WGCPARIS2015
WORLD GAS CONFERENCE
"GROWING TOGETHER TOWARDS A FRIENDLY PLANET"

26th World Gas Conference | 1-5 June 2015 | Paris, France

THE PETERHEAD GAS CCS PROJECT

DRIVERS AND DEVELOPMENT

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Background

A substantial amount of the world's rising energy demand is forecasted to be met by fossil fuels over the next decades. Carbon capture and storage (CCS) is currently the only technology available to mitigate emissions from large-scale fossil fuel use and developing and commercialising this technology is essential to help avert serious climate change.

Shell is helping to advance CCS through support for a number of demonstration projects around the world, including: the European CO_2 Technology Centre Mongstad, Norway, the largest CO_2 capture demonstration facility in the world; the Quest CCS Project in Canada, which was announced in September 2012 and where construction is currently nearing completion; Australia's Gorgon natural gas liquefaction project, which plans to store some 3 to 4 million tons of CO_2 per annum, once it will be in operation, and in which Shell is a partner. Furthermore, Cansolv Technologies Inc. (a subsidiary of Royal Dutch Shell) has provided the sulphur dioxide & CO_2 capture technology for SaskPower's Boundary Dam CCS project in Canada, which began its operations in October 2014.

Combined Cycle Gas Turbine power plants (CCGT) are one of the major users of natural gas. Shell, a major natural gas producer, is looking to develop the Peterhead CCS Project under the UK CCS commercialisation competition. If it goes ahead it will be the world's first integrated commercial-scale full-chain gas power carbon capture and storage (CCS) demonstration project

This paper describes the objective for a low-carbon electricity CCS gas power demonstration project, the scope of the Peterhead CCS project, some process conditions, power plant integration, efficiency optimisation and integrated low carbon power operation elements, permitting and public consultation and the first of a kind role of the project in moving up the learning curve and down the cost curve of commercial-scale, low-carbon CCS gas power.

Detailed process descriptions and quantitative details of the project will become available in due course as part of the UK CCS Competition's Knowledge Transfer component.

Objective

Natural gas has a material position in the power market. A large number of scenarios project that gas, on the basis of its low carbon intensity and competitive costs will play an increasingly important role for flexible electricity supply in the global energy mix. However, as the IEA highlights in its 2013 CCS roadmap, "…natural gas is not a carbon-free fuel. Switching from coal to gas can assist with meeting near-term GHG emissions reduction goals, but from 2025 in the ETP 2012 2DS scenario, the goal for average emissions intensity of global electricity generation is below that of a gas-fired plant. The only way to enable gas-fired plants to conform to a lower emissions trajectory will be to fit many of them with CCS." To ensure the commercial availability of gas CCS from the mid-2020s a commercial scale full-chain gas CCS power plant demonstration is an important next step. Whilst it is building upon the operation at smaller scale of all the elements of a CCS chain, such a project will include several "first of a kind" (FOAK) technical as well as non-technical features. This demonstrator should deliver the technical, commercial, regulatory and public consultation elements needed to develop and operate a commercial low-carbon gas project. The demonstration project development and performance will provide developers, regulators and the public with the learnings and confidence to proceed with full-scale, commercial deployment of gas CCS.

The Peterhead Project Scope

Shell U.K. Limited and SSE are looking to develop the world's first commercial-scale full-chain gas carbon capture and storage (CCS) demonstration project – the Peterhead CCS Project. Up to 10 million tonnes of carbon dioxide (CO_2) emissions could be captured from the Peterhead Power Station and then transported by pipeline and stored, approximately

100km offshore in a depleted gas reservoir, at a depth of more than 2km under the floor of the North Sea.

The scope of the project includes:

- Operation of an existing gas turbine (GT13) at the Peterhead Power Station in Aberdeenshire, Scotland,
- A new steam turbine dedicated to GT 13 and low pressure (LP) steam generation,
- Capture of ~ 1 million tonnes per annum of carbon dioxide (CO_2) emissions, over a period of ten to 15 years, from the GT flue gas in a large concrete absorber tower using Shell Cansolv's amine capture technology,
- Regeneration of the amine in a regeneration column using steam from the power plant,
- Compression and conditioning (oxygen and water removal) of the CO_2,
- Transportation of the dense phase CO_2 via an offshore pipeline of approximately 100km,
- Injection of the CO_2 using the adapted Goldeneye platform and wells, and
- Storage in the depleted Goldeneye gas reservoir, at a depth of more than 2km under the floor of the North Sea.

It is the objective that the plant will operate as one integrated, low-carbon power supply chain.

In March 2013, the Peterhead CCS Project was chosen as one of two CCS demonstration projects to progress to the next stage of the UK Government's CCS Commercialisation Competition. The project is now in the front-end engineering design, or FEED, stage. An agreement was signed between Shell and the UK Government on February 24, 2014, allowing the project to move into this phase, which is expected to last through 2015.

The performance and the learnings of the demonstration project will, in due course, become available through the structured knowledge transfer programme.

Process conditions and Power Plant Integration

From the process conditions of the gas turbine its flue gas has low CO_2 concentrations (3-4 %) and high oxygen concentration. Compared to capture from other higher CO_2 concentration sources, like coal flue gas, these conditions are technically more challenging. The low CO_2 concentration results in large flue gas duct flows which result in substantial equipment sizes for ducts, flue gas fans, direct contact coolers and CO_2 absorbers. Also, the capture system and its process conditions are to be optimised for bulk CO_2 removal and oxygen tolerance. These put specific requirements on:

- lean amine conditions to be achieved in the regenerator to obtain the required CO_2 capture ratios,
- solvent type,
- degradation, reclamation and waste disposal and
- process energy efficiency.

The project has delivered valuable learnings in optimisation of process conditions. For example, a gas/gas heat exchanger is planned to be used to integrate the heat between the hot gas turbine flue gas and the decarbonised cold flue gas. This enables a lower cooling load on the flue gas cooler. To lower the energy penalties of the plant, and as low flue gas temperatures are favourable for the absorption process, low temperature approach heat exchangers have been selected in some parts of the process in order to maximise heat exchange between the different process streams.

The Peterhead Power Station is situated on a generous plot space on the North East coast of Scotland. The site is composed of numerous level pitches at varying elevations. The targeted gas turbine 13/WHB is one of a block of three which have been installed in the 1990s next to a 1970s two-train oil boiler power plant. The three gas turbines have been historically coupled with two existing steam turbines in the turbine hall of the older power plant. The capture plant will have a relatively large footprint originating from the larger absorber surface area to capture the low concentration CO_2 from the ambient pressure gas turbine flue gas exhaust. The CO_2 compression train, integrated with the dehydration and oxygen removal units, has a smaller footprint. The duct connections from the gas turbine flue gas exhaust to the absorber and from the absorber to the stack have large surface area (>30 m^2). Flue gas duct fans will be installed to overcome the overall pressure drop of ducts/direct contact cooler/absorber/duct/stack which adds an additional process duty. A number of different lay-out options have been developed and assessed on different criteria; amongst others HSSE impact, capital expenditure, operating costs, site segregation, access, constructability, operability/maintenance, and process impact. Finally a plot plan was chosen where the capture plant and the compression plant are separate operating sites with clear access from the power plant. The compression plant will be constructed in a recently cleared tank farm area.

Different project development and integration elements are being addressed, which will give insight into the necessary steps to progress a brown field retrofit gas CCS project. The Peterhead Power Station is owned and operated by SSE who will be responsible for the electricity generation facilities and the provision of flue gas from which the CO_2 will be captured, and for supporting services to the Peterhead CCS Project. Shell will be responsible for the CO_2 capture, compression and conditioning, the CO_2 transportation and the CO_2 storage facilities

Efficiency optimisation

The overall power plant efficiency (MWe low carbon power/MWth gas) is a key performance indicator for low-carbon CCS power plants. The "efficiency penalty" defined as the utilities requirement for the capture and compression operations incurred on the power plant is expected to be in the range of 11-16 % on fuel gas.

The power efficiency penalty originates from power and steam use in the CCS plant. The parasitic electrical consumptions include the power use for the CO_2 compressor, the flue gas duct fans, and also from all secondary services such as the amine recirculation pumps, cooling water pumps, dehydration regeneration energy, etc. Low pressure steam to regenerate the CO_2 rich amine incurs an efficiency penalty on the power production from diverting that steam from the steam turbine.

In an effort to minimise the efficiency penalty resulting from CCS, detailed studies for overall system efficiency penalty have been conducted.

One parameter that was optimised was the steam extraction pressure. Reducing the supply pressure of low pressure steam to the CCS plant increases the electrical power generated by the new steam turbine, since more energy is extracted from the steam expanded through the turbine, and increases the size of the CO_2 regenerator reboilers due to the reduction in the temperature driving force in the heat exchanger. A study has evaluated the energy and cost benefits of different steam extraction pressures and has defined the economic optimum for low pressure steam reboiler pressure.

Another example is the overall flue gas pressure drop optimisation to lower the booster fan power consumption. This was achieved by optimising the cross-sectional areas of both the direct contact cooler and the absorber column and operating at lower gas velocities, resulting in savings in operating costs associated with the flue gas fans at the trade-off of the capital cost of the absorber columns with the cross-sectional areas. The optimal diameters and fan power consumption were selected on the basis of vendor estimates and the predictions for the cost of clean electricity.

The electrical consumption of the CO_2 compressor could be reduced by minimising the required total pressure ratio by operating the amine regeneration column slightly pressurised, thus minimising the pressure drop in the line to the compressor suction.

Benchmarking of the Peterhead CCS project is valuable to validate the design and ensure replication for future gas CCS plants. Preliminary benchmarking against publicly available studies for low-carbon CCS gas power has been conducted and concluded that the Peterhead Project falls within the expected efficiencies for similar plants.

Low-Carbon Power generation

The UK Electricity Market Reform (EMR) realises a contract for difference (CFD) that offers a higher price for the net amount of low-carbon power produced, which is applied for the project. The integrated operation of power production, capture plant, compression plant, pipeline, platform and injection wells operation needs to be quantified, designed, operated and commercially metered. It is important that all captured CO_2 is accurately measured, monitored and reported across the full CCS chain for the overall demonstration of the commercial structure for low-carbon CCS power and for verification and offsetting under emission trading schemes. The project is reviewing different metering technologies used in different CO_2 operations to select an optimal solution for metering CO_2.

Another area requiring specific attention with regards to integrated operation is the operating ranges and transient conditions of the main process, as well as the utilities for the full CCS chain. Dynamic modelling for start-ups, shut-downs and various scenario trips have been simulated to gain a better understanding of the integrated operability of the equipment in the chain. This will support the delivery of the overall systems availability, with achieving optimal start-up procedures.

In parallel, reliability, availability and maintenance (RAM) studies of the overall plant availability over the commercial lifetime have been conducted for design choices on e.g. sparing and as input in contractual arrangements. Specific attention has been given to the overall process control of the operation, both in conceptual design and in the FEED, the metering of different process flows and CO_2 accounting and "losses".

Permitting

Being the first full-scale CCS project in the UK, the Peterhead project is facing particular attention in the establishment and attainment of the necessary permits to operate. Regular meetings with the Scottish Environmental Protection Agency (SEPA) and information-sharing between subject matter experts (in the field of amine emissions, for example) are essential in order to progress.

For the benefit of the regulators, the local community and the general public, Onshore and Offshore Impact Assessment Scoping Reports were prepared in 2014. These set out the scope of work to be covered by the lengthy and detailed Environmental Impact Assessments (EIAs) describing the potential environmental impacts associated with the scopes of work for the Peterhead CCS Project.

The Offshore Environmental Impact Assessment covers a wide range of topics associated with activities on the project from the mean low water mark (close to the Peterhead Power Station in Sandford Bay) to the offshore Goldeneye reservoir, including all work on the wells, the existing Goldeneye Platform, as well as on the proposed new section of pipeline. The outputs have been published in an environmental statement which has been submitted to the appropriate authorities for review and for the public to view as part public consultation.

The Onshore Environmental Impact Assessment covers all processes and activities taking place within the boundary of the Peterhead Power Station. The environmental statement arising from these detailed assessments and studies has also been submitted to the the appropriate authorities.

A specific point of attention is the atmospheric emission of amines and potentially atmospheric formation/degradation of nitrosamine species. These, along with any other emissions to air via the stack, are specifically being addressed via advanced dispersion modelling which incorporates atmospheric chemistry. Discussions are ongoing with SEPA to ensure that the appropriate methods, endorsed by industry experts worldwide, are considered in the design of the Peterhead CCS project. Equipment, like additional wash sections, has been included in the project scope to achieve acceptable emission levels of amine species. Similarly, all liquid waste streams from the CCS plant are tested for toxicity and modelled. To meet as low as reasonably practicable (ALARP) concentrations of amines in the various plant effluents, the project is evaluating different technologies for these streams.

Communication, public consultation and opportunities

One of the critical success factors of the project is creating awareness, confidence and acceptance with developers, regulators and the public on the safety and viability of full-scale, commercial deployment of gas CCS. The Peterhead CCS project has focused resources to aid in informing and involving key stakeholders, including the communities closest to Peterhead, of the objectives of the project and its potential impact. A series of communication and consultation events have taken place since late 2013, targeting different groups varying from high school students, to university academics and field professionals. Local and more widespread media features have already appeared in publications (including the Economist), social media and magazines portraying positive coverage of the project, with much more planned ahead during the further development of the project. Initial feedback received has been taken into account during the development of the FEED.

It is very important that the proposed Peterhead CCS Project is developed with input from the local communities around Peterhead. To achieve this, the project is committed to ongoing engagement throughout the development of the project.

Over 500 people attended the first phase of public consultation with a series of exhibitions in the communities closest to the proposed project – Boddam, Peterhead and Cruden Bay – as well as in Fraserburgh and Aberdeen, where the public was invited to read about the project plans, ask questions to members of our project team and feedback. Briefings with local community councils and other local organisations were also part of this phase.

Follow-on consultations – during phases 2 and 3 – provided updates on the progress of the design work and responses to earlier feedback, while also providing opportunities for further feedback. Public exhibitions held during phases 2 and 3 of public consultation focused on key areas which had been highlighted by the community during the previous phase as being of greatest interest to them. A series of CCS-focused site tours of the Peterhead Power Station took place in August 2014, while project update presentations to local community councils and other community organisations were also provided throughout 2014 and early 2015. The Project also had a presence at two key, family-focused community events during the summer of 2014.

Throughout the construction and operations phases of the Peterhead CCS Project, Shell is committed to maximising benefits to local communities. The main benefit will be the contribution to the local economy during the anticipated two-and-a-half year construction phase. During construction, there is likely to be an average construction workforce on-site of approximately 400 people, which may reach 600 people at peak construction. Shell will employ a partnership approach to ensuring that local opportunities are explored and optimised. These will include employment opportunities for locals (where appropriate skills and levels of experience exist), sub-contracting and supply opportunities for local businesses, along with opportunities for local facilities and service providers.

The partners in this effort will be Shell; SSE as strategic partners in the project; the main contractors who will be carrying out the construction work; Scottish Enterprise, who have vast experience of supporting SMEs and the development of new industries; and Aberdeenshire Council, who have extensive local knowledge and experience of supporting the delivery of local benefits during other local development projects.

First of a Kind

In the FEED phase, the project is developed into significant detail to make it ready for detailed design, construction and operation in the next phase. As such the FEED of this first of a kind project confirms the viability of low-carbon gas power from technical, commercial, regulatory and public acceptance perspectives to the next level of detail. Detailed learnings acquired during FEED development in these areas will be made available through the Department of Energy and Climate Change (DECC) Knowledge Transfer programme.

The project will also set a "First of a Kind" cost datapoint for low-carbon power, determined by the project specifics and constraints (duration, scale, supply chain, brownfield, etc.). Like all first applications it will be a first point on a learning curve which will be valuable for cost optimisation of follow-on commercial CCS projects and for focus areas for cost reduction. Specifically, equipment standardisation and simplification and supply chain optimisation have been shown to be areas for cost reduction in comparable energy industries, like combined cycle gas turbines (CCGTs).

A CCS industry cost reduction learning curve was developed in a joint government and industry UK CCS Cost Reduction Task Force report and it is projected that gas power stations equipped with CCS have a clear potential to be cost-competitive with other forms of low-carbon power generation and that gas CCS can play a significant long-term role in delivering the lowest cost decarbonised electricity mix.

Conclusions

This paper has touched on the objective for a low-carbon electricity CCS gas power demonstration project, the scope of the Peterhead CCS project, some process conditions, power plant integration, efficiency optimisation and integrated low-carbon power operation elements, permitting, communication and public consultation and the First of a Kind demonstration role of the project in moving up the learning curve and down the cost curve of commercial-scale, low-carbon CCS gas power.

In order to ensure that gas CCS is commercially available from the mid-2020s, a commercial-scale, full-chain demonstration is important. It will provide developers, regulators and the public with the learnings to support their confidence to pursue further deployment.

The project is part of Shell's broader CCS demonstration portfolio.

References

DECC. 2013. UK CCS Cost Reduction Task Force: The potential for reducing the costs of CCS in the UK. Available from: https://www.gov.uk/government/publications/ccs-cost-reduction-task-force-final-report

IEA. 2013. Technology Roadmap: Carbon Capture and Storage 2013. Available from: http://www.iea.org/publications/freepublications/publication/technology-roadmap-carbon-capture-and-storage-2013.html

Shell U.K. Limited. 2014. Peterhead Carbon Capture and Storage (CCS): Onshore Impact Assessment (1A) Scoping. Available from: http://s02.static-shell.com/content/dam/shell-new/local/country/gbr/downloads/pdf/upstream/peterhead-ccs-scoping-report.pdf

Shell UK Limited. 2014. Peterhead CCS Project. Available from: http://www.shell.co.uk/gbr/environment-society/environment-tpkg/peterhead-ccs-project.html

The Economist. 2014. Carbon Capture: Pipe Dreams - A fresh effort to store pollutants underground. July 15th. pp.31 e