PROJECT PIONEER

PIONEER'S TECHNOLOGY SELECTION
A NON-CONFIDENTIAL REPORT

Produced for the Global CCS Institute | 2013

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IMPORTANT NOTE REGARDING PROJECT PIONEER – APRIL 2012

On April 26, 2012, TransAlta, along with partners Capital Power and Enbridge, announced the decision not to proceed with the carbon capture and storage (CCS) project called *Project Pioneer*.

The Pioneer partners concluded that the technology works and that capital costs were in line with expectations. However, the market for CO_2 sales and the value of emissions reductions in Alberta and Canada are not sufficient, at this time, to allow the project to proceed.

While it is disappointing to be unable to achieve the result hoped for, it is important to remember that the purpose of Project Pioneer was to 'prove out' the technical and economic feasibility of CCS before going down the major capital investment path. That purpose was achieved: the two years of hard work by the Project Pioneer team was a major success.

The Pioneer partners come out of this with a much deeper understanding of CCS in an Alberta setting. And of course, it is the intention to share this understanding with the federal and provincial governments and the global scientific community so others can benefit from what was learned.

This decision isn't a reflection on the long-term viability of CCS or the future of coal-fired generation. Coal is a critical fuel for power generation in Alberta and world-wide, and TransAlta believes it will continue to be a vital part of the global fuel mix.

TransAlta, Project Lead, Project Pioneer *fig.* 1.0

KEEPHILLS 3 PLANT

1.0

INTRODUCTION TO THE PROJECT

Project Pioneer would have been one of the first carbon capture and storage (CCS) projects to utilize an integrated approach for CCS, and was expected to serve as a prototype for the long-term, commercial-scale application and integration of CCS technologies to achieve reductions in greenhouse gas emissions. The partners in Project Pioneer were TransAlta Corporation (TransAlta), Capital Power L.P. (CPLP), Enbridge Inc. (Enbridge), the Alberta provincial and Canadian federal governments, and the Global CCS Institute as a Knowledge Sharing Partner.

Project Pioneer was proposed to capture 1 million tonnes of carbon dioxide (CO_2) annually from a coal fired power plant (Keephills 3[1]) and transport the CO_2 by pipeline to a sequestration site or to be utilized for enhanced oil recovery (EOR) in a depleted oil/gas field.

[1] The Keephills 3 power plant is a 495-gross-megawatt (MW) (450 MW net) coal-fired generating facility.

Keephills 3 began commercial operations in September 2011 as one of Canada's largest and cleanest coal-fired facilities and one of the most advanced facilities of its kind in the world. CO_2 emissions per MW will be lower than those from a conventional coal plant because less fuel is used to produce the same amount of power.

The key components of Project Pioneer were:

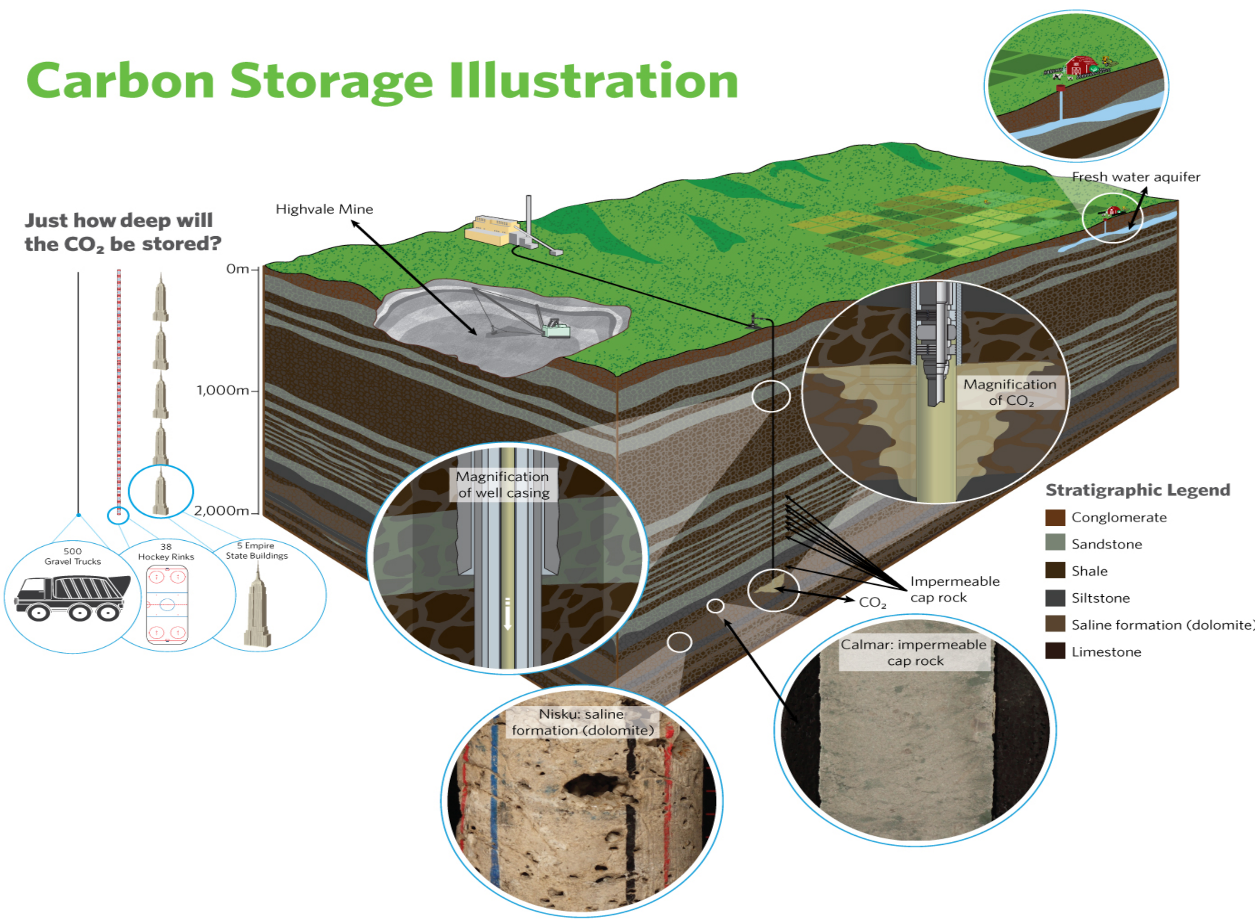
- Carbon capture facility (CCF)
- Pipeline from the CCF to the sequestration site
- Pipeline from the CCF to the EOR site
- Saline formation sequestration site

The Carbon Capture Facility (CCF) portion of Project Pioneer was to have been retrofitted onto the Keephills 3 coal-fired power plant. Keephills 3 is located approximately 70 km west of Edmonton, Alberta and is jointly owned by TransAlta and Capital Power.

The CCF was planned to treat approximately one third of the flue gas from Keephills 3 and would have captured approximately 1 million tonnes of CO_2 annually. The CO_2 was to be compressed and transported by pipeline to a sequestration site to be injected approximately 2 km underground into a saline formation known as the Nisku Formation. A pipeline was also to be built to transport the CO_2 to the primary EOR target, the Pembina oilfield, where the CO_2 would have been injected and used for EOR. The Pembina oilfield is approximately 80 km southwest of the Keephills 3 facility.

fig. 2.0

CARBON STORAGE ILLUSTRATION



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INTRODUCTION TO THIS REPORT

Before the inception of Project Pioneer, TransAlta had entered into a relationship with Alstom to examine the potential use of chilled ammonia as a CO_2 capture technology.

Alstom's proprietary chilled ammonia process removes CO_2 from flue gas streams and can be retrofitted to existing power plants. TransAlta identified the chilled ammonia process as one with the potential to be a low cost application for CCS.

As a demonstration project, an important part of Project Pioneer's purpose was the careful consideration of a range of technologies on a near-commercial scale. While several pilot or demonstration projects were under development in the early stages of Pioneer, the chilled ammonia process was not yet in commercial use. The largest chilled ammonia installation at the time of Pioneer's initial review was the pilot plant product verification facility at AEP Mountaineer in West Virginia, United States, which operated at a nominal 100,000 tonnes per year from September 2009 to May 2011. In 2011, AEP decided not to proceed with a larger demonstration plant due to government environmental policy uncertainties.

After completion of due diligence and careful consideration of a range of technologies, it was determined that amine scrubbing, a robust and well-established technology that has been in use since 1930 to separate CO_2 from natural gas, was a better fit for Pioneer given its particular circumstances.

This transition of capture technology was a natural output of the assessment process and proof that due diligence was working. Large-scale demonstration projects especially those involving new technologies or applications require careful thought, and it is not unusual for projects to consider all options to ensure they have the best fit for their particular needs.

TransAlta retains a strong existing relationship with Alstom, who has provided the company with technology and services for decades. Alstom remains committed to developing CCS technology solutions, and supports the progression of key demonstration projects like Pioneer so that CCS technology may be optimized in a manner that can only be accomplished via demonstration projects at scale.

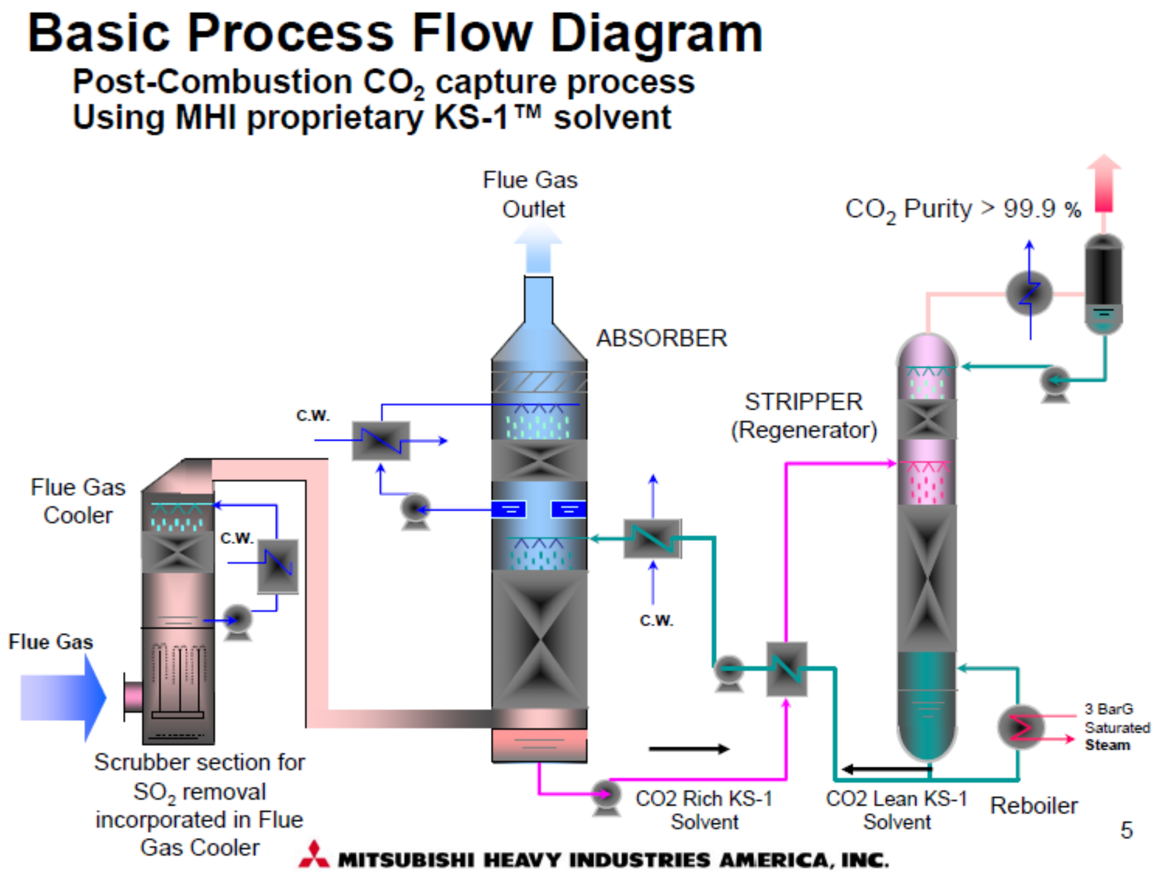
The process finally selected by Pioneer for the CCF was amine scrubbing, which is a widely practiced chemical process also known as amine gas treating, gas sweetening and acid gas removal. It is a process commonly employed in oil refineries, but also in natural gas processing plants in Alberta and other natural gas producing regions. One of the goals of Project Pioneer was to demonstrate the applicability of amine absorption to coal-fired power plants, which would be a relatively new application for the process.

Amine scrubbing refers to a number of commercial technologies that use various alkanolamines to remove acidic components such as hydrogen sulfide (H_2S) and CO_2 from gas streams. The underlying principle is the exothermic, reversible reaction between a weak acid such as CO_2 and a weak base such as an alkanolamines. The flue gas to be treated is contacted by the aqueous alkanolamines solution in an absorbing column or vessel where a soluble salt is formed from the reaction between the CO_2 and the alkanolamines. The flue gas, now depleted of CO_2, is then released to the atmosphere. The solution, 'enriched' with the CO_2, is sent to a stripping column or vessel where, by the addition of heat, the salt formation reaction is reversed and the CO_2 and the alkanolamines are regenerated. The "lean" alkanolamines solution is recycled to the absorbing unit while the CO_2 is made ready for transportation by dehydrating and compressing it.

fig. 3.0

AMINE SCRUBBING PROCESS

This report will discuss the process chosen by Project Pioneer to select a technology provider for its carbon capture facility.



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CARBON CAPTURE FACILITY

Overview

The CCF was designed to the following objectives:

- Being an addition to the operating Keephills 3 power plant, the CCF was not, under any circumstances, to adversely impact Keephills 3 operations;
- The CCF was to divert approximately one third of the flue gas emitted by Keephills 3 and treat it to remove 90% of the CO_2 before releasing the treated flue gas to the atmosphere;
- The CCF was to capture 1 million tonnes of CO_2 annually for 10 years from the CCF inlet flue gas stream to meet contractual obligations to the EOR customer, according to a supply and purchase agreement and to governments according to the various funding agreements;
- The instantaneous capture capacity of the CCF was designed to be 1.17 million tonnes per year to account for the Keephills 3 average availability of 90% and a minimum CCF availability of 95%; and
- The technology employed was amine scrubbing, which is the most technologically mature CO_2 capture technology available and the one nearest to commercialization at the scale required for coal-fired power plants.

Amine Scrubbing Technology

The process selected by Pioneer for the CCF was amine scrubbing. This process has been practiced for decades and is a standard chemical process in the oil and gas industry for removing CO_2 and sulfur dioxide (SO_2) from natural gas (also known as natural gas sweetening or acid gas removal) and for removing sulphur from refinery tail gas streams. It is also employed in the petrochemical sector in the manufacture of fertilizers and petrochemicals such as methanol and ethylene. Finally, it is in the early stages of commercialization on a pilot plant/demonstration unit scale for capturing CO_2 from the flue gas of both natural gas and coal-fired power plants.

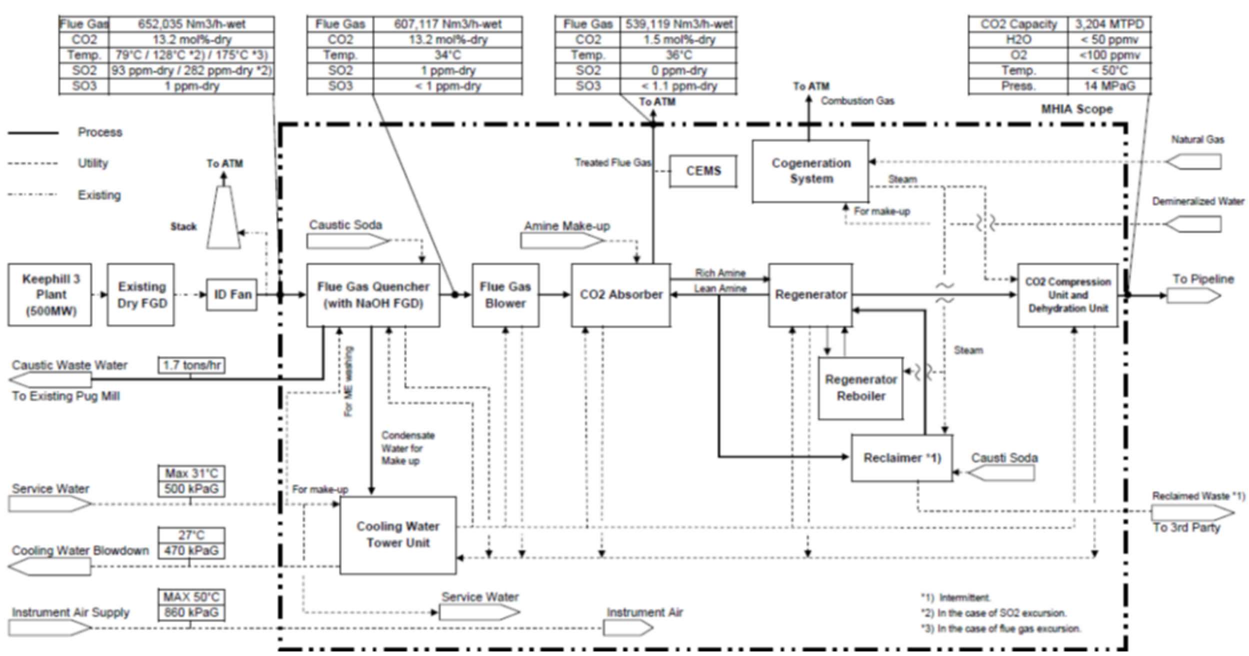
However, amine scrubbing is not yet commercially practiced on the scale for removing CO_2 from the flue gas of modern coal-fired power plants (typically 500 MW or larger). The critical differences between flue gas service and petroleum and petrochemical applications are the pressure of operation and the inclusion of particulates in power plant flue gas. In petroleum and petrochemical applications, the gas to be treated is available at a high pressure and the amine scrubbing process is conducted at the same high pressure. When capturing CO_2 from power plant flue gas, the flue gas is at near atmospheric pressure and the amine scrubbing process is conducted at this relatively low pressure. Consequently, the driving force for CO_2 transfer from the flue gas to the amine is lower, requiring increased amine circulation rates. In addition, the lower pressure of the flue gas results in a lower gas density which necessitates a larger diameter amine absorber. Project Pioneer was designed to be one of the world's largest scale implementations of amine scrubbing in coal flue gas service. It was intended to take a technologically-ready chemical process and demonstrate its performance, reliability and economics in an industrial scale situation.

As noted above, a second challenge when treating coal flue gas is the presence of contaminants in the flue gas. These may include traces of sulphur compounds, mercury and particulate matter. These contaminants are generally not present in flue gas from natural gas combustion. These contaminants may react or interfere with the amine scrubbing reaction and potentially cause problems such as degradation of the amines and/or fouling of reaction vessels. Therefore, the amine scrubbing process must be designed to be tolerant to such contaminants using methods such as trim sulphur removal, amines purification or reclamation, or other techniques.

A number of amine scrubbing processes are available worldwide and they share the same general design. The flue gas is contacted with a solution of formulated and synthetic amine compounds which may be primary, secondary, or tertiary amines. The amine reacts with the CO_2 present in the flue gas in the amine absorber according to a mild reversible reaction. The “rich” amine solution (enriched with the absorbed CO_2) is then transferred to a regeneration unit where heat is applied. The application of heat reverses the CO_2 absorption reaction. The CO_2 is stripped from the rich amine solution and is transferred to a downstream drying unit where the moisture content of the CO_2 stream is reduced to parts per million (ppm) levels. The CO_2 is then compressed for transportation by pipeline. The “lean” amine solution (containing a significantly reduced content of CO_2) is recirculated to the amine absorber tower for absorption of CO_2 from the incoming flue gas.

fig. 4.0

AMINE SCRUBBING FLOW SHEET



The major units of an amine scrubbing process are:

- Flue gas blower to facilitate flow of the power plant flue gas to the CCF;
- Vessel or column for contacting flue gas with the amine solution and removing the CO_2;
- Vessel or column for regenerating the amine solution and releasing the CO_2;
- CO_2 dehydration unit; and
- CO_2 compression unit.

Depending on the application and specific proprietary amine scrubbing processes, additional unit operations may be included such as flue gas cooling, flue gas sulphur removal, and amine purification/reclamation.

Distinguishing features between various processes offered by technology vendors include the use of specialized solvents and mixtures exhibiting performance parameters such as low heat of reaction, fast absorption rate, high capacity for CO_2, and resistance to thermal degradation. Various cost reduction opportunities offered include improved solvent regeneration, higher energy efficiency, and specialized proprietary equipment.

Process for the Initial Phase Engineering Studies

As the Project Pioneer leader, TransAlta initiated and managed the process to execute and deliver the Initial Phase engineering studies for the CCF. A review of all suppliers offering CO_2 capture using amine scrubbing was undertaken by Stantec, Pioneer's Owners Engineer. From this, a short list of 6 suppliers was developed. In January 2011, TransAlta contacted the selected suppliers of amine scrubbing technology and issued to them a Request for Information (RFI) to obtain preliminary information about their process capability and their interest in Pioneer. In April 2011, TransAlta invited the same suppliers to participate in a competitive Request for Proposals (RFP) for a Front End Engineering and Design (FEED) study. The initial structure of this RFP process was modified during its implementation as a result of discussions between TransAlta and the proponents. The process that was implemented can be outlined as follows:

- An RFP for a FEED study for the CCF was issued in April 2011 to suppliers of amine scrubbing technology:
- Full FEED *proposals* were received from 6 proponents including all major vendors of amine scrubbing systems;
- The proposals were evaluated during May 2011 against established criteria. As result of discussions with the proponents, it appeared that it could be possible to obtain a fixed price engineering, procurement and construction (EPC) contract;
- Two proponents were selected to provide fixed price EPC contract proposals. As a parallel undertaking, one of the proponents was selected to perform the actual FEED study for the Pioneer CCF;
- The EPC proposal from Mitsubishi Heavy Industries was selected and would have been the basis for a fixed price EPC contract in the next phase of Project Pioneer.

Request for Proposal

RFP Timelines

The detailed RFP with the requirements outlined below was issued in April 2011. During that month, and with confidentiality agreements in place, proponents were required to make a 3-hour presentation to members of the Pioneer team on certain criteria that were key elements for the Project. Six final responses to the RFP were received in early May 2011.

RFP Objectives

The objectives of the RFP were as follows:

- To define the objectives and schedule of the Initial Phase engineering studies to meet the requirements of the Pioneer Partners as well as the requirements of the funding agreements with the Provincial and Federal Governments;
- To outline TransAlta's expectation for management of the studies;

- To provide an indicative cost for the supply and installation of the CCF;
- To provide information as to the capability of the proponents proprietary process in meeting the Project Pioneer objectives of reasonable scale-up, proven process design and proven operability and reliability;
- To define the budget for the studies; and
- To select proponent(s) for the Initial Phase studies.

Required Contents for the RFP Response

The RFP was a detailed document intended to procure services from qualified EPC organizations and technology providers. It contained all the necessary information for proponents to prepare a response according to established contents specifications and selection criteria.

The required response contents included the following:

- Executive summary
- Assumptions and constraints
- Proponent’s organization
- Innovation
- Management, controls and reporting
- Specific information requirements:
  - Technology Status
  - Technical Information
  - Commercial Information
  - Cost of Services
  - Exceptions to the proposed Professional Services Agreement
  - Comments to the Scope of Work
  - Preliminary Action Plan
  - Schedules and Contract Dates
  - Table of Key Personnel
  - Basis of Estimate

RFP Evaluation Criteria

The following features received careful consideration during the evaluation process:

1. *Technology status.* The maturity of proponent’s capture technology in terms of status of commercial plant experience using flue gas other than coal-fired flue gas, pilot plant experience using coal-fired flue gases, etc. was a critical evaluation criterion.
2. *Project scope.* It was the intent of TransAlta to maximize the proponent’s scope in order to minimize TransAlta’s involvement in the management of work between various contracting parties. In addition to the process design of the CCF, proponents were expected to maximize their scope by adding other detailed engineering, procurement, construction, and management tasks for the CCF. The proponent needed to indicate ability and willingness for:
   a) Detailed engineering and procurement of the capture island;
   b) Balance of plant design, engineering and procurement; and
   c) Construction of the CCF.
3. *Construction of the CCF.* Pioneer’s preference for engineering, procurement, construction and commissioning of the CCF was a fixed price turnkey contract. The proponent had to advise whether this would be available or, in the alternative, what approach would be offered. Details including the description of in-house capabilities and alliances or partnerships, if any, for executing each specific task had to be provided.

4. *Schedule.* It was critical that an in-service date prior to January 1, 2016 be achieved for the CCF. Assuming that a Limited Notice to Proceed (LNTP) which would allow detailed engineering and long lead procurement to proceed, would be issued not later than August 1, 2012 and a Full Notice to Proceed (FNTP) issued not later than April 1, 2013, the proponent was required to indicate whether the CCF would be declared operational at full capacity by January 1, 2016 and the guarantee that would be available to support this commitment.

5. *Performance guarantees.* The proponent was required to provide details, including structure and remedies (with amounts), of guarantees that would be available to address the following:

   a) *Capture volume.* The target net capture volume for Project Pioneer was 1.0 million tonnes per year. The CCF was to be in service for a minimum of 10 years. The basis for ensuring that this capture volume was met had to be outlined, including estimated nominal design capacity, capture efficiency and capture facility availability, assuming that the Keephills 3 host facility will have an average availability of 90% and that major maintenance of the CCF could be coordinated with planned maintenance outages at Keephills 3.

   b) *Parasitic load.* Parasitic load is typically defined as the total equivalent power consumption for the CCF and is comprised of the electrical load from the grid and the power plant derate power (due to use of power plant steam). Power and steam consumption by the capture process were important economic considerations. The proponent needed to indicate how the design consumption values would be guaranteed.

   c) *CO_2 product quality.* The design CO_2 specification had to be met to assure suitability for pipeline transportation and sales to EOR customer. The proponent was expected to indicate how achieving design quality values would be guaranteed.

   d) *Emissions levels.* The CCF had to meet all environmental regulations. The proponent was required to indicate how compliance with environmental regulations would be guaranteed. In addition, the proponent was required to describe an approach to deal with potential public concern over nitrosamine emissions.

   e) *Chemicals and solvent consumption.* The unit price of solvent and the solvent consumption rate have a significant impact on the operating cost of the CCF. The proponent was required to guarantee the price of solvent and its consumption rate per unit of CO_2 captured over the life of the Project. Similarly, any significant requirement for other chemicals for reclamation of amines had to be guaranteed.

   f) *Cooling water requirement.* The cooling water requirement in terms of MW thermal load for the amine scrubbing plant was to be provided by the balance of plant facility. The proponent was required to indicate how cooling water requirements would be guaranteed so that the amine scrubbing plant performance would not be constrained by cooling water supply.

6. *Aboriginal content.* It is TransAlta's stated policy to maximize aboriginal content, giving consideration for labour, material, equipment and services. Further, it is TransAlta's objective to provide special consideration to sourcing from aboriginal owned firms, and the employment of aboriginal people. The proponent was expected to give full consideration to this policy, and submit with its proposal a summary of the aboriginal content anticipated.

7. *Investment in Pioneer.* Recognizing that CCS technology is still in a development phase and that it is not yet fully commercial, proponents were invited to participate in the funding of Pioneer. This participation could have been in an amount of up to $50 million. The proponent was required to outline amounts that would be available and the preferred participation structure(s) relating to an investment in Pioneer.
8. *Knowledge sharing.* One of the key objectives of Pioneer is the furtherance of knowledge transfer relating to CCS. The various funding arrangements contained obligations to share knowledge gained from Pioneer. The proponent was required to advise of knowledge sharing policy and approach, and to provide details of circumstances where knowledge sharing commitments had been observed in other carbon capture projects.

EPC Contract Proposals

Purpose

The purpose of Project Pioneer was the demonstration of a technology that had yet to be proven at the scale of 1 million tonnes per year CO_2 capture. Thus, a number of uncertainties existed that could result in cost overruns and schedule delays. Many of these uncertainties arose from the design, construction and operation of the CCF.

Therefore, a critical requirement of the Initial Phase engineering studies was that they would lead to a fixed price lump-sum turnkey contract for detailed design, engineering, procurement, construction and commissioning of the CCF. The deliverables from the engineering studies were to provide the information for Pioneer to negotiate the terms of a fixed price EPC contract at the end of the Initial Phase and to understand the long term performance and risks of the CCF.

Only 2 of the original 6 proponents were selected to provide fixed price EPC contract proposals. As a parallel undertaking, one of the proponents was selected to perform the actual FEED study for the Pioneer CCF.

Technical Scope

The scope of the CCF FEED was to further the engineering design and to evaluate alternatives to facilitate the development of a firm price lump sum turnkey bid and to allow the Project to proceed to the next stage (Detailed Design). The design the CCF was to incorporate engineering and process control methods such that the CCF would have no impact on the Keephills 3 plant reliability and availability over the expected life of the CCF. This was to be achieved by a combination of sound engineering practice, failure analysis, high quality equipment procurement, maintainability, some degree of equipment redundancy, control design strategy and other appropriate techniques. The design also optimized CCF performance by utilizing proven design with acceptable risk to Pioneer. First-of-a-kind and prototype designs were not acceptable for the Project. Any heat integration and other interface with the Keephills 3 facility was required to be evaluated for risk and benefit before being incorporated into the final design.

Proponents were to design the CCF: (i) to comply with all applicable codes and standards; (ii) to be suitable for the site ambient conditions; and (iii) in accordance with generally accepted industry standards having reference to similar plants in Alberta with respect to:

a) Safety;

b) Automatic, remote operation;

c) Expected operating lifetime of the equipment life of 30 years; however, the business case was based on CCF plant life of 10 years (approximately 2016 to 2025); and

d) Maintainability based on a major overhaul every 24 months.

The Project Pioneer CCF design was divided into two major components:

- The *Amine Scrubbing Unit* (ASU). The ASU system included flue gas cooling and desulphurization, CO_2 capture, CO_2 compression and the dehydration unit.
- The *Balance of Plant* (BOP). The BOP covered remaining items not in the scope of the ASU including the heat rejection system, utility tie-ins, civil and structural work, and construction of all ASU and BOP components.

A summary description of the key technical elements of the engineering studies is provided below.

- *ASU.* The proponent's proprietary process for amine scrubbing CO_2 from the flue gas was to be proposed. The flue gas for the ASU was to be sourced from the Keephills 3 boiler after the induced draft fan and before the stack inlet. Any cooling and pre-treatment for the flue gas to meet the condition necessary for proponents' absorption process would need to be incorporated by the proponent. Pioneer required that the treated flue gas be vented at the CCF rather than returned back to the existing Keephills 3 stack. CO_2 recovered would be compressed in the CO_2 compression system and dehydrated to meet the pipeline and EOR specification.
- *BOP.* The BOP was comprised of the systems to provide various utilities such as steam, cooling water, air, service water, fire water, electrical power, control and instrumentation as necessary for the ASU to be a fully functional plant.
- *Steam for the ASU.* The original design expectation for providing steam to the ASU was to supply it from the existing Keephills 3 steam turbine, specifically from the intermediate pressure to low pressure crossover, with the condensate from the ASU returning to the Keephills 3 power cycle.
- *Water sourcing.* All cooling and service water requirements would be provided from existing Keephills cooling water ponds. Demineralized and potable water would also be provided from the Keephills 3 unit.
- *Waste disposal.* The Project could utilize the existing Keephills effluent treatment pond, chemical treatment pond and sewage lagoon for disposing liquid discharge from the CCF. Spent chemicals would be neutralized and drains from these ponds directed to the cooling water pond. Options were available regionally for truck disposal to dedicated chemical disposal sites. No amine discharge to the environment was permitted.
- *Geotechnical investigation.* A geotechnical investigation report for the Keephills site was available for preliminary foundation design. The proponent would determine further geotechnical investigation requirements as the site layout and general arrangement drawings would be finalized.

The FEED study was divided into two phases – Phase I and Phase II. Phase I work was designed to provide early information need for ongoing permitting and commercial activities such as the negotiation of the government funding agreements. Phase II work would assist the Pioneer team with selecting the successful proponent for entering into the fixed price EPC contract for the CCF.

Specific technical scope elements of the required engineering studies are listed below:

Phase I

- Preliminary site layout and general arrangement of the CCF;
- Design concepts for all major parts of the CCF;
- Development of the CCF process design, design basis and project definition documents;
- Physical scope of the CCF in terms of all major systems, equipment, buildings and structures necessary to provide for a highly reliable Project;
- Process Flow Diagrams (PFD) and Piping and Instrumentation Diagrams (P&ID);
- Heat and material balances for different scenarios;
- Performance of the CCF in terms of net capture, steam, auxiliary power consumption etc.;
- Development of the modularization concepts ranging from prefabrication of vessels or assemblies to full truck or rail transportable skid assemblies including electrical, instrumentation and control, and utilities preinstalled;
- Preparation of the bidders list for equipment and construction packages;
- Invitation for and receipt of major equipment bid packages;
- Annual operation and maintenance estimate for the CCF;
- Necessary engineering data, drawings, design basis documents for supporting Environment Assessment applications by TransAlta;
- Update of the expected project performance and capital cost to the accuracy of +/-30%;
- Performance guarantees and associated liquidated damage clauses as applicable;
- Project report on Phase I deliverables;
- A high level (Level 2) schedule; and
- Preliminary cash flow projection based on the Level 2 schedule.

Phase II

- Preparation of detailed technical specifications and data sheets for inviting bids from potential suppliers for critical CCF equipment;
- Evaluation of critical equipment bids as received, and review of preliminary contracts and vendors selected for Project execution;
- Engagement of critical equipment suppliers to provide process, civil/structural, mechanical, electrical engineering data for supporting cost estimate with +/-15% accuracy;
- Start of building steel design and engineering, based on the data from equipment vendors;
- Revision and update of the site layout, PFDs, P&IDs with vendor provided data;
- Preparation of bill of quantities for civil/structural, piping, and electrical items;
- Preparation of risk assessment documents for different sub-systems and incorporation in the design;
- Invitation for and receipt of bids or proposals/ quotes for other non-critical items;
- Preparation of contract ready documentation for all long lead critical items;
- Invitation for and receipt of bids for major construction packages;
- Predicted plant performance in terms captured CO_2, steam, cooling water and other auxiliary power consumption, reagent feed for CO_2 capture and other air pollution controls;
- Capital cost estimate to the accuracy of +/-15%;
- Detailed CCF execution plan for Project implementation;
- Hazard Identification Study (HAZID) and/or Hazard and Operability Analysis (HAZOP) and incorporation of results in designs; and
- Detailed (Level 3) schedule.

Deliverables

The deliverables for the required engineering studies were the following:

1. FEED study plan, cost estimate and schedule;
2. Management of the FEED study under the proponent's scope;
3. All design work and deliverables within proponent's scope to enable the Project team to complete the study objectives and deliverables;
4. Process design completed to the extent that performances guarantees for the process can be negotiated with liquidated damages;
5. Capital cost estimate to the accuracy of +/- 15%;
6. Level 3 EPC schedule for all work in proponent's scope;
7. All design work to enable TransAlta to progress with environmental permitting of the facility;
8. All design work to enable the Project team to complete an economic business case model and other criteria for final Project execution approval;
9. Studies for optimization of various process sub-systems, if required;
10. Risk assessment for all work in proponent's scope;
11. Major supply contracts negotiated to the point of scope and pricing certainty;
12. Major construction contract(s) terms and conditions negotiated; and
13. Monthly reporting as required.

Operations and Maintenance Overview

The CCF was designed to be a fully functional stand-alone facility and included typical Alberta based chemical plant design, operations and maintenance considerations. The following key aspects were incorporated in the CCF design:

- Minimization of the total life cycle costs (capital, operating and maintenance);
- Minimization of regulated and unregulated emissions;
- Safe, reliable and efficient operation;
- Inclusion of a high degree of automation to minimize operator staffing;
- Designed in a manner so as to facilitate long term operation and maintenance;
- Designed with safety of the utmost importance, with the safety of all construction and CCF operating and maintenance personnel, and equipment considered in all aspects of plant design.

In addition, the CCF was designed to be a relatively easy plant to start-up and operate and incorporated elements for the effective and safe performance of routine maintenance activities, The CCF design gave a high priority to process and personnel safety, including typical chemical industry equipment layout including ladders, platforms and interconnecting walkways for general routine operations and maintenance access.

Outcome of the Technology Selection Process

The result of the RFP process was the selection of the Mitsubishi Heavy Industries America to perform the FEED study.

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CONCLUSION

Selection of the capture technology provider was a competitive process, which considered experience (as demonstrated by pilot projects) and the ability to offer a fixed price EPC contract as key selection criteria. Construction of the CCF facility was planned to commence shortly after the FNTP date in April 2013, and was planned to be completed and commissioned ready for commercial operation in December 2015. The EPC contract negotiated but not signed with MHI was a fixed price, turnkey contract and included the design, procurement, construction, commissioning, warranty, and performance guarantee of the complete CCF plant. MHI would have acted as the “prime” contractor for the construction of the CCF, and would have been responsible for all site activities and safety under an “open managed site”. TransAlta would have managed this contract directly.

The relative newness of the capture technology and the requirements of the government funding agreements with respect to reimbursement of funding if the Project did not meet certain schedule and performance targets meant that a great deal of effort was spent on the EPC agreement performance guarantees. A unique structure was developed where different levels of CCF performance had to be achieved to meet both government and industry partners expectations. Liquidated damages were specified for failure to meet minimum performance levels by a certain date.

Lessons Learned

The amine scrubbing technology was determined to be the technology most mature and closest to commercialization from a technical standpoint. Project Pioneer concluded that it was technically and operationally feasible to retrofit amine scrubbing technology onto a coal-fired power plant.

It is best to consider the CCF as a standalone CO_2 production unit and not as a power plant compliance unit. When designing the CCF as a compliance unit, the key goal will be the carbon intensity of the power plant and, consequently, a mandated amount of CO_2 must be captured per unit of electricity produced in order to meet the emissions target. In other words, the design must ensure that the prescribed percentage of CO_2 in the flue gas must be captured for all volumes of flue gas. This implies a close-coupled interface and a high requirement for CCF availability and reliability which drives the design to specify redundant and spare units that must be available on short notice. It also implies that the process must be designed to capture the prescribed CO_2 percentage under a number of power plant operating load scenarios which drives the design to specify process safety allowances. On the other hand, designing the CCF as a standalone production unit removes the need to match the power plant’s operations and reliability. The goal becomes to produce the contracted amount of CO_2 for customers. This approach opens opportunities for cost reductions, particularly in the interface with the power plant and the approach to online sparing of process units.

Reliability practices from the chemical industry, rather than from the power industry should be applied to the design of the CCF. Power plants are designed for very high reliability because of the impossibility to “inventory” electricity. Thus, very high availability is required to meet customer needs. This drives the design to specify many online equipment redundancies. This practice is further enabled by the ability of the industry to earn a set return on capital in the case of operation in a fully regulated setting. By contrast, availability requirements are not as high in the chemical industry due to the capability to inventory product and the full exposure of capital to market fluctuations. In general, the chemical industry practices call for fewer redundancies in process units, compensating somewhat with specifying more reliable equipment.

Costs and operating complexity are reduced when minimizing the interface between the CCF and the power plant. Sourcing of power and steam from the power plant to supply the CCF, while apparently attractive, entails higher costs than expected due to (i) the imperative to protect power plant operations; (ii) the requirement to avoid long term reliability impact; and (iii) the need to ensure CO_2 production under a number of power plant operating scenarios. Production of steam and power by a standalone cogeneration unit, might simplify the interface and reduce overall cost.

Deep and early involvement of the power plant owners (TransAlta and Capital Power) made for a win-win situation that allowed the identification of many cost saving opportunities. The engineering process adopted by Pioneer did not insulate the technology provider (MHI) from the power plant engineers.

Project cancellation was a tough decision for the industry partners to make.

The decision to terminate the Project was not a reflection on the long-term viability of CCS or the future of coal-fired generation. It was dictated by specific Project circumstances such as the preference for new technologies using horizontal wells over CO_2 EOR in the regional oilfield, uncertainties about the current and future value of emissions credits and strict government funding deadlines that did not allow more time for alternative market strategies to be investigated and brought to fruition.

The approximately $30 million spent on Pioneer studies and technical investigations has had the substantial benefit of contributing to the growing body of knowledge around CCS technology. In addition, it also accomplished exactly what it was supposed to – determining engineering and economic feasibility and informing the decision about taking Project Pioneer to the next stage. As such, the Project team felt that the outcome of the Initial Phase studies and investigations contributed value to protected shareholder value and government funds.

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APPENDIX

Technology Evaluation Scorecard

Assessment Criteria	Importance Weighting
Technical	**50%**
Technology Status	**20%**
Piloting and commercial experience	10%
Ongoing participation and demonstration unit experience	5%
Solvent/technology development opportunities	1%
FMEA	4%
Technical Response	**20%**
General performance parameters	7%
Pioneer specific information (PFDs, P&IDs, general layout drawings)	8%
Class 5 cost estimate for CCF	5%
Commercial Response	**10%**
Performance guarantees (capture volume, parasitic load, CO_2 product quality, emissions levels, chemicals and solvent consumption, cooling water requirement) and LDs	10%
Commercial/Contractual	**10%**
Cost of Services	**5%**
Cost of FEED study	5%
Exceptions to Terms and Conditions	**5%**
Exceptions to terms and conditions of the PSA	5%

Assessment Criteria	Importance Weighting
Execution	**40%**
FEED Execution	**10%**
Ability to meet project schedule and contract dates	3%
Preliminary action plan	4%
Key personnel	3%
EPC Execution	**30%**
Execution team: Key alliance partners	8%
Willingness to provide full wrap EPC price	10%
Exceptions to EPC contract term sheet, if any	4%
High level execution plan	5%
Proponent's organization (safety record and quality management and/or quality control program)	3%
Total percentage	**100%**

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