33	26	18	23	15	1
Site 22	23	17	28	7	39	32	30	24	25	1
Site 23	24	19	11	32	23	33	19	24	18	1
Site 24	25	3	37	7	4	11	36	15	24	0
Site 25	26	37	20	7	26	12	26	21	22	1
Site 26	27	28	2	1	11	31	20	17	12	1
Site 27	28	7	8	26	5	9	11	14	13	0
Site 28	29	2	39	7	30	17	39	21	28	1
Site 29	30	1	35	32	2	19	34	20	27	0
Site 30	31	6	10	26	25	5	13	17	16	0
Site 31	32	30	14	26	9	28	24	23	21	1
Site 32	33	26	15	32	22	21	25	25	22	1
Site 33	34	25	38	1	28	27	38	26	31	1
Site 34	35	23	23	18	18	15	27	22	24	1
Site 35	36	9	36	7	36	3	37	21	29	1
Site 36	38	39	19	1	17	36	28	25	24	1
Site 37	38	8	34	1	29	16	35	21	28	1
Bmk GY	39	18	25	7	19	7	29	19	25	1

Figure 11 - Site Ranking Results for the "Rounded View" Case



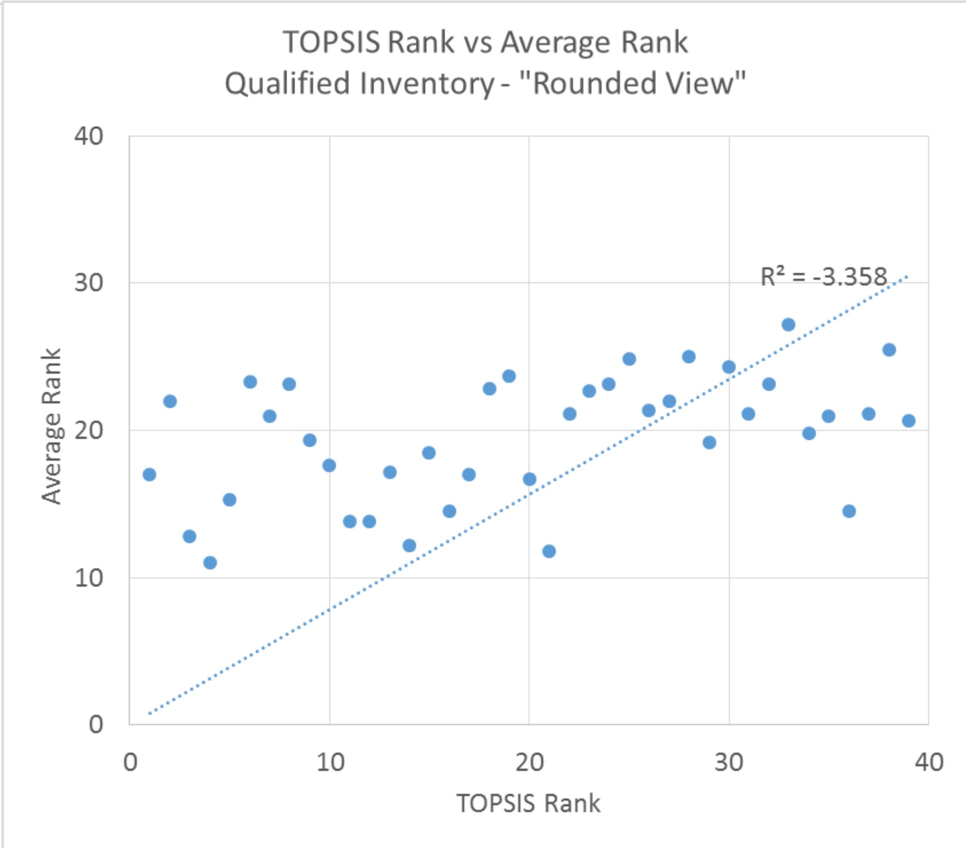


Figure 12 - Ranking Method Performance Check

Site Selection from Initial Results

A "Rounded View" base case of 20 top ranked sites was made using the results from each ranking method. Wherever there was agreement across all three ranking methods (TOPSIS, Average Rank, Weighted Average Rank) to "progress" (because the site was always in the top 20 of the Qualified Inventory) or to "drop" (because the site was always in the bottom 17 of the Qualified Inventory) then these were preserved. Sites were then either added or removed based upon their overall ranking performance. Figure 13 illustrates this process for the "Rounded View" base case. The right hand column carries the final result with a simple pass or fail (green or red).

From Figure 13, it is clear that had the Benchmark Site 5/42 reached the "Qualified Inventory", then it would have performed very well in this base case ranking process in positions ranging from fourth to eleventh from a total list of 39 sites (The Qualified Inventory of 37 sites plus two unqualified benchmarks). Benchmark Site 6 – the Hewett Sandstone in the depleted Hewett gas field also performed well in positions ranging from ninth to nineteenth. The Final Benchmark Site, Goldeneye performed poorly with a highest position of nineteenth and a lowest position of twenty ninth. This is due to the importance of capacity in the ranking and the fact that all other sites had a capacity significantly bigger than Goldeneye. Extension of Goldeneye to adjacent stores (or other combinations of stores) was not considered.

Across the process, the use of weighting criteria is important to balance each ranking criteria against the others.

Site Rankings	TOPSIS	Average Rank Excl TOPSIS	Weighted Average Rank Excl TOPSIS	Manual Drop Selection
				0 - Pass / 1- Fail
Site 1	1	17	18	0
Site 2	2	22	14	0
Site 3	3	13	15	0
Bmk 5/42	4	11	5	1
Site 4	5	15	13	0
Site 5	8	23	19	0
Bmk Site 6 - Hewett	9	19	16	0
Site 7	10	18	14	0
Site 8	22	21	23	1
Site 9	12	14	14	0
Site 10	16	15	19	0
Site 11	21	12	19	0
Site 12	15	19	14	0
Site 13	7	21	16	0
Site 14	14	12	9	0
Site 15	31	21	13	1
Site 16	6	23	26	0
Site 17	33	27	28	1
Site 18	32	23	25	1
Site 20	23	23	25	1
Site 19	17	17	19	0
Site 21	18	23	15	0
Site 22	30	24	25	1
Site 23	19	24	18	0
Site 24	36	15	24	1
Site 25	26	21	22	1
Site 26	20	17	12	0
Site 27	11	14	13	0
Site 28	39	21	28	1
Site 29	34	20	27	1
Site 30	13	17	16	0
Site 31	24	23	21	1
Site 32	25	25	22	1
Site 33	38	26	31	1
Site 34	27	22	24	1
Site 35	37	21	29	1
Site 36	28	25	24	1
Site 37	35	21	28	1
Bmk - Goldeneye	29	19	25	1

Figure 13 - Final Selection of Top 20 Sites - "Rounded View"

6.5 Sensitivities

A set of four scenarios was developed to test the robustness of the ranking process and evaluate the sensitivity of the site rankings to different criteria weightings:

1. **Rounded View (Base Case)** – This uses all six criteria and the initial weighting from a pairwise consideration matrix.
2. **Equal Weighting** - Uses all six criteria with equal weighting.
3. **Container View** – This puts the technical aspects of the store first and foremost and uses the four subsurface characteristics (Capacity, Injectivity and both Containment criteria) equally weighted.
4. **Simple View** – This focuses on capacity and unit cost by using only theoretical capacity, Development cost factor and the Upside Potential as a proxy for a "keep it simple" or 'large and low-cost' approach advocated by some stakeholders.

Results of Sensitivity Analysis

The results for these cases were developed in exactly the same way as described in the previous section. Figure 14 shows the results for each sensitivity case together with the recommended decision in the column on the far right for progression to WP4 of this project.

The analysis shows that there is full agreement to progress 14 top sites to the Select Inventory and also full agreement to drop a further 14 sites from further consideration at this time. Stakeholder review and input helped to resolve the position of the further six sites that would be progressed and the 5 sites that would not progress, but would be held on a reserve list.

Overall given the nature of the screening data available and the uncertainties present, the Simple View case gained most support from the Stakeholder Group. However specific questions and suggestions led to the following modifications in the final Selected Inventory:-

1. Site 8 (Bruce Field) was taken forward in place of Site 16 (Britannia Field). The rationale behind this was that whilst Britannia has significantly more potential upside and was closer to both St Fergus and Goldeneye, Bruce had a P50 Theoretical Capacity that was over 60% larger and a forecasted COP date several years before that of Britannia.
2. Site 29 (Lennox Field) was removed as the weakest qualified site in the East Irish Sea to improve the balance with the ETI Scenarios plan. It was replaced by the next strongest candidate in the Qualified Inventory which was Site 26, a Bunter saline aquifer closure in the Southern North Sea.
3. Site 28 (Harding Central Field) was promoted and displaced Site 30 into the reserve list. This was done despite the high well density on Site 28 because the Harding reservoir is known to contain injected sandstones which require a higher well density to characterise effectively and may have a significant Georisk issue which may not be perceived with poor well data coverage..

The outcome of the final Top 20 recommended selection is a portfolio of sites which pass all the qualification screening thresholds and represent the sites with the greatest potential for success with respect to the objectives of this project.

The ranking process has taken the Qualified Inventory of 37 sites to a Select Inventory of 20 sites: a reduction of 46% of the fully qualified sites. Total theoretical capacity has, however, decreased from 8,295 MT at the end of qualification (37 sites) to 6,765MT, a reduction of only 19%, reflecting the focus upon capacity and cost in the 'Simple View'. The average theoretical site capacity rose by over 50% from 224MT in the Qualified Inventory to 342MT in the Select Inventory. This remains in line with the overall project objectives.

Table 18 through Table 21 highlight the diversity of the Select Inventory. The target storage reservoirs are distributed from the Permian to the Paleogene, but interestingly include only one Jurassic reservoir. Many of the Jurassic reservoirs failed to qualify on the basis of small capacity levels and deep reservoirs often below 3000m. Further Northern Brent Province sites were excluded as they are beyond the 450km threshold set out in this project basis of design.

The Select Inventory has a 50:50 balance of saline aquifers and depleted hydrocarbon fields. Most of the hydrocarbon fields are gas fields in the Southern North Sea. Bruce is the gas condensate field with Captain and Harding Central representing the oilfields after those with significant CO_2 EOR potential have been removed.

70% of the Select Inventory comprises structural traps, with the remaining 30% representing large open aquifer systems with or without associated structural confinement. It is anticipated that the presence or absence of structural or stratigraphic potential on these may well be refined in WP4.

Finally, the Select Inventory provides a portfolio of sites that can service all the major emission centres and beachheads identified in the ETI scenarios plan (Energy Technologies Institute, 2015). With 3 sites in the East Irish Sea, 8 sites in the Southern North Sea and 9 in the Central North Sea. Whilst there are no sites in the Select Inventory for which Redcar on Teesside or Medway in the Thames area are the nearest landfall, both have sites within relatively short transport distance. Table 22 presents a view of the distance weighted Capacity in the Select Inventory for each of the key beachheads. This in effect describes the Theoretical Capacity in the Select Inventory divided by the Distance to the Beachhead. This highlights the very strong position of Barmston on the Yorkshire coast, Connah's Quay on the North Wales and Redcar on Teesside.

Top 20 sites by Geological Age	
1. Paleogene	5
3. Lower Cretaceous	3
5. Lower Jurassic	1
6. Triassic	9
7. Permian	2

Table 18 - Select Inventory Sites by Geological Age

Top 20 sites by Unit Designation	
Saline Aquifer	10
Gas	7
Oil & Gas	2
Gas Condensate	1

Table 19 - Select Inventory Sites by Unit Designation

Top 20 sites by Storage Type	
Structural/Stratigraphic Trap	14
Fully Confined (closed box)	0
Open, no identified structural/ stratigraphic confinement	4
Open, with identified trap	2

Table 20 - Select Inventory Sites by Storage Type

Top 20 sites by Beachhead	
Medway	0
Barmston	8
St Fergus	9
Connah's Quay	3
Redcar	0

Table 21 - Select Inventory Sites by Nearest Beachhead

Top 20 sites by Distance Weighted Capacity (MT/km)	
Medway	20.9
Barmston	29.5
St Fergus	23.6
Connah's Quay	28.5
Redcar	25.3

Table 22 - Beachhead Distribution of Distance Weighted Capacity in the Select Inventory

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													Top 20 Theoretical Capacity -	6749	6510	6645	6741	6765 MT
		Normal Criteria 1	Normal Criteria 2	Reversed Criteria 3	Reversed Criteria 4	Reversed Criteria 5	Normal Criteria 6							"Rounded View"	"Equal Weighting"	"Container View"	"Simple View"	"Final Recommendation"
Code	Site Number	Capacity MT	Injectivity mDm	Engineering Containment Risk per sq km	Geo Containment Risk	Development Cost Factor $M	Proximal Upside Potential MT	Unit Designation	Geological Age	Geological Formation	Storage Type	Site Description	Nearest Beachhead	Manual Drop Selection 1	Manual Drop Selection 2	Manual Drop Selection 3	Manual Drop Selection 4	Recommended Action
226.011	Site 1	1691.0	33380.0	0.6	9.0	292.1	3898.0	Saline Aquifer	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Bunter Closure 9	Barmston	0	0	0	0	Progress to WP4
372.000	Site 2	1388.0	19012.0	0.1	16.0	396.2	2534.0	Saline Aquifer	1. Paleogene	Sele Fm	Open, with identified structural/ stratigraphic confinement	Forties 5	St Fergus	0	0	0	0	Progress to WP4
248.005	Site 3	776.0	90753.0	0.4	10.0	167.1	4429.0	Gas	6. Triassic	Ormskirk Sandstone Fm	Structural/Stratigraphic Trap	South Morecambe gas field	Connah's Quay	0	0	0	0	Progress to WP4
227.007	Site 4	409.0	23926.0	0.2	9.0	313.7	4287.0	Saline Aquifer	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Bunter Closure 3	Barmston	0	0	0	0	Progress to WP4
266.001	Bmk Site 6 - Hewe	243.0	20500.0	0.3	11.0	299.5	3812.0	Gas	6. Triassic	Bunter Shale Fm	Structural/Stratigraphic Trap	Hewett gas field	Barmston	0	0	0	0	Progress to WP4
139.016	Site 7	232.0	11051.5	0.2	6.0	301.5	1179.0	Saline Aquifer	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Bunter Closure 36	Barmston	0	0	0	0	Progress to WP4
303.001	Site 9	205.0	82749.2	0.3	8.0	276.9	3856.0	Gas	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Hewett gas field (Bunter)	Barmston	0	0	0	0	Progress to WP4
248.004	Site 10	175.0	109728.0	0.6	10.0	193.8	5958.0	Gas	6. Triassic	Ormskirk Sandstone Fm	Structural/Stratigraphic Trap	North Morecambe gas field	Connah's Quay	0	0	0	0	Progress to WP4
336.000	Site 11	175.0	612500.0	2.0	8.0	304.1	9624.1	Saline Aquifer	1. Paleogene	Horda Fm	Open, no identified structural/ stratigraphic confinement	Grid Sandstone Member	St Fergus	0	0	0	0	Progress to WP4
361.000	Site 12	174.0	48906.0	0.1	13.0	476.6	7140.0	Saline Aquifer	1. Paleogene	Lista Fm	Open, no identified structural/ stratigraphic confinement	Mey 1	St Fergus	0	0	0	0	Progress to WP4
366.000	Site 13	162.0	10978.0	0.1	15.0	434.9	6868.0	Saline Aquifer	1. Paleogene	Maureen Fm	Open, no identified structural/ stratigraphic confinement	Maureen 1	St Fergus	0	0	0	0	Progress to WP4
218.000	Site 14	156.0	430010.0	0.1	12.0	194.8	5777.0	Saline Aquifer	3. Lower Cretaceous	Wick Sandstone Fm	Open, with identified structural/ stratigraphic confinement	Captain_013_17	St Fergus	0	0	0	0	Progress to WP4
133.001	Site 8	211.0	36540.0	1.2	8.0	685.2	3923.0	Gas Condensate	5. Lower Jurassic	Statfjord Fm	Structural/Stratigraphic Trap	Bruce Gas Condensate Field	St Fergus	1	1	0	1	Progress to WP5
248.002	Site 19	120.0	175715.0	0.5	11.0	116.1	3946.0	Gas	6. Triassic	Ormskirk Sandstone Fm	Structural/Stratigraphic Trap	Hamilton gas field	Connah's Quay	0	0	0	0	Progress to WP6
217.000	Site 27	81.0	378585.0	0.1	11.0	177.5	5946.0	Saline Aquifer	3. Lower Cretaceous	Wick Sandstone Fm	Open, no identified structural/ stratigraphic confinement	Coracle_012_20	St Fergus	0	0	0	0	Progress to WP4
218.001	Site 24	97.0	630000.0	4.6	8.0	167.1	5746.0	Oil & Gas	3. Lower Cretaceous	Wick Sandstone Fm	Structural/Stratigraphic Trap	Captain Oil Field	St Fergus	1	0	0	0	Progress to WP4
139.020	Site 26	84.0	22673.0	0.0	6.0	278.0	2127.0	Saline Aquifer	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Bunter Closure 40	Barmston	0	0	0	1	Progress to WP4
141.035	Site 5	271.0	8350.0	0.4	11.0	423.5	2711.0	Gas	7. Permian	Leman Sandstone Fm	Structural/Stratigraphic Trap	Viking gas fields	Barmston	0	1	1	0	Progress to WP4
141.002	Site 20	120.0	11430.0	0.6	9.0	359.4	4019.0	Gas	7. Permian	Leman Sandstone Fm	Structural/Stratigraphic Trap	Barque gas field	Barmston	1	1	1	0	Progress to WP4
252.001	Site 28	76.0	723900.0	18.4	8.0	443.1	4139.6	Oil & Gas	1. Paleogene	Balder Fm	Structural/Stratigraphic Trap	Harding Central oil field	St Fergus	1	0	1	1	Progress to WP4
248.007	Site 29	72.0	1286651.3	3.5	12.0	163.9	3982.0	Oil & Gas	6. Triassic	Ormskirk Sandstone Fm	Structural/Stratigraphic Trap	Lennox oil & gas field	Connah's Quay	1	0	0	0	Reserve List
220.001	Site 16	130.0	4572.0	1.4	10.0	548.2	10016.1	Gas Condensate	3. Lower Cretaceous	Britannia Sandstone Fm	Structural/Stratigraphic Trap	Britannia Condensate Field	St Fergus	0	0	0	0	Reserve List
252.000	Site 30	64.0	424080.0	0.2	11.0	432.0	6947.1	Saline Aquifer	1. Paleogene	Balder Fm	Fully Confined (closed box)	Balder Sandstone Member 1	St Fergus	0	0	0	0	Reserve List
244.000	Site 21	114.0	46288.0	0.1	12.0	555.4	3379.0	Saline Aquifer	1. Paleogene	Sele Fm	Fully Confined (closed box)	Teal Sandstone Member	St Fergus	0	1	1	1	Reserve List
241.000	Site 23	99.0	64860.0	0.2	12.0	412.1	1889.5	Saline Aquifer	1. Paleogene	Sele Fm	Fully Confined (closed box)	Flugga Sandstone Member	St Fergus	0	1	1	1	Reserve List
139.015	Bmk 5/42	554.0	98052.0	0.0	6.0	210.4	1057.0	Saline Aquifer	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Bunter Closure 35 (5/42)	Barmston	1	1	1	1	BENCHMARK ONLY
232.000	Site 15	137.0	177000.0	0.1	10.0	562.8	421.0	Saline Aquifer	1. Paleogene	Horda Fm	Fully Confined (closed box)	Frigg Sandstone Member	St Fergus	1	1	1	1	Hold
129.004	Site 17	128.0	10500.0	2.3	8.0	576.0	1495.5	Gas Condensate	4. Mid/Upper Jurassic	Brae Fm	Structural/Stratigraphic Trap	Brae North Condensate Field	St Fergus	1	1	1	1	Hold
129.003	Site 18	122.0	178560.0	2.1	8.0	625.7	1825.5	Gas Condensate	4. Mid/Upper Jurassic	Brae Fm	Structural/Stratigraphic Trap	Brae East Condensate Field	St Fergus	1	1	1	1	Hold
166.002	Site 22	104.0	81600.0	1.0	8.0	751.3	1947.0	Oil & Gas	4. Mid/Upper Jurassic	Tarbert Fm	Structural/Stratigraphic Trap	Alwyn North Oil Field	St Fergus	1	1	1	1	Hold
141.058	Site 25	85.0	5720.0	0.4	8.0	432.7	5102.0	Gas	7. Permian	Leman Sandstone Fm	Structural/Stratigraphic Trap	Victor gas field	Barmston	1	1	1	1	Hold
226.007	Site 31	63.0	19068.0	0.3	11.0	271.3	2978.0	Saline Aquifer	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Bunter Closure 24	Barmston	1	1	1	1	Hold
141.038	Site 32	62.0	24888.4	0.3	12.0	410.9	3928.0	Gas	7. Permian	Leman Sandstone Fm	Structural/Stratigraphic Trap	Audrey gas field	Barmston	1	1	1	1	Hold
365.001	Site 33	60.0	27800.0	7.3	6.0	435.8	3285.5	Oil & Gas	1. Paleogene	Lista Fm	Structural/Stratigraphic Trap	Andrew oil field	St Fergus	1	1	1	1	Hold
226.002	Site 34	56.0	35476.0	0.5	9.0	317.5	4179.0	Saline Aquifer	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Bunter Closure 18	Medway	1	1	1	1	Hold
82.002	Site 35	53.0	182500.0	4.5	8.0	578.7	7543.0	Oil & Gas	4. Mid/Upper Jurassic	Fulmar Fm	Structural/Stratigraphic Trap	Fulmar Oil Field	St Fergus	1	1	1	1	Hold
141.003	Site 36	50.0	2743.0	0.4	6.0	315.7	1420.0	Gas	7. Permian	Leman Sandstone Fm	Structural/Stratigraphic Trap	Amethyst East gas field	Barmston	1	1	1	1	Hold
252.002	Site 37	50.0	228600.0	3.1	6.0	442.4	4165.6	Oil & Gas	1. Paleogene	Balder Fm	Structural/Stratigraphic Trap	Harding South oil field	St Fergus	1	1	1	1	Hold
218.002	Bmk - Goldeneye	37.0	79000.0	0.6	8.0	331.4	6113.0	Gas Condensate	3. Lower Cretaceous	Wick Sandstone Fm	Structural/Stratigraphic Trap	Goldeneye Gas Condensate Field	St Fergus	1	1	1	1	BENCHMARK ONLY

Focus of WP3 Decision

Figure 14 - WP3 Down-select Recommendation

7.0 Conclusions

1. CO2Stored is an excellent basis for this study and represents a single consistent source of site storage attributes, albeit with challenging uncertainty issues. This project could not progress in the time and scope in the absence of the CO2Stored database.
2. The methodology outlined in WP1 has been successfully deployed with only minor refinements to achieve the WP3 objective.
3. The recommended Top 20 sites for progression to work package 4 ("Twenty to Five") represent a broad portfolio covering a strong diversity of unit type, store type and geography (beachhead); this is illustrated in Table 18 to Table 22.
4. The selection and screening process used here is fully compliant with DNV (Det Norsk Veritas, 2012) and IEAGHG (IEA Greenhouse Gas R&D Programme, 2009) recommended best practice.
5. The many to twenty down-select was based substantially upon the data in CO2Stored, augmented by information from Wood Mackenzie regarding estimated Cessation of Production for oil and gas fields and general publications such as the Millennium Volume (Gluyas & Hitchens, 2003). CO2Nomica (The ETI's storage costing tool) was not used at this stage of the project.
6. A large number of small hydrocarbon fields were missing from CO2Stored. Five additional sites were added to the Initial Inventory, but all were subsequently screened out on the basis of capacity.
7. The methodology has navigated issues of data uncertainty to minimise the risk of site exclusion because of data uncertainty.
8. Both the threshold for Theoretical Capacity and permeability were maintained at low levels to accommodate data uncertainty in these key factors.
9. The Identification of the sites was hidden from stakeholders until the end of the project to try to minimise any bias.
10. The 50MT capacity and 50mD permeability threshold were the most impactful criteria in the qualification process. 387 sites failing the capacity test and 188 sites failing the permeability test. Both are indicative of cost rather than security.
11. Neither Goldeneye nor 5/42 reached the Qualified Inventory. Goldeneye was smaller than the threshold and 5/42 lacked the required data availability test (the project did not have access to 3D seismic over most of the structure). Furthermore both sites fail on the availability criterion because they either are or expect to be licensed to Phase1 participants.
12. After careful consideration, it was concluded that updating the CO2Stored capacities for hydrocarbon field production between 2010 and 2015 could not be justified as only the very largest fields had enough capacity to meet the project qualification criteria, and many of these either had produced very little in the period or were younger fields and were unavailable until after 2030.
13. The Project Requirements qualification had the overall effect of removing 68% of the Initial Inventory eliminating a large number of sites with low individual capacities. Some of these sites, such as

Goldeneye are excellent storage locations for small volumes, but they do not meet the requirements of this project.

- Site numbers reduced from 579 to 186; total theoretical capacity reduced from 78,142MT to 77,051MT.
- Removed 68% of Initial Inventory sites.
- Removed1.4% of Initial Inventory capacity.
- Removed Sites had an average theoretical P50 capacity of 3MT.

14. The IEAGHG Qualification step resulted in the removal of a large number of potential sites which did not meet the minimum cautionary key attribute metrics for a potential CO_2 storage site. Some of these sites carried large to very large capacities, but failed other key tests.

- Site numbers reduced from 186 to 37; total theoretical capacity reduced from 77,051MT to 8,295MT.
- Removed 80% of project qualified sites.
- Removed89% of project qualified capacity.
- Removed Sites had an average theoretical P50 capacity of 461 MT.

Some of these tests are temporal or use indicative criteria, and so deselection now does not necessarily mean deselection in the future. In any case, 8MT exceeds the UKs likely needs for many decades.

15. IEAGHG cautionary screening thresholds alone removed 396 (68%) sites from the Initial Inventory and 87% of the P50 Theoretical capacity within the Initial Inventory. Some of these effects cost rather than security.
16. The TOPSIS method worked well in handling the multiple criteria for ranking. Meeting the independence requirements for the criteria was achievable with care, although the method was impacted by very high or very low value outliers.
17. The weighting of the criteria was important to create a balanced ranking.
18. The Stakeholder group expressed a preference for the “Simple View” ranking which focussed upon Capacity and Development Cost Factor (including Upside Potential).
19. Ranking sensitivities agreed on whether to maintain or drop sites across 76% of the Qualified Inventory (28 out of 37).
20. If 5/42 and Goldeneye had been qualified then 5/42 would have ranked around 5th out of 37 and Goldeneye would have ranked around 27th out of 37 (because of its small capacity).
21. There is a 50:50 balance of saline aquifers and depleted hydrocarbon fields in the recommended Select Inventory of twenty sites.
22. 70% of the recommended Select Inventory are structural traps.
23. Neither of Redcar or Medway are the closest landfall to any of the sites in the recommended Select Inventory, but both Redcar and Medway are serviced by the Select Inventory.

8.0 Recommendations

The following twenty sites are recommended for progression to WP4 and for further consideration:-

CO2stored Code	Site Number	Capacity MT	Injectivity mDm	Engineering Containment Risk per sq km	Geo Containment Risk	Development Cost Factor $M	Proximal Upside Potential MT	Unit Designation	Geological Age	Geological Formation	Storage Type	Site Description	Nearest Beachhead
226.011	Site 1	1691	33380	0.6	9	292	3898	Saline Aquifer	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Bunter Closure 9	Barmston
372.000	Site 2	1388	19012	0.1	16	396	2534	Saline Aquifer	1. Paleogene	Sele Fm	Open, with identified structural/ stratigraphic confinement	Forties 5	St Fergus
248.005	Site 3	776	90753	0.4	10	167	4429	Gas	6. Triassic	Ormskirk Sandstone Fm	Structural/Stratigraphic Trap	South Morecambe gas field	Connah's Quay
227.007	Site 4	409	23926	0.2	9	314	4287	Saline Aquifer	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Bunter Closure 3	Barmston
266.001	Site 6	243	20500	0.3	11	299	3812	Gas	6. Triassic	Bunter Shale Fm	Structural/Stratigraphic Trap	Hewett gas field	Barmston
139.016	Site 7	232	11052	0.2	6	302	1179	Saline Aquifer	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Bunter Closure 36	Barmston
303.001	Site 9	205	82749	0.3	8	277	3856	Gas	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Hewett gas field (Bunter)	Barmston
248.004	Site 10	175	109728	0.6	10	194	5958	Gas	6. Triassic	Ormskirk Sandstone Fm	Structural/Stratigraphic Trap	North Morecambe gas field	Connah's Quay
336.000	Site 11	175	612500	2.0	8	304	9624	Saline Aquifer	1. Paleogene	Horda Fm	Open, no identified structural/ stratigraphic confinement	Grid Sandstone Member	St Fergus

361.000	Site 12	174	48906	0.1	13	477	7140	Saline Aquifer	1. Paleogene	Lista Fm	Open, no identified structural/ stratigraphic confinement	Mey 1	St Fergus
366.000	Site 13	162	10978	0.1	15	435	6868	Saline Aquifer	1. Paleogene	Maureen Fm	Open, no identified structural/ stratigraphic confinement	Maureen 1	St Fergus
218.000	Site 14	156	430010	0.1	12	195	5777	Saline Aquifer	3. Lower Cretaceous	Wick Sandstone Fm	Open, with identified structural/ stratigraphic confinement	Captain_013_17	St Fergus
133.001	Site 8	211	36540	1.2	8	685	3923	Gas Condensate	5. Lower Jurassic	Statfjord Fm	Structural/Stratigraphic Trap	Bruce Gas Condensate Field	St Fergus
248.002	Site 19	120	175715	0.5	11	116	3946	Gas	6. Triassic	Ormskirk Sandstone Fm	Structural/Stratigraphic Trap	Hamilton gas field	Connah's Quay
217.000	Site 27	81	378585	0.1	11	177	5946	Saline Aquifer	3. Lower Cretaceous	Wick Sandstone Fm	Open, no identified structural/ stratigraphic confinement	Coracle_012_20	St Fergus
218.001	Site 24	97	630000	4.6	8	167	5746	Oil & Gas	3. Lower Cretaceous	Wick Sandstone Fm	Structural/Stratigraphic Trap	Captain Oil Field	St Fergus
139.020	Site 26	84	22673	0.0	6	278	2127	Saline Aquifer	6. Triassic	Bunter Sandstone Fm	Structural/Stratigraphic Trap	Bunter Closure 40	Barmston
141.035	Site 5	271	8350	0.4	11	423	2711	Gas	7. Permian	Leman Sandstone Fm	Structural/Stratigraphic Trap	Viking gas fields	Barmston
141.002	Site 20	120	11430	0.6	9	359	4019	Gas	7. Permian	Leman Sandstone Fm	Structural/Stratigraphic Trap	Barque gas field	Barmston
252.001	Site 28	76	723900	18.4	8	443	4140	Oil & Gas	1. Paleogene	Balder Fm	Structural/Stratigraphic Trap	Harding Central oil field	St Fergus

Table 23 - Select Inventory - Full Details

The following five sites are recommended as reserve list sites and will only be progressed if due diligence in WP4 fails one of the Select Inventory

Code	Site Number	Capacity MT	Injectivity mDm	Engineering Containment Risk per sq km	Geo Containment Risk	Development Cost Factor $M	Proximal Upside Potential MT	Unit Designation	Geological Age	Geological Formation	Storage Type	Site Description	Nearest Beachhead
248.007	Site 29	72	1286651	3.5	12	164	3982	Oil & Gas	6. Triassic	Ormskirk Sandstone Fm	Structural/Stratigraphic Trap	Lennox oil & gas field	Connah's Quay
220.001	Site 16	130	4572	1.4	10	548	10016	Gas Condensate	3. Lower Cretaceous	Britannia Sandstone Fm	Structural/Stratigraphic Trap	Britannia Condensate Field	St Fergus
252.000	Site 30	64	424080	0.2	11	432	6947	Saline Aquifer	1. Paleogene	Balder Fm	Fully Confined (closed box)	Balder Sandstone Member 1	St Fergus
244.000	Site 21	114	46288	0.1	12	555	3379	Saline Aquifer	1. Paleogene	Sele Fm	Fully Confined (closed box)	Teal Sandstone Member	St Fergus
241.000	Site 23	99	64860	0.2	12	412	1890	Saline Aquifer	1. Paleogene	Sele Fm	Fully Confined (closed box)	Flugga Sandstone Member	St Fergus

Table 24 - Reserve Inventory - Full Details

Key features of the Top Twenty are:

- Significant overall capacity target of 6.8GT.
- Strong balance between saline formations and depleted hydrocarbon fields.
- Elimination of sites with high risk high confidence containment issues.
- Strong compliance with IEAGHG screening guidelines.
- Compliance with Project BoD qualifications.
- A strong portfolio with a broad geographic spread:
  - SNS, CNS and EIS.
  - Proximal sites to 5/42 and 5/42
  - .
  - Strong technical diversity of sites.

Further recommendations drawn from this work include:-

1. The sites that do not meet IEAGHG cautionary thresholds should be clearly flagged within the CO2Stored database.
2. Careful consideration should be given regarding the merits of further investment into the CO2Stored database entries that do not meet IEAGHG cautionary criteria.
3. Any future consideration of the CO_2 storage resource potential of the UKCS should deploy a more rigorous handling of uncertainty to capture a more realistic range.
4. The staged approach used in the screening process worked well and allowed effort to be focussed on the sites that had some potential to meet the project objectives.
5. The TOPSIS ranking methodology was an effective and robust way of considering multiple attributes to help discriminate between sites. This was enhanced by considering two additional and simpler ranking methods. Care should be taken with data sets that contain outlier values as these tend to reduce the effectiveness of the technique.

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App. 1 Key Valuation Assumptions – Wood Mackenzie 2Q 2015

Last updated: May 2015

Methodology and Assumptions

Key valuation assumptions - 2Q 2015

Introduction

This document sets out our key valuation assumptions, including prices, inflation and exchange rates. It also explains the difference between Wood Mackenzie's valuation assumptions and forecasts and provides insight into how the valuation assumptions are derived each quarter.

Oil price assumptions

Wood Mackenzie uses Brent and West Texas Intermediate (WTI) as the benchmark blends for its oil price assumption. Brent is reviewed by a peer group within Wood Mackenzie on a quarterly basis to ascertain both a short-term view over the next three years and a long-term price assumption thereafter reflecting stable conditions. We assess prices for other crude blends in relation to Brent and then assign a percentage premium or discount.

Although the short-term view may fluctuate due to a number of macro-environmental factors (political, social, economic and technological), the long-term view should remain static over a prolonged period and should therefore not change markedly every quarter when our new price assumptions are released.

Wood Mackenzie Brent and West Texas Intermediate (WTI*) crude price assumptions (US$ per bbl)

Crude	2015	2016	2017	2018	2019
Crude	60.00	65.00	70.00	92.01	93.85
WTI*	55.00	60.00	65.00	85.51	86.81

Source: Wood Mackenzie

Prices are in nominal terms, escalated at 2.0% thereafter

** We assume a discount for WTI of 8.33% in 2015, 7.69% in 2016, 7.14% in 2017, 7.06% in 2018 and 7.5% from 2019 onwards*

Wood Mackenzie benchmark crude price assumptions (US$ per bbl)

Crude	2015	2016	2017	2018	2019
Arab Light (Brent -3%)	58.20	63.05	67.90	89.25	91.03
Bonny Light (Brent +2.1%)	61.26	66.36	71.47	93.94	95.82
Dubai (Brent -4%)	57.60	62.40	67.20	88.33	90.10
Isthmus (Brent -5.5%)	56.70	61.42	66.15	86.95	88.69
Saharan Blend (Brent +1%)	60.60	65.65	70.70	92.93	94.79
Tapis (Brent +6%)	64.38	69.45	74.44	97.53	99.48
Urals (Brent -1%)	59.40	64.35	69.30	91.09	92.91

Source: Wood Mackenzie

Prices are in nominal terms, escalated at 2.0% thereafter

The graph depicts the trend of the long-term Brent price assumption over the past four years presented in real 2014 terms.

Long-term Brent price assumption US$/bbl (2014 real terms)

Price scenarios

Wood Mackenzie models an additional two price scenarios. The scenarios are a high and low assumption based on a (+/-) US$20 per barrel sensitivity to the Wood Mackenzie benchmark crude oil price assumption.

High and low crude price assumptions (US$ per bbl)

Crude	2015	2016	2017	2018	2019
Brent - high	80.00	85.40	90.81	113.23	115.50
Brent - low	40.00	44.60	49.19	70.79	72.20
WTI* - high	73.34	78.83	84.32	105.24	106.84
WTI* - low	36.67	41.17	45.68	65.79	66.79

Source: Wood Mackenzie

Prices are in nominal terms, escalated at 2.0% thereafter

** We assume a discount for WTI of 8.33% in 2015, 7.69% in 2016, 7.14% in 2017, 7.06% in 2018 and 7.5% from 2019 onwards*

These price scenarios are used in our Global Economic Model (GEM), Upstream Data Tool, Corporate Analysis Tool, Corporate Benchmarking Tool and Exploration Tool.

Gas price assumptions

Netherlands

Our assumption for gas prices in the Netherlands varies according to the calorific value of the gas being produced. Our Dutch gas price assumption is based on the Dutch hub price, known as the Title Transfer Facility (TTF). This provides for the following nominal Netherlands gas prices.

Netherlands gas prices (US$ per mcf)

Gas	2015	2016	2017	2018	2019
Dutch gas	7.42	7.15	7.76	8.84	9.12

Source: Wood Mackenzie

Prices are in nominal terms, escalated at 2.0% thereafter.

Norway

Our price assumption for Norwegian gas assumes the gas to be of high calorific value (40.0 MJ/m3). This provides for the following nominal Norwegian gas prices.

Norwegian gas prices (US$ per mcf)

Gas	2015	2016	2017	2018	2019
Norwegian gas	8.02	7.47	7.98	8.96	9.18

Source: Wood Mackenzie

Prices are in nominal terms, escalated at 2.0% thereafter.

North America

Wood Mackenzie's nominal Henry Hub assumption is based on a link to the Brent oil price assumption.

North America uncontracted gas prices (US$ per mcf)

Gas	2015	2016	2017	2018	2019
Henry Hub - Base	3.09	3.40	3.71	4.46	4.55
Henry Hub - High	3.61	3.92	4.24	5.01	5.11
Henry Hub -Low	2.58	2.87	3.17	3.91	3.99

Source: Wood Mackenzie

Prices are in nominal terms, escalated at 2.0% thereafter.

UK

We assume that prices for UK uncontracted gas are based on supply and demand fundamentals.

UK uncontracted gas prices (US$ per mcf)

UK gas	7.56	7.26	7.87	8.96	9.18

Source: Wood Mackenzie

Prices are in nominal terms, escalated at 2.0% thereafter.

Inflation
Our inflation assumption is 2.0% from 2015 onwards.

Interest rates
Our interest rate assumption is 5.0% from 2015 onwards.

Discount rate and date
Our default central discount rate is 10% nominal and our discount date is 1 January 2015.

Exchange rate assumptions
Exchange rate assumptions (local currency unit per US$)

Country	Currency	2013	2014	2015	2016	2017 Onwards
Australia	dollar	1.04	1.11	1.20	1.19	1.21
Canada	dollar	1.03	1.10	1.20	1.15	1.10
China	renminbi	6.15	6.16	6.20	6.17	6.10
Denmark	krone	5.62	5.62	6.63	6.72	6.43
Eurozone	euro	0.75	0.75	0.92	0.90	0.86
India	rupee	58.59	61.04	61.93	61.00	60.50
Japan	yen	97.59	105.89	121.28	125.00	130.00
New Zealand	dollar	1.22	1.21	1.32	1.30	1.30
Norway	krone	5.86	6.31	7.36	7.16	6.88
Russia	rouble	31.86	38.59	64.50	55.00	40.00
Thailand	baht	30.73	32.49	33.31	34.00	34.50
Ukraine	hryvnya	8.16	12.02	16.02	18.00	20.00
UK	pound	0.64	0.61	0.66	0.66	0.65

Source: Wood Mackenzie

Specific valuation and other assumptions
Wood Mackenzie uses a number of specific economic assumptions and other assumptions in its economic analysis. These assumptions can be found in the Economic Assumptions sections of each research report we publish, because by their nature they are very specific to each asset or company we are valuing. For example, we take a variety of factors into account when valuing upstream assets and companies, including regional economic conditions, hydrocarbon quality and whether domestic and export prices are realised.

Assumptions versus forecasts
Wood Mackenzie's valuation assumptions capture an industry view based on opinions from the Wood Mackenzie client survey conducted every quarter.

Assumptions are used by Wood Mackenzie for valuation modelling and reflect the latest industry view on the price a buyer would pay to acquire an asset.

The aim is to distinguish between short-term cycle (years one to three) and long-term equilibrium trend (years four to 30) which incorporates a flat real long-term equilibrium price for valuation modelling.

A price assumption is therefore distinctly different to a price forecast which is based on internal supply-demand models and other determinants to derive a discrete outcome in every year in the future.

App. 2 Stakeholder Meeting Report – 2nd July 2015

A Stakeholder workshop (02) was held on 2nd July in London and hosted by Pinsent Masons. The objectives of this workshop were:-

- To keep CO2 Storage stakeholders appraised of project progress and enrol interest from the CCS stakeholder community
- Stimulate debate around the selected top twenty candidate sites & gather input to the process.

The materials assembled here represent a workshop report and were "work in progress" as of 2nd July.

Participants

Jeb Tyrie APEC Ltd
Ken Johnson Axis Well Technology
Stephen Cawley BP
Don Reid Capture Power
Brian Allison DECC
Graham Dawe DNV GL
Den Gammer ETI
Andrew Green ETI
Benjamin Court GCCSI
Bill Senior Ind
Nick Reeves National Grid
Eva Halland NPD
David Hartney OGA
Frances Harding Pale Blue Dot Energy
Alan James Pale Blue Dot Energy
Steve Murphy Pale Blue Dot Energy
Chris McGarvey Pinsent Masons

Agenda

09:30 Welcome & Safety Briefing SJM
09:35 Purpose of Workshop SJM
09:40 Strategic UK CCS Storage Appraisal Project SJM
09:55 Screening & Selection ATJ
10:15 Results ATJ
10:45 Break All
11:00 Workshop Session All
12:00 Feedback
12:20 Next Steps SJM
12:30 Close SJM

Output

The following comments arose after group review and discussion of the process adopted for down-select and also the preliminary results of the work:-

Group A

1. Suggestion to be clear that the "Development Cost Factor" is not a true cost but a high level proxy for cost at this point. Perhaps consider finding an alternative label for this.
2. Suggest swap sites 30 and 28 – although that would lose the only "fully confined box" in the top 20
3. Concern that the Upside potential has played too much of a role in the selection. Suggest testing selection without the inclusion of the upside potential
4. Also suggested another sensitivity just using the "Qualified Inventory" in the Upside potential (ie exclude all capacity from outside the "Qualified Inventory"
5. The group has some concerns about site 16 and suggested perhaps promoting site 8 in its place.

Group B

1. Agree with the broad focus on the "Simple View".
2. From a portfolio perspective it is good to see East Irish Sea sites in the Top 20, but suggest reducing this to keep storage site distribution proportionate with thee regional emissions picture.
3. Notes that two of the Top 20 sites are representing the Hewett field and suggest that these could be amalgamated to simplify things
4. Suggest that the ranked sites would benefit from adding some well-known benchmarks including 5/42 and Goldeneye
5. Happy with the diversity of store types – note that there are a number of open aquifers without structural confinement and suggest careful treatment of these going forwards.
6. Suggest swap sites 28 and 33
7. Suggest start to look for hybrid sites where confidence from a depleted hydrocarbon field might be coupled with the capacity afforded by a saline aquifer build out. Noted that this effect is reflected in the Upside potential available within a 20km radius of a site.
8. Note that there is a good diversity of geological ages of potentials storage sites, but that the Jurassic is missing from the Top 20.
9. Important to look at the build out scenarios in WP4 and how sites might be connected together.

Strategic UK CCS Storage Appraisal Project
R03, Stakeholder Meeting 02

2nd July 2015

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Welcome & Objectives

- Safety moment
- Introductions
- Objectives
  - Keep CO2 storage stakeholders appraised of project progress and enrol interest from the CCS stakeholder community
  - Stimulate debate around the selected top twenty candidate sites & gather input to the process

Strategic UK CCS Storage Appraisal Project

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Agenda

Start	Topic	Lead
09:30	Welcome & Safety Briefing	SJM
09:35	Purpose of Workshop	SJM
09:40	Strategic UK CCS Storage Appraisal Project	SJM
09:55	Screening & Selection	ATJ
10:15	Results	ATJ
10:45	Break	All
11:00	Workshop Session	All
12:00	Feedback	
12:20	Next Steps	SJM
12:30	Close	SJM

Strategic UK CCS Storage Appraisal Project

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Attendee List

Name		Organisation
Jeb	Tyrie	APEC Ltd
Ken	Johnson	Axis Well Technology
Stephen	Cawley	BP
Don	Reid	Capture Power
Brian	Allison	DECC
Graham	Dawe	DNV GL
Den	Gammer	ETI
Andrew	Green	ETI
Benjamin	Court	GCCSI
Bill	Senior	Ind
Nick	Reeves	National Grid
Eva	Halland	NPD
David	Hartney	OGA
Frances	Harding	Pale Blue Dot Energy
Alan	James	Pale Blue Dot Energy
Steve	Murphy	Pale Blue Dot Energy
Chris	McGarvey	Pinsent Masons

Strategic UK CCS Storage Appraisal Project

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Project Objectives & Value Objective

- **Project Objectives:**
  - Develop storage options which contribute to an extendable storage scheme for 1500MT of storage, injecting 50Mt/a, by 2030, incorporating storage previously de-risked by other initiatives. This will include expansion from both Phase 1 projects;
  - Screen and de-risk commercially attractive options for storage for Phase 2 projects, de-risking onshore investments by 2026;
  - Estimate and schedule the resources needed to get down-selected stores fully appraised and then operational;
  - **Facilitate the future commercial development of UK storage capacity by accelerating development of capacity and making the results of the Project available to all current and potential future stakeholders.**
- **Value Objective:**
  - Materially progress the development of strategically important UK CO2 storage capacity, bring together existing storage appraisal initiatives, leverage future investment in building storage capacity and will inform a UK national strategy for roll-out of storage capacity development
  - Do so within the Maximum ETI Funding and complete by the Target Date (1st April 2016)

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Project Overview
Objectives

Develop practical cost effective storage options that contribute to an extendable storage scheme for 1.5GT of storage capacity and 50MT/y of injection capacity by 2030

Screen Many Sites	Consider a large number of possible stores & screen objectively to identify those with high potential & that form a robust portfolio of 5 sites
Appraise Top 5	Assess top 5 sites and create output material which makes a significant and tangible difference to future storage developers and complements the DECC CCS Commercialisation Programme
Plan Risk Reduction	Identify specific risk factors associated with each of the 5 sites and prepare a risk reduction plan for each site
Development Options	Estimate and schedule resources needed to fully appraise, develop and operate the 5 sites
Make Output Public	Facilitate future commercial development of UK storage capacity

Strategic UK CCS Storage Appraisal Project

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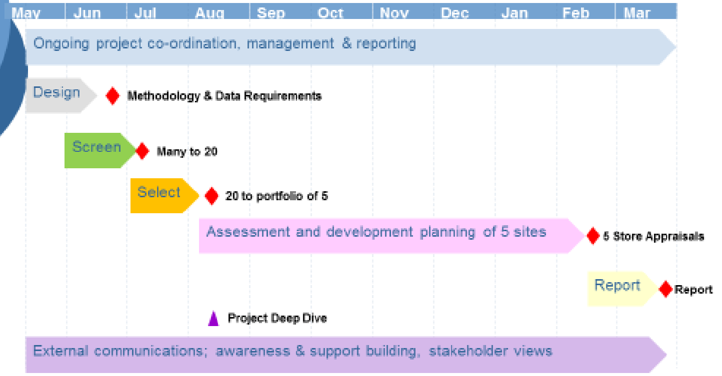
Project Overview
Schedule



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Project Overview
Delivery Team

Pale Blue Dot — Management Consultancy for the Energy Transition
- Consortium Lead & Project Manager
- CO_2 storage specialists
- Site and portfolio evaluation

AXIS — Well Technology & Reservoir Development Specialists
- Geological & Geophysical characterisation of sites
- Reservoir & injectivity modelling
- Well design & costing

COSTAIN — Engineering Solutions Provider
- Offshore infrastructure and facilities requirements
- Cost and schedule estimates

Strategic UK CCS Storage Appraisal Project

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Project Overview

Stakeholder Interactions

	Title & Purpose	Target Date
R02	Broad Stakeholder Project Roll Out (WP1) Explain project scope to invited stakeholders, enrol interest & gather some input for screening & selection activity. Post D01 & D02 Broad range of stakeholders to maximise awareness and input 30-40 attendees. Mary Sumner House Westminster venue, ½ day	15/6/2015
R03	Stakeholder Methodology Acceptance (WP3) Presentation of screening results & secure agreement Post D03 & D04 ETI Advisory panel & selected stakeholders with specific interest 15-20 attendees. Pinsent Masons, City of London, ½ day	2/7/2015
R04	Stakeholder Input to WP5 (WP4) Present down-select results & secure agreement for the portfolio of 5 sites. Post D06 ETI Advisory panel & selected stakeholders with specific interest 15-20 attendees. Brathens Aberdeen venue, ½ day	20/7/2015
R08	Stakeholder - Launch of Summary Report Present final results from project and project summary report Broad range of attendees. London, ½ day	21/3/2016

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Screening and Selection

Overview

- Beachheads
- Site Attributes
- Facilities
- Composition
- Phase & Temp

- Eligibility
- Screening

- Due Diligence
- Portfolio Creation and Assessment

- Define the Complex
- Populate the Store Model
- Outline Development Plan
- Containment Risk Assessment

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Project Overview

Feedback from Workshop 1

- "Please consider the East Irish Sea"
- "SNS, CNS and EIS"
- "Beyond 5/42 and the EIS"
- "Maintain diversity approach for shortlist selection"
- "Monitor TOPSIS performance carefully"
- "Take caution with data uncertainty on downselect decisions"

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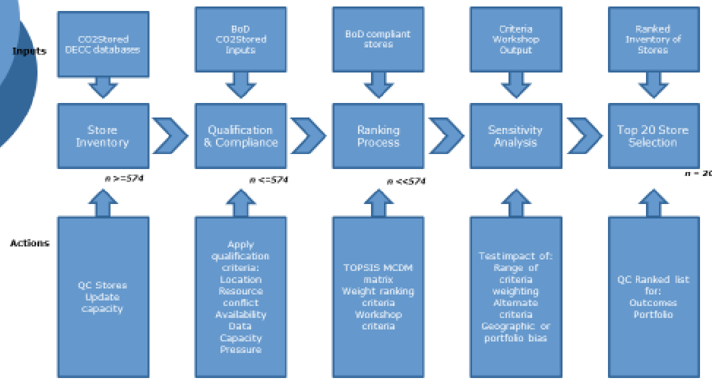
Screening and Selection

WP3 Workflow



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Screening and Selection

"Initial Inventory"

	Unit Designation				
Storage Unit Type	Saline Aquifer	Oil & Gas	Gas Condensate	Gas	Total
Fully Confined (closed box)	228	3	1	8	**240**
Open, with identified structural/ stratigraphic confinement	20	0	0	0	**20**
Open, no identified structural/ stratigraphic confinement	62	0	0	0	**62**
Structural/Stratigraphic Trap	50	90	15	101	**256**
Uncategorised	1	0	0	0	**1**
Total	**361**	**93**	**16**	**109**	**579**

Store Inventory

CO2Stored carries 574 sites,
5 oilfield sites with significant cumulative production were added,
These were: Alba, Gryphon, Bittern, Maureen & Braemar

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Screening and Selection

Qualification steps

- Project Qualification
- IEAGHG Recommended Practice Qualification

	Positive Indicators	Cautionary Indicators
Storage Capacity		
Total storage capacity	Total capacity estimated to be much larger than the total amount produced from the CO_2 source	Total capacity estimated to be similar to or less than the total amount produced from the CO_2 source
Reservoir Properties		
Depth	Between 1000 and 2500 m	< 800 m or > 2500 m
Reservoir thickness	> 50 m	< 20 m
Porosity	> 20%	< 10%
Permeability	> 300 mD	< 10-100 mD
Salinity	> 100,000 mg/l (ppm)	< 30,000 mg/l (ppm)
Caprock Properties		
Lateral continuity	Unfaulted	Lateral variations, faulted
Thickness	> 100 m	< 20 m
Capillary entry pressure	Much greater than buoyancy force of maximum predicted height of CO_2 column	Similar to the buoyancy force of maximum predicted height of CO_2 column

Table 5: Key geological indicators for storage site suitability (from Chadwick et al., 2008)

Qualification & Compliance

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Screening and Selection

Qualification & Ranking

- Addition of key missing oilfields – 574 to 579
- Project qualification – 579 to 186 (78.1GT to 77.0GT)
  - Eliminated 68% of "Initial Inventory" sites
  - Eliminated 1.4% of "Initial Inventory" capacity
- IEAGHG qualification - 186 to 37 (77.0GT to 8.2GT)
  - Eliminated 80% of project qualified sites
  - Eliminated 89% of project qualified capacity
- Ranking – 37 to 20 (8.2GT to 6.7GT)
  - Eliminated 46% of fully qualified sites
  - Eliminated 19% of fully qualified capacity

Qualification & Compliance

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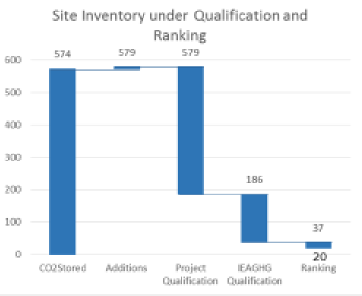
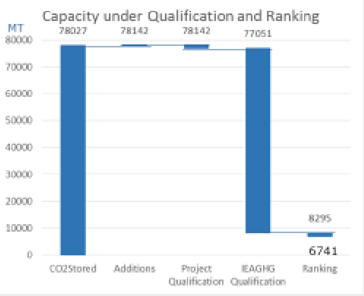
Screening and Selection

Qualification and Selection Waterfall





Qualification & Compliance

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Screening and Selection

Inventory Reduction through WP3

Qualification & Compliance

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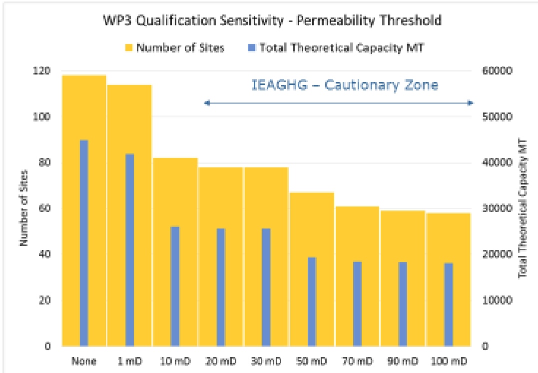
Screening and Selection

The Impact of 50mD Permeability Threshold



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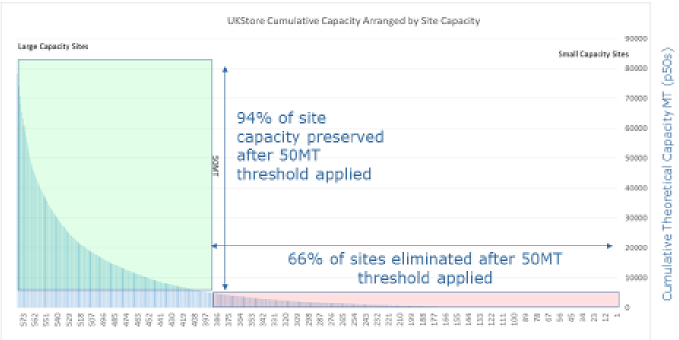
Screening and Selection

The Impact of 50MT Capacity Threshold



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Screening and Selection

Ranking Criteria (1 to 3)

- Capacity
  - P50 Theoretical Capacity in MT held by CO2Stored in the *pvalues* table
- Injectivity
  - Kh (Permeability & Thickness) product of P50 values from CO2Stored in the *inputanddeterministic* table as a proxy for injectivity index

$$II = \frac{kh}{141.2\,\mu B(\ln\frac{rw}{re} + S)}$$

- Engineering Containment Risk
  - The density of legacy wells per square km from the area (mid) in the *inputanddeterministic* table and the well count on the *oilandgaswell* table

Ranking Process

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Screening and Selection

Ranking Criteria (4 to 6)

- Geo Containment Risk
  - A quantification of the containment risk in the *risk* table

Seal Characterisation			Fault Characterisation			Georisk Factor
Fracture pressure capacity	Seal chemical reactivity	Seal degradation	Fault Density	Throw and fault seal	Fault vertical extent	
low	high	medium	high	high	medium	14
low	low	low	low	low	low	6
medium	medium	medium	medium	medium	medium	12
high	high	high	high	high	high	18

low = 1 medium = 2 high = 3

- Development Cost Factor
  - A quantification of a five well development based upon the distance to nearest beachhead and the reservoir depth (pipeline and well cost only)
- Upside Potential
  - A summation of the P50 theoretical capacity of all sites with centroid positions within 20km of the target site

Ranking Process

AXIS

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Screening and Selection

Initial Weighting Development

Pairwise comparison

	Theoretical Capacity	Injectivity (Kh)	Containment (Engineered)	Containment (Georisk)	Development Cost Factor	Upside Potential	Weighting
Theoretical Capacity	1.00	3.00	5.00	0.20	3.00	3.00	21%
Injectivity (Kh)	0.33	1.00	3.00	0.20	1.00	3.00	11%
Containment (Engineered)	0.20	0.33	1.00	0.20	3.00	3.00	9%
Containment (Georisk)	5.00	5.00	5.00	1.00	5.00	5.00	46%
Development Cost Factor	0.33	1.00	0.33	0.20	1.00	3.00	8%
Upside Potential	0.33	0.33	0.33	0.20	0.33	1.00	4%

1	Equal imortance	Options are equally important
3	Moderate importance	Experience and judgement slightly in favour of one Option over the other
5	Strong importance	Experience and judgement strongly in favour of one Option over the other
7	Very Strong importance	One Option is very strongly favoured over the other
9	Extreme importance	One Option is favoured over the other to the highest order possible

Ranking Process

AXIS

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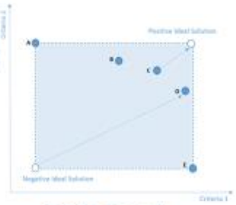
Screening and Selection

TOPSIS and Criteria Independency



TOPSIS Principle

An absence of clear correlations suggests that there are minimal dependencies between the criteria and therefore that TOPSIS condition is satisfied.

Ranking Process

AXIS

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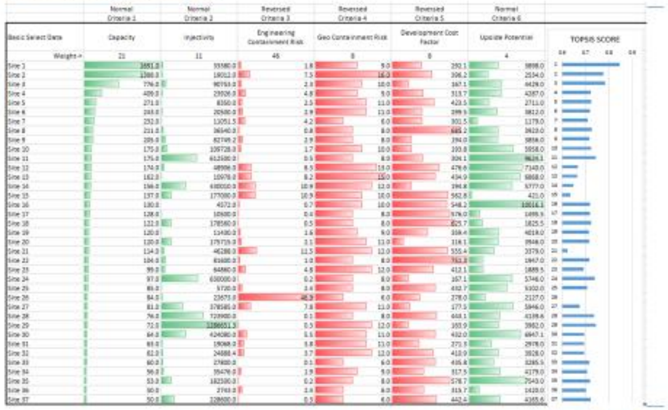
Screening and Selection

Results (example)



AXIS

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Pale Blue Dot.

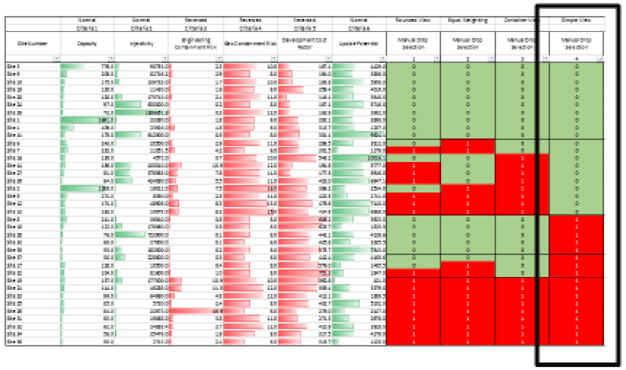
Screening and Selection

Sensitivities

- Four weighting scenarios were developed to test robustness of the ranking process
  - Rounded View – Uses all six criteria and initial weighting from a pairwise consideration matrix
  - Equal Weighting - Uses all six criteria with equal weighting
  - Container View – Uses the four subsurface characteristics (Capacity, Injectivity and 2x Containment) equally weighted
  - Simple View – Uses only capacity and development cost to focus on a "keep it simple" approach and taking advantage of all "qualified sites" having passed the IEAGHG site characterization guidelines (DNV RP-203)
- Further qualification sensitivities were completed
  - 50MT Capacity threshold
  - 50mD Permeability threshold

Screening and Selection

Draft Outcome & Recommendation



Screening and Selection

Outcome Review – Case 1 - "Rounded View"

Screening and Selection

Top 20 Recommended Selection

Store Type	count
Structural/Stratigraphic Trap	13
Fully Confined (closed box)	1
Open, no identified structural/ stratigraphic confinement	4
Open, with identified structural/ stratigraphic confinement	2

Geological Age	count4
1. Paleogene	5
3. Lower Cretaceous	4
6. Triassic	9
7. Permian	2

Unit Designation	Column1
Saline Aquifer	10
Gas	7
Oil & Gas	2
Gas Condensate	1

Beachhead	count2
Medway	0
Barmston	7
St Fergus	9
Connah's Quay	4
Redcar	0

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Screening and Selection

Recommended UKStore Twenty Portfolio

- Significant overall capacity target of 6.7GT
- Strong balance between saline formations and depleted hydrocarbon fields
- Elimination of sites with high risk high confidence containment issues
- Compliance with IEAGHG screening guidelines
- Compliance with Project BOD qualifications
- Twenty Portfolio
  - SNS CNS and EIS
  - Proximal sites to 5/42 and Goldeneye
  - SNS, CNS and EIS
  - Strong diversity of sites
  - Sites in proximity to potential CO2 EOR projects
  - Strong build out potential

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Workshop

Background

- This Screening phase has reduced 579 possible sites to 20 candidates for further assessment
  - Rapid Screening based largely upon CO2Stored database
- We are now seeking your thoughts on the 20 proposed candidate sites to sense check this selection
- Next steps
  - Technical due diligence will be performed on these sites in order to identify the portfolio of 5 stores considered most likely to meet project objectives
  - This will be work package 4

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Workshop

Activity

- On Your Own -10 mins
  - Review the results table provided and consider whether you believe the selection to represent a sound basis from which to achieve the project objectives
- As a Team – 20 mins
  - After your individual deliberations on the results – discuss and resolve amongst the team your preferred selection. Be prepared to summarize your rationale
- Feedback session

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Workshop

Draft Results Sheet Handout for Review

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Workshop
Activity

- Discussion & feedback from workshop groups
- Thank you for everyone's time and input

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