



# UK Carbon Capture and Storage Demonstration Competition

SP-SP 6.0 - RT015  
FEED Close Out Report

April 2011  
ScottishPower CCS Consortium



# UK Carbon Capture and Storage Demonstration Competition

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## CCS Project Costs

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**Information provided further to UK Government's Carbon Capture and Storage ("CCS") competition to develop a full-scale CCS facility (the "Competition")**

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## 10. CCS Project Costs

This section of the report contains the cost estimate for the End-to-End CCS Chain for the purpose of providing potential developers of CCS projects with refined cost information.

One of the key objectives of the FEED phase of the UKCCS Demonstration Competition was to increase the cost certainty for the overall project.

During the Outline Solution development, costs were estimated to an accuracy of -30% to +50%. Through the design and project development across the various Consortium workstreams (as outlined in the previous sections of this report), it has been possible to refine this accuracy and increase the cost certainty of the core capital costs to approximately -12%/+15% accuracy.

The cost schedules at the Outline Solution and post-FEED stage are provided in Appendix J under the following references:

- UKCCS - KT - S5.2 - OS - 001 Outline Solution project Cost Schedule
- UKCCS - KT - S5.1 - E2E - 001 Post-FEED project Cost Schedule

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## Overview

### Costing Methodology

The ScottishPower Consortium Partners have well established and robust cost estimating methodologies. These methodologies are individual to each organisation and must be followed in order to comply with their internal governance procedures. As such, it is inevitable that the total cost of the CCS project is made up of three underling cost estimates.

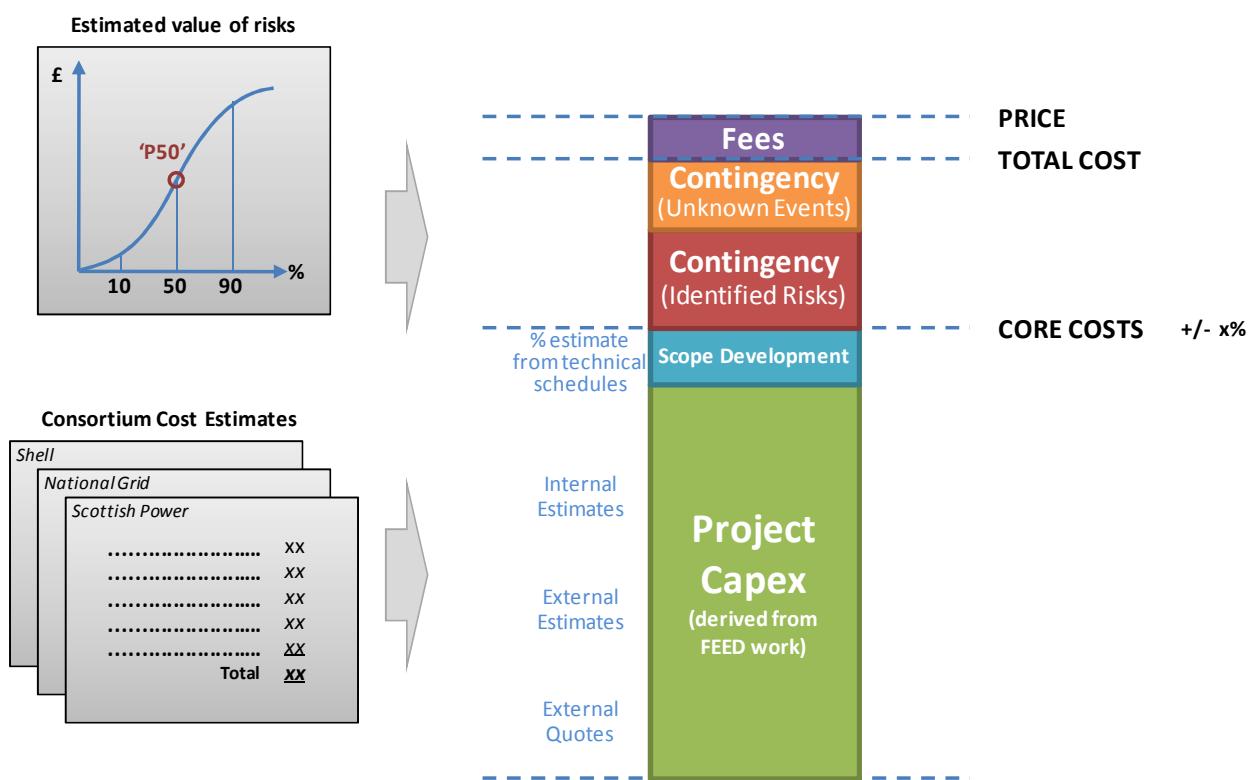
The Consortium has adopted the following key principles in compiling the cost estimate:

- A coherent end-to-end cost submission
- Value for money test to ensure best value
- A transparent and fully auditable approach

### Capital Costs

The core cost estimates from the FEED scope are the majority, but not the entirety, of the full capital cost picture. Figure 10.1-1 illustrates the main components of the estimate.

Figure 10.1-1: Main Components of the Cost Estimate



Source: ScottishPower Consortium

The main components of the cost estimate are:

- Core Costs
  - Those directly identifiable elements of cost which make up the majority of the capital costs, and comprise equipment, civil works, pipework, electrical, etc. These costs are

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based on a combination of external quotes, external estimates (which may be factored to the required volumes), and internal estimates. These are based on the technical specifications developed through the FEED programme of work.

- Scope Development
  - An estimate, based on the technical drawings and drafters expertise, of the additional requirements which are likely when moving from FEED to the implementation phase of the project. This typically accounts for the additional 'nuts and bolts' which are not specifically drawn and identified at the FEED stage, but are known omissions at the time of drafting.
- Contingency & Risk
  - An additional amount to cover the expected value of risks facing the project, calculated using the Consortium Partners internal risk pricing approach and is based on a P50 (ie midpoint) probability estimate. The calculation of the contingency amount depends critically on the contracting approach adopted, and the final risk/reward allocation of the project, and as such is indicative at this stage of the commercial negotiations.
- Fees
  - The developer fees associated with managing the project. As per the contingency calculations, these numbers are indicative, pending further commercial discussions.

### Breakdown of Capital costs

The capital cost estimates are produced in discrete segments which cover the following elements of the CCS chain. When combined, they cover the full End-to-End CCS chain:

ScottishPower (with Aker Clean Carbon as a key contractor):

- SPS – Steam & Power Supply
- CCP – Carbon Capture Plant
- Comp – Compression
- BoP – Balance of Plant and Utilities
- Site/Other – additional items required at Longannet Power Station over and above the Aker cost estimate
- OE/Mgt. – Owners Engineer (Technical Assurance) / Project Delivery

National Grid:

- New Pipeline – New link-line from Longannet Power Station to Dunipace
- No. 10 Feeder – Existing pipeline from Dunipace to St. Fergus Terminal
- Compressor Station – Works at Blackhill Compressor Station in the vicinity of St. Fergus Terminal

Shell:

- Advance works – advance works scope
- Surveys – offshore surveys around the platform and well location
- St Fergus – onshore modification works to St Fergus
- Pipeline Prep – including pigging
- Topsides/Platform – infrastructure required above the seabed at the Goldeneye site
- Subsea – components required at the wellhead/seabed
- Wells – injection and/or monitoring well work at the Goldeneye site
- Pre-injection – preparation works

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The costs are summarised for each segment of the CCS chain (see above) and presented for consolidation using the following categories:

- Mobilisation & Enabling
- Land
- Equipment
- Civil works
- Mechanical
- Electrical
- Buildings
- Testing & Commissioning
- Strategic Spares
- First-fill chemicals
- Insurance
- Legal, Permits, Licence fees
- Interconnections
- Other
- Contractors fees

In order to achieve the principles outlined above, the following assumptions have been applied across the full CCS cost chain:

- All prices are in 2010 terms.
- Real costs, with no inflation applied.
- The operating life is 15 years and there will be zero residual value – unless otherwise specified.

For each item of cost, the following information was assessed:

- Basis of cost – e.g. Estimate/Budget/Tendered/Quote.
- Accuracy of cost – e.g. +/- 10%.
- Inflation profile which costs are linked to – e.g. link to CPI, RPI, etc.
- Spend profile – % p.a. (either for individual items, or summarised at a higher level).
- Any element of foreign currency.

Contingency is separately identified, and the calculation basis noted.

### **Operating Costs**

Operating costs have been estimated using the internal cost estimating process for each of the Consortium Partners. The key principle is to separate the underlying unit cost and volume drivers, in order that the Pricing Model can reflect estimated operating costs based on changes in those underlying volume drivers.

The costs have been summarised for each segment of the CCS chain and presented for consolidation using the following categories:

- Fuel / Power / Energy
- Amine
- Consumables
- Maintenance
- Waste disposal
- Staff
- Leasing
- Rates
- Insurance
- Overheads

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- Other

### **Decommissioning Costs**

On the basis that the project has a defined operating period of 10-15 years, a provision has been calculated for decommissioning costs for each element of the End-to-End CCS chain where applicable.

### **Post-injection monitoring and well closure costs**

These additional costs have currently been excluded from the operating cash-flows of the project, due to the uncertainty on the final treatment and liability for those costs. However, it should be noted that they will be an integral part of the full project cash-flow.

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### Outline Solution project Cost Estimates

Appendix J contains the cost schedule prepared for the entire project at the Outline Solution stage of development. The capital, abandonment and operating costs are summarised in Table 10.2-1, Table 10.2-2 and Table 10.2-3 respectively.

Table 10.2-1: Summary of Estimated Project Capital Costs at the Outline Solution stage

Chain Segment	Total CAPEX (£m)	Cost estimate range (+/-%)	Cost estimate range (£m)
Steam and Power Supply	153.6	-30% to +50%	-
Carbon Capture Process	241.8	-30% to +50%	-
Compression & Conditioning	43.5	-30% to +50%	-
Balance of Plant and Utilities	54.0	-30% to +50%	-
Owner's Engineer (Technical Assurance)	58.7	-30% to +50%	-
Knowledge Share	8.2	-30% to +50%	-
Link-line between Longannet and Dunipace	43.6	-30% to +50%	-
No. 10 Feeder (Existing pipe)	54.7	-30% to +50%	-
Compression and facilities at St Fergus (Blackhill)	100.5	-30% to +50%	-
Offshore pipe	114.4	-30% to +50%	-
Infrastructure at the Goldeneye field	32.4	-30% to +50%	-
Wells at the Goldeneye field	171.9	-30% to +50%	-
<b>Total</b>	<b>1,077.2</b>	<b>-30% to +50%</b>	<b>754 to 1,616</b>
<b>Risk &amp; Contingency<sup>1</sup></b>	<b>102.8</b>	<b>n/a</b>	<b>103<sup>1</sup></b>
<b>Total Project Capex</b>	<b>1,180.1</b>	<b>-</b>	<b>857 to 1,719</b>

<sup>1</sup> Indicative subject to final agreement of the risk/reward balance and procurement strategy

Table 10.2-2: Summary of Estimated Project Abandonment Costs at pre-FEED stage

Chain Segment	Total ABEX (£m)
Steam and Power Supply	47.5
Carbon Capture Process	70.2
Compression & Conditioning	12.8
Balance of Plant and Utilities	14.7
Owner's Engineer	-
Knowledge Share	-
Link-line between Longannet and Dunipace	10.8
No. 10 Feeder (Existing pipe)	8.0
Compression and facilities at St Fergus (Blackhill)	10.4
Offshore pipe	-
Infrastructure at the Goldeneye field	9.3
Wells at the Goldeneye field	16.9
<b>Total</b>	<b>200.6</b>

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Table 10.2-3: Summary of Estimated Project Operating Costs at pre-FEED stage

Chain Segment	Annual Fixed OPEX (£m)	Annual Variable OPEX (£m)
Steam and Power Supply	2.4	62.2
Carbon Capture Process	5.0	8.7
Compression & Conditioning	4.2	0.1
Balance of Plant and Utilities	16.5	0.0
Owner's Engineer / Management	3.0	0.0
Knowledge Share	2.9	0.0
Link-line between Longannet and Dunipace	0.0	0.0
No. 10 Feeder (Existing pipe)	0.0	0.0
Compression and facilities at St Fergus (Blackhill)	1.2	10.5
Offshore pipe	15.5	0.0
Infrastructure at the Goldeneye field	0.0	0.0
Wells at the Goldeneye field	0.3	0.0
<b>Total</b>	<b>51.0</b>	<b>81.4</b>

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### Post-FEED project Cost Estimate

#### FEED Cost Estimate

Appendix J contains the cost estimate prepared for the entire project at the post-FEED stage. The capital, abandonment and operating costs are summarised in Table 10.3-1, Table 10.3-2 and Table 10.3-3 respectively.

Table 10.3-1: Summary of Estimated project Capital Costs at post-FEED stage

Chain Segment	Total CAPEX (£m)	Cost estimate range (+/- %)	Cost estimate range (£m)
Steam and Power Supply	114.8	-20% to +20%	-
Carbon Capture Process	228.1	-10% to +10%	-
Compression & Conditioning	47.2	-10% to +10%	-
Balance of Plant and Utilities	119.7	-10% to +10%	-
Site - Other <sup>1</sup>	146.7	-10% to +10%	-
Link-line between Longannet and Dunipace	81.3	-10% to +15%	-
No. 10 Feeder (Existing pipe)	78.9	-10% to +15%	-
Compression and facilities at St Fergus (Blackhill)	121.0	-10% to +15%	-
FEED Extension	12.5	-25% to +30%	-
Surveys/Licenses	22.1	-25% to +30%	-
St Fergus	14.9	-15% to +25%	-
Pipeline preparation	4.6	-25% to +30%	-
Topsides / Platform	91.3	-15% to +30%	-
Subsea	8.9	-15% to +30%	-
Wells	37.5	-15% to +25%	-
Pre-injection	16.0	-15% to +25%	-
<b>Total</b>	<b>1,145.5</b>	<b>-12.3% to +15.6%</b>	<b>1,005 to 1,324</b>
<b>Risk &amp; Contingency<sup>2</sup></b>	<b>194.8</b>	<b>n/a</b>	<b>195</b>
<b>Total Project Capex</b>	<b>1,340.3</b>	<b>-</b>	<b>1,200 to 1,519</b>

<sup>1</sup> Includes technical assurance, management and knowledge transfer

<sup>2</sup> Indicative subject to final agreement of the risk/reward balance and procurement strategy

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Table 10.3-2: Summary of Estimated Project Abandonment Costs at post-FEED stage

Chain Segment	Total ABEX (£m)
Steam and Power Supply	23.0
Carbon Capture Process	45.6
Compression & Conditioning	9.4
Balance of Plant and Utilities	23.9
Site - Other	-
Link-line between Longannet and Dunipace	16.3
No. 10 Feeder (Existing pipe)	15.8
Compression and facilities at St Fergus (Blackhill)	24.2
Offshore Topsides & Subsurface	25.7
Wells	39.3
Pipelines	31.4
Onshore Facilities	1.5
Post C.O.P.	25.2
<b>Total</b>	<b>281.3</b>

Table 10.3-3: Summary of Estimated Project Operating Costs at post-FEED stage

Item	Longannet Site	Transport	Storage
Fuel / Power / Energy	Calculated based on volume and energy price profiles	0.04533MWh/t CO <sub>2</sub>	£4k/month
Consumables	£4.86/t CO <sub>2</sub>	-	£8k/month
Waste disposal	£0.31/t CO <sub>2</sub>	-	£2k/month
Maintenance	£505k/month	£58k/month	Annual profile, averaging £284k/month
Staff	£421k/month	£350k/month	£202k/month
Rates	£425k/month	£4k/month	-
Insurance	£425k/month	£33k/month	Annual profile, averaging £19k/month
Overheads	£325k/month	£602k/month	£178k/month
Lease Costs	-	-	£8k/month
Other Fixed Costs	£238k/month	-	£96k/month + Annual profile, averaging £267k/month

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## Summary

### Capital Costs

Table 10.4-1 displays a summary comparison of the capital cost estimates at the Outline Solution stage and post-FEED for the capture, transport and storage sections of the scheme.

Table 10.4-1: Summary of Estimated Project Capital Costs at pre- and post-FEED

Section	Outline Solution (£m)	Post-FEED (£m)	Change (£m)
Capture <sup>1</sup>	559.8 (47%)	656.5 (49%)	+96.7
Transport	198.7 (17%)	281.2 (21%)	+82.5
Storage	318.7 (27%)	207.8 (16%)	-110.9
<b>Total</b>	<b>1,077.2 (91%)</b>	<b>1,145.5 (85%)</b>	<b>+68.3</b>
Risk & Contingency	102.8 (9%)	194.8 (15%)	+92.0
<b>Total Project Capex</b>	<b>1,180.1 (100%)</b>	<b>1,340.3 (100%)</b>	<b>+160.2</b>
<b>Estimated Range</b>	<b>857 to 1,719</b>	<b>1,200 to 1,519</b>	<b>n/a</b>

<sup>1</sup> Includes technical assurance, management and knowledge transfer

The central case capital cost estimate for the capture and transport sections rose following FEED by £96.7m (+17%) and £82.5m (+42%) respectively whereas the estimate for the storage section fell by £110.9m (-35%).

The variations to the overall capital costs can be attributed to the following:

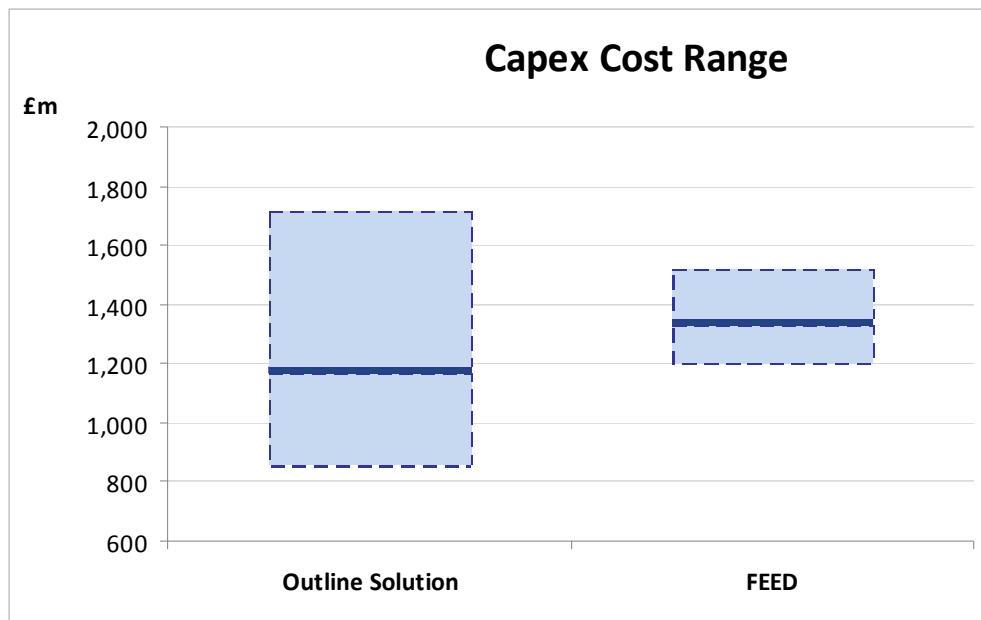
- The rise in the capture section estimate was principally due to refined estimates of the balance of plant and utilities costs. These include enabling works, buildings including the control room and a larger electrical substation, a greater definition of the water intake works and steelwork required for the ductwork combined with other site costs which were only apparent as a result of the FEED.
- The increase in the estimate for the transport section was due primarily to increases in the estimates of the work required for the new pipeline connecting Longannet Power Station to the No. 10 Feeder pipeline. FEED has enabled closer identification of river crossing risks and therefore better understanding of costs in respect to ground conditions along the pipeline route - specifically the requirement for tunnelling under the Firth of Forth river instead of Horizontal Directional Drilling (HDD) as was originally proposed in the Outline Solution. The FEED study has enabled a greater understanding of the work required and consequently a more accurate estimate to be compiled.
- The decrease in the storage section cost estimate was due to a better understanding of the work required as a result of the FEED and in particular the scope and costs of work to be undertaken at the wells.
- The risk and contingency costs increased by £92m (82%) as a result of FEED reflecting the better identification and quantification of risks as outlined in Section 7. This value is indicative and is subject to final identification of the risk/reward balance of the project, and the procurement strategy adopted.

The capital costs at the Outline Solution and post-FEED stage are summarised in Figure 10.4-1.

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Figure 10.4-1: Capital costs



Source: ScottishPower CCS Consortium

All these changes to the cost estimate reflect the uncertainty present at the Outline Solution stage and the refinements that the FEED study brought to the cost estimate. Whilst the midpoint cost estimate has increased by £160m, it should be noted that the costs accuracy has improved significantly with the result that the maximum estimated costs have fallen by £200m as a result of the FEED work undertaken.

## Decommissioning/Abandonment Costs

Table 10.4-2 shows a summary comparison of abandonment cost estimates pre- and post-FEED for the capture, transport and storage sections of the scheme.

Table 10.4-2: Summary of Estimated Project Abandonment Costs at pre- and post-FEED

Section	Pre-FEED (£m)	Post-FEED (£m)	Change (£m)
Capture	145.2 (72%)	102.0 (36%)	-43.2
Transport	29.1 (15%)	56.2 (20%)	+27.1
Storage	26.2 (13%)	123.1 (44%)	+96.9
<b>Total Project AbEx</b>	<b>200.6 (100%)</b>	<b>281.3 (100%)</b>	<b>+80.7 (+40%)</b>

Abandonment costs were only estimated using rough approximations at the Outline Solution stage so the changes to the estimates reflect the greater level of understanding and work undertaken on this topic during FEED.

## Operating Costs

The methods for estimating the operating costs changed from pre-FEED (annual fixed and variable cost estimates) to post-FEED (price per tonne of CO<sub>2</sub> or per month) so a direct comparison of the cost estimates is not possible.

# Glossary

<b>AGI</b>	Above Ground Installation
<b>AOI</b>	Areas of Interest
<b>ARP</b>	Asset Reference Plan
<b>ALARP</b>	As Low As Reasonably Practicable
<b>BAT</b>	Best Available Techniques
<b>Bscf</b>	Billion Standard Cubic Feet
<b>CA</b>	Corrosion Allowance
<b>CCP</b>	Carbon Capture Plant
<b>CCS</b>	Carbon Capture and Storage
<b>CDA</b>	Consortium Design Authority
<b>CO<sub>2</sub></b>	Carbon Dioxide
<b>COMAH</b>	Control of Major Accidents and Hazards
<b>CITHP</b>	Closed In Tubing Head Pressure
<b>CP</b>	Cathodic Protection
<b>CPA</b>	Coastal Protection Act
<b>CPO</b>	Compulsory Purchase Order
<b>CS</b>	Carbon Steel
<b>CSL</b>	Carbon Storage License
<b>CSP</b>	Carbon Storage Permit
<b>CTR</b>	Cost Time Resource
<b>CW</b>	Cooling Water
<b>DCC</b>	Direct Contact Cooler
<b>DCS</b>	Distributed Control System
<b>DTS</b>	Distributed Temperature Sensor
<b>DECC</b>	Department of Energy and Climate Change
<b>E&amp;A</b>	Exploration & Appraisal
<b>ECU</b>	Energy Consents Unit
<b>EEC</b>	European Economic Community
<b>EHR</b>	Enhanced Hydrocarbon Recovery
<b>EIA</b>	Environmental Impact Assessment
<b>EOS</b>	Equation of State
<b>EPC</b>	Engineering Procurement Construction
<b>ES</b>	Environmental Statement
<b>ESD</b>	Emergency Shut Down
<b>ESP</b>	Electro-static Precipitators
<b>ETS</b>	Emissions Trading Scheme

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<b>EU</b>	European Union
<b>FEED</b>	Front End Engineering Design
<b>FEPA</b>	Food and Environment Protection Act
<b>FGD</b>	Flue Gas Desulphurisation
<b>FIT</b>	Formation Integrity Test
<b>GDP</b>	Gross Domestic Product
<b>GEMA</b>	Gas and Electricity Markets Authority
<b>GHG</b>	Greenhouse Gas
<b>HCI</b>	Hydrochloric Acid
<b>HDD</b>	Horizontal Directionally Drilled
<b>HF</b>	Hydrofluoric acid
<b>HIPPS</b>	High Integrity Pipeline Protection Systems
<b>HMI</b>	Human Machine interface
<b>HP</b>	High Pressure
<b>HRA</b>	Habitat Regulation Appraisal
<b>HRSH</b>	Heat Recovery Steam Generator
<b>HSC</b>	Hazardous Substance Certificate
<b>HSE</b>	Health and Safety Executive
<b>HSS</b>	Heat Stable Salts
<b>IED</b>	Industrial Emissions Directive
<b>IIP</b>	Initially In Place
<b>ILI</b>	In Line Inspection
<b>ITT</b>	Invitation to Tender
<b>JNCC</b>	Joint Nature Conservation Committee
<b>JV</b>	Joint Venture
<b>KDM</b>	Key Decision Maker
<b>LCPD</b>	Large Combustion Plant Directive
<b>LOPs</b>	Local Operating Procedures
<b>LOT</b>	Leak-off Test
<b>LP</b>	Low Pressure
<b>LPA</b>	Local Planning Authority
<b>LPS</b>	Longannet Power Station
<b>LTCS</b>	Low Temperature Carbon Steel
<b>MAOP</b>	Maximum Allowable Operating Pressure
<b>MD</b>	Measure Depth
<b>MMV</b>	Metering, Monitoring and Verification
<b>MOD</b>	Ministry of Defence
<b>MP</b>	Medium Pressure
<b>MSG</b>	Minimum Stable Generation
<b>MTO</b>	Material Take Off

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<b>MTU</b>	Mobile Test Unit
<b>NaOH</b>	Sodium Hydroxide
<b>NGC</b>	National Grid Carbon
<b>NGG</b>	National Grid Gas
<b>NGO</b>	non-governmental organisations
<b>NH<sub>3</sub></b>	Ammonia
<b>NO<sub>x</sub></b>	Oxides of Nitrogen
<b>NO</b>	Nitrogen Monoxide
<b>NO<sub>2</sub></b>	Nitrogen Dioxide
<b>NRT</b>	NO <sub>x</sub> Reduction Technology
<b>NTS</b>	National Transmission System
<b>NUI</b>	Normally Unattended Installation
<b>OGUK</b>	Oil and Gas UK
<b>PAR</b>	Pre-assembled Rack
<b>PAU</b>	Pre-assembled Unit
<b>PCA</b>	Pipeline Construction Authorisation
<b>PEC</b>	Pulse Eddy Current
<b>PEM</b>	project Execution Model
<b>PBR</b>	Polished Bore Receptacle
<b>PFD</b>	Process Flow Diagram
<b>PPC</b>	Pollution Prevention and Control
<b>ppmv</b>	Parts per million volume
<b>P&amp;ID</b>	Piping and Instrumentation Diagram
<b>PRDS</b>	Pressure Reduction De-superheater Stations
<b>PRS</b>	Pressure Reduction Station
<b>PSR</b>	Pipeline Safety Regulations
<b>PVT</b>	Pressure Volume Temperature
<b>RAM</b>	Reliability, Availability and Maintainability
<b>RCIS</b>	Route Corridor Investigation Study
<b>RFT</b>	Repeat Formation Test
<b>ROV</b>	Remote Operating Vehicle
<b>SAC</b>	Special Area of Conservation
<b>SCAL</b>	Special Core Analysis Report
<b>SDP</b>	Storage Development Plan
<b>SEA</b>	Strategic Environmental Assessment
<b>SEC</b>	Securities and Exchange Commission
<b>SEPA</b>	Scottish Environmental Protection Agency
<b>SNH</b>	Scottish Natural Heritage
<b>SPA</b>	Special Protection Area
<b>SPS</b>	Steam and Power Supply

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<b>SO<sub>2</sub></b>	Sulphur Dioxide
<b>SRM</b>	Static Reservoir Model
<b>SSIV</b>	Sub-Sea Isolation Valve
<b>SSSV</b>	Subsurface Safety Valve
<b>TCPA</b>	Town and Country Planning Act
<b>TD</b>	Total Depth
<b>TSG</b>	Technical Steering Group
<b>TVDSS</b>	True Vertical Depth Subsea
<b>WRM</b>	Well and Reservoir Management
<b>UK</b>	United Kingdom
<b>UXO</b>	Unexploded Ordnance
<b>WBS</b>	Work Breakdown Structure

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