PROJECT PIONEER

TRANSPORTING CO_2

A NON-CONFIDENTIAL REPORT

Produced for: Global CCS Institute | 2012

Capital Power Corporation

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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

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 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.

The key components of Project Pioneer were:

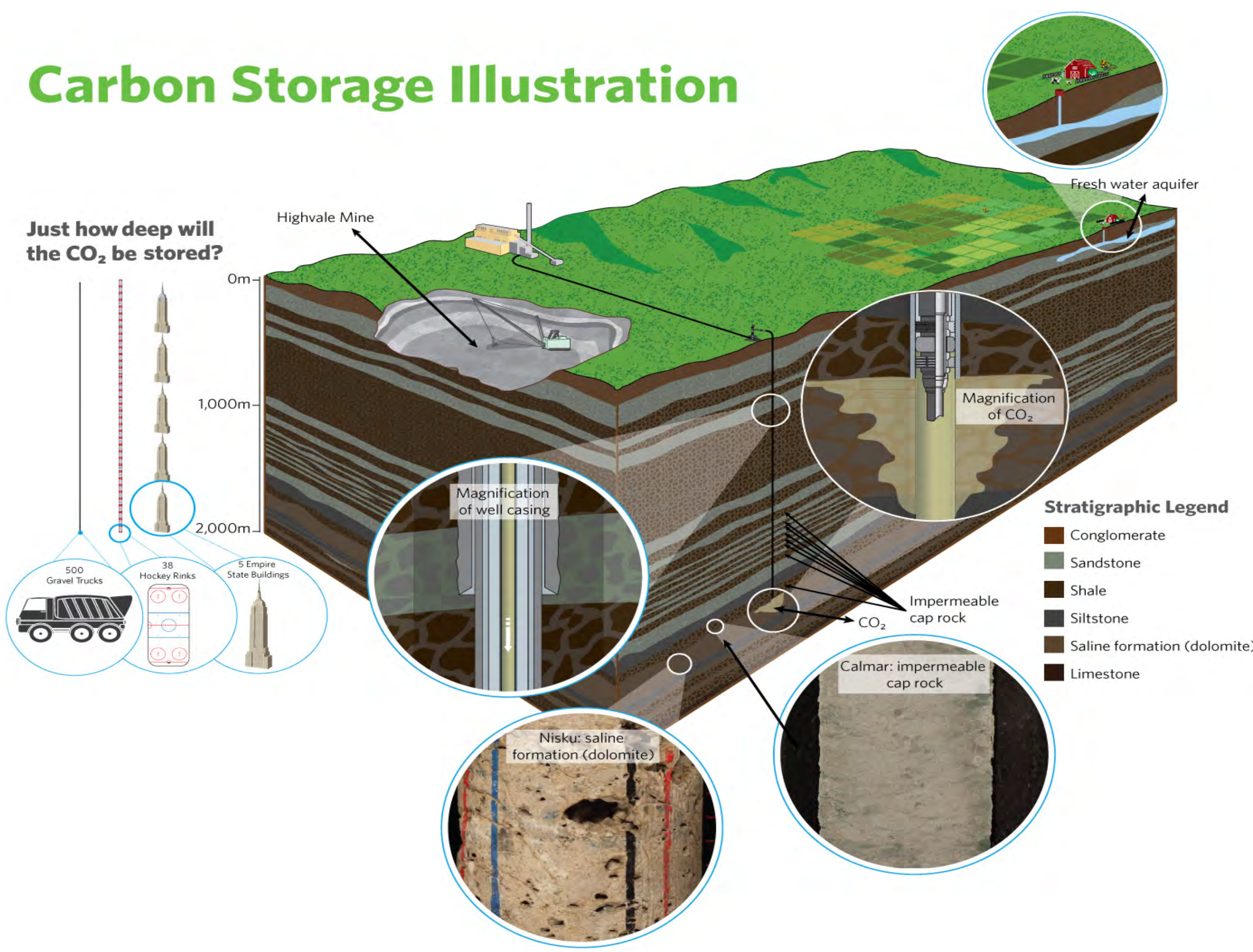
- Carbon capture facility (CCF)
- Pipeline from the CCF to the sequestration site
- Pipeline from the CCF to the EOR site
- Saline formation sequestration site

The Carbon Capture Facility (CCF) portion of Project Pioneer was to be 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 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 would have been 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 would also have been built to transport the CO_2 to the primary EOR target, the Pembina oilfield, where the CO_2 was to 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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CO_2 TRANSPORTATION: UNDERSTANDING THE BASICS

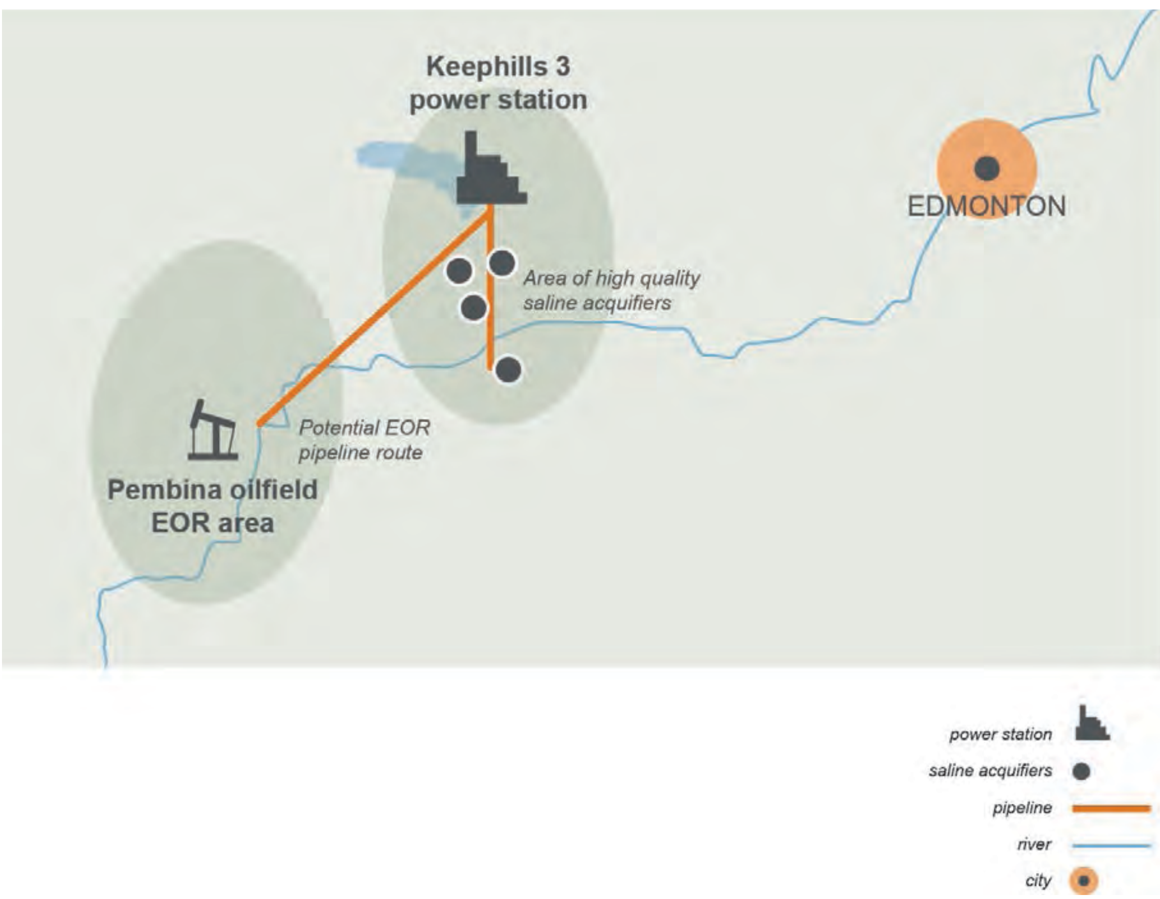
Project Abstract

Project Pioneer would have been a multi-year partnership between industry and government committed to providing leadership, expertise and financing for a commercial scale carbon sequestration project in Alberta, Canada.

The transportation of CO_2 was considered and designed as two systems; the EOR pipeline system, with routing from the Keephills 3 CCF Plant to the Pembina Oil Field, (the Pembina Oil Field is located 15 km south west of Drayton Valley, Alberta), and the sequestration pipeline system, from the Keephills 3 Plant to the designated sequestration field located 6 km south east of Keephills 3.

fig. 3.0

COMPONENTS OF PROJECT PIONEER



CO_2 Pipelines Part of Global Development of Carbon Capture and Storage

Carbon Capture and Storage (CCS) projects are being built in countries around the world as a key tool to reducing greenhouse gas (GHG) emissions.

Canada and Alberta are fast becoming leaders in CCS development, and with an already existing energy infrastructure in Alberta, that puts the CCS industry and projects at an advantage.

As facilities are built to capture CO_2 at oil sands upgraders, coal-fired power plants and other industrial sites, and as CO_2 is stored in deep underground rock formations or used for enhanced oil recovery, we know that the CO_2 will have to be transported and in Alberta that will be by pipelines.

CO_2 Pipelines Operating Safely for Decades

CO_2 pipelines are very similar to the pipelines that have been used to transport oil and natural gas safely for decades. Most of the world's CO_2 pipelines are in the U.S. and, according to a Congressional Research Service Report for Congress, approximately 5,800 kilometres of CO_2 pipelines currently operate safely and successfully in that country.

CO_2 pipelines have not been as prevalent in Canada, however a CO_2 pipeline has been operating safely now for a decade delivering CO_2 from a North Dakota coal gasification plant in the U.S. to Weyburn, Saskatchewan for enhanced oil recovery. As with existing large-diameter pipelines in Alberta, new CO_2 systems that will be built in the province will be buried, regularly inspected and maintained, and monitored 24 hours a day from a pipeline control centre.

CO_2 Pipelines in Alberta Subject to Existing ERCB Regulations

Alberta's Energy Resources Conservation Board (ERCB) has regulated CO_2 projects in the province for more than 20 years and will continue to do so. The ERCB has stated that the processes described in its Directive 56 "set out the key applications requirements for prospective developers of CCS projects with respect to transportation of CO_2 via pipeline and CO_2 disposal to underground geologic formations." The Board has also noted that project developers must also "comply with other ERCB regulations as well as legislation, laws, regulations and requirements of other government jurisdictions that may be applicable to CCS projects in Alberta."

That means that proponents of CO_2 pipeline projects in Alberta will continue to comply with all of the recently updated Directive 56 requirements, including participant involvement, notification of landowners and stakeholders, providing information to landowners and stakeholders, holding informational open houses, answering questions, and seeking confirmation of non-objection from landowners and occupants of the right-of-way.

CO_2 Pipelines Safely Constructed and Operated

CO_2 is a naturally occurring gas that exists in trace amounts in the earth's atmosphere. It is produced from the combustion of coal or hydrocarbons, and the breathing of humans and animals. Plants convert CO_2 to carbohydrates, producing oxygen in the process. CO_2 has a slightly irritating odor, is colorless and heavier than air. The main risk with it occurs when a large release of gas lingers at ground level, displacing oxygen.

Industry has been working for a number of years to advance CCS in terms of technology, policies and regulations, economics and safety. Studies have been done to better understand the behaviour of CO_2 in pipelines and in the event of a pipeline release. As a result of such work, industry is developing best practices to ensure that when a large-diameter CO_2 pipeline is built in Alberta it is designed, built and operated safely. Factors such as pipe diameter and thickness, location of shut-off valves, development of an Emergency Planning Zone along the pipeline route, and the pipeline route itself are all part of safety planning.

The bottom line is that, as stated in a research report entitled "Carbon Dioxide Pipelines: A Preliminary Review of Design and Risks" by Canadian researchers Barrie, Brown, Hatcher and Schellhase, "CO_2 pipelines can be safely constructed by ensuring that adequate risk assessment is done and that conventional wisdom is used in both design and operation."

Regulatory Framework Assessment (RFA)

In order to identify and address any potential regulatory gaps associated with CCS in Alberta, a multi-disciplinary steering committee that is being supported by an international panel of experts is working to review the existing rules and regulations, at the operational level, that impact CCS activities such as approval and operation of CO_2 pipelines.

Assessments are being conducted to ensure the regulatory framework around CCS activities is world class, and will ensure these activities are conducted safely at large scale. In the province of Alberta, oil and gas activities are typically regulated by the Energy Resources Conservation Board (ERCB), Alberta Energy, and Alberta Environment and Water. It is anticipated that the RFA will conclude its work by the end of 2012.

2.0

CO_2 TRANSPORTATION: THE CASE OF PIONEER

Pioneer's Proposed CO_2 Transportation Pipeline Overview

The proposed Project Pioneer CO_2 transportation pipeline, the longest component of the EOR Pipeline System, would capture CO_2 from the existing Keephills 3 coal-fired electricity generation facility and transport the substance by conventional pipeline technology to EOR wells located in the maturing Pembina oilfield, southwest of Drayton Valley.

Once CO_2 has been captured, it is dehydrated, compressed and pressurized, prior to transport. The CO_2 is pressurized so that it becomes denser and behaves more like a liquid, allowing easier and more cost efficient transportation.

Two Pipelines

It's important to note in the context of this report, that the pipelines have been treated separately and in separate sections. This has been done very deliberately.

The pipelines, like the other project components, were treated in a varying way – as either "part of a larger project as a whole" or as "separate mini-projects within the major project". This approach was driven by the regulatory review and permitting approach adopted by the various federal and provincial departments who had review and permitting jurisdiction over the project as a whole, or the project individual components.

Within the federal Canadian Environmental Assessment Act (CEAA) review, the project components were regarded holistically at one stage (submission of the Environmental Impact Submission, or EIS), but also to some extent separately.

▪

In the provincial regulatory process, the project was split into components, largely because the provincial regulatory agencies responsible for the project had their own individual processes for applications for the project components – Energy Resources Conservation Board (ERCB) for the pipelines, and the Alberta Utilities Commission (AUC) for the plant. The one agency that would tend to require an integrated approach to the project (Alberta Environment) elected not to require the partners to provide an environmental assessment, which could have been the mechanism at the provincial level to develop an integrated assessment of the whole project.

Other considerations for the separate treatment include:

- pipelines were to be developed by Enbridge, a separate company than the developer(s) of the capture plant and sequestration field;
- the pipelines; apart from the federal environmental assessment; were necessarily following a different federal and provincial regulatory schedule; and
- within the pipelines regulatory schedule, the two pipelines – sequestration and enhanced oil recovery – were potentially following different regulatory schedules, and
- fundamentally, the two pipelines went in opposite directions, so there would be different areas affected, a different stakeholder community, and other distinctions.

Enhanced Oil Recovery Pipeline System

About the System

The proposed Enhanced Oil Recovery (EOR) system would have consisted of the following components:

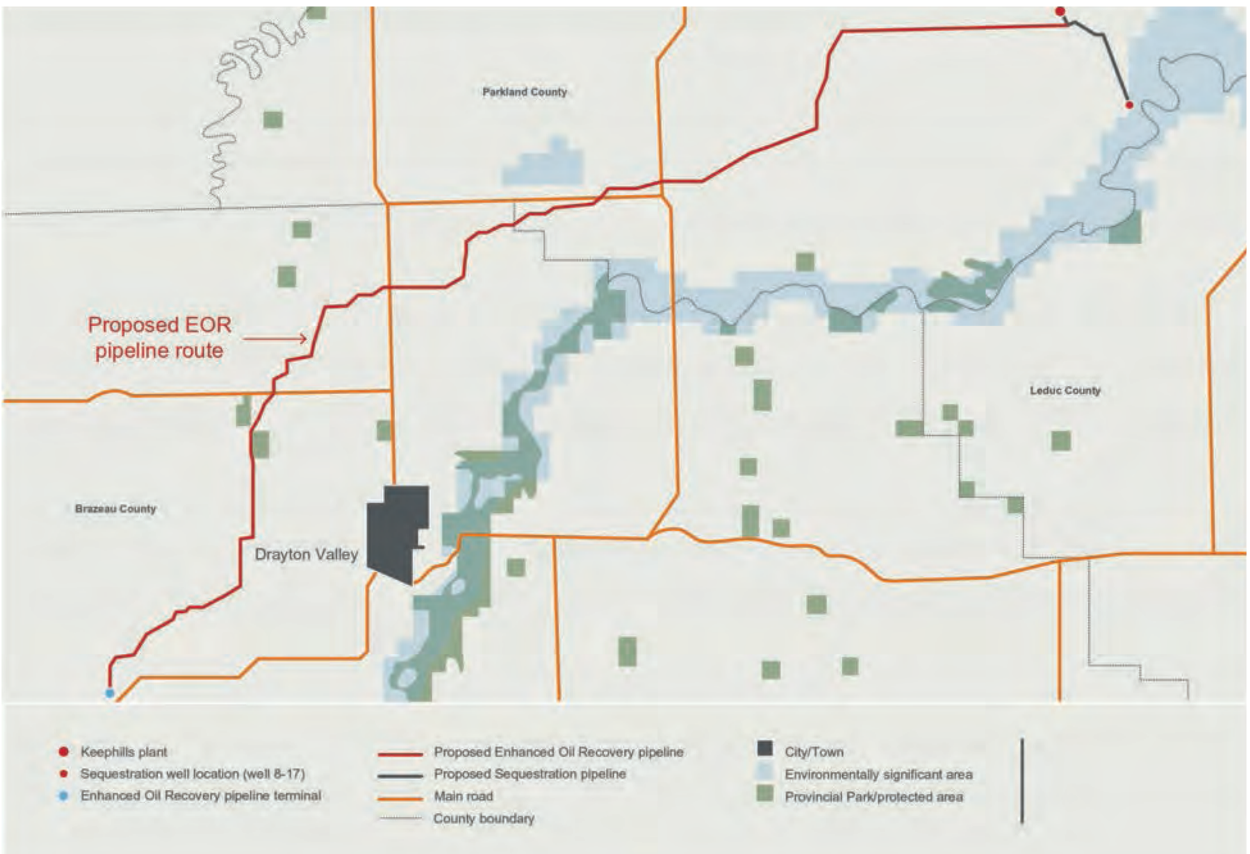
- One NPS 10 (273.1 mm OD) pipeline to transport CO_2 from the Keephills facility to the Pembina Oilfield located southeast of the Keephills facility;
- Product metering facilities and leak detection equipment to ensure safety and custody transfer to the EOR customer;
- A pig launcher at the Keephills facility and a pig receiver at the PennWest receipt site to launch inspection tools to ensure pipeline integrity;
- Block valves along the route to protect communities and to reduce release volumes in case of a product release;
- Throughput and pressure (1.17 million metric tons of CO_2, with a line pressure of 14.8 MPa or 2,150 psi).

Pipeline Route

The last version of the proposed EOR pipeline route is below. The Project was in the process of conducting environmental studies, engineering design work, and stakeholder engagements and consultations, when the decision was taken not to proceed with the Project.

fig. 4.0

PROJECT PIONEER PROPOSED EOR PIPELINE ROUTE



Safety

Safety begins with design and construction. The Project Pioneer pipeline was being designed and built by Enbridge. Enbridge has more than 60 years of experience in pipeline construction and assuring integrity and safety inspections before and after putting a pipeline into service.

Project Pioneer had planned to continuously gather data and monitor the facilities and pipeline system for leak detection. In the unlikely event of a leak, an alarm system would have alerted control room operators to system changes. If a leak would have been suspected, valves would have automatically closed to isolate the section of the pipeline and minimize the release of CO_2 into the atmosphere. If the EOR mainline would have had a leak, the CO_2 would have been vented at Keephills 3, or alternatively the flow could have been sent to the sequestration line. The sequestration well would keep everything online and also act as a sink for the CO_2.

Emergency Planning Zone

An emergency planning zone (EPZ) is a geographical area surrounding a well, pipeline, or facility that requires specific emergency response planning.

The EPZ for the Project Pioneer pipeline system had been determined to be 320 m for open grasslands and 520 m for forested areas. These values are based on a double guillotine rupture of the pipeline with full depressurization. The shape and size of the EPZ takes into account feedback from stakeholders, site-specific features of the area and other factors such as population density, topography, and access/egress routes, which may affect timely implementation of emergency response procedures in the EPZ.

The construction and operation of the new infrastructure would have been incorporated into Keephills 3’s existing Emergency Response Plan (ERP). Enbridge and the Pioneer Partners, in consultation with residents and public land users, would also have developed a specific pipeline ERP for the Project to meet the latest regulatory emergency response requirements.

Project Schedule
Project Pioneer expected to submit the pipeline system application to the Energy Resources Conservation Board (ERCB) in September 2012. Subject to final agreement by the project partners and required regulatory approvals, construction was anticipated to start in Fall 2014, with a projected in-service date of Winter of 2015.

fig. 5.0

PROJECT PIONEER KEY MILESTONES SCHEDULE

Key Milestones (Subject to regulatory approvals)	Start Date	Completion Date
Class III Proposal/FEED	01-Dec-11	30-Mar-12
Public consultation	Apr-11	Mar-14
ERCB Application Submit/Approval (EOR)	Sep-12	Jan-13
ERCB Application Submit/Approval (CCS)	Apr-13	Sep-14
Engineering – Detailed	Aug-12	Aug-13
ROW Clearing	Aug-14	Sep-14
Construction	Jul-14	Jan-15
In-service Date	Q1, 2015	

Sequestration Pipeline System

About the System
The proposed sequestration system would have consisted of the following components:

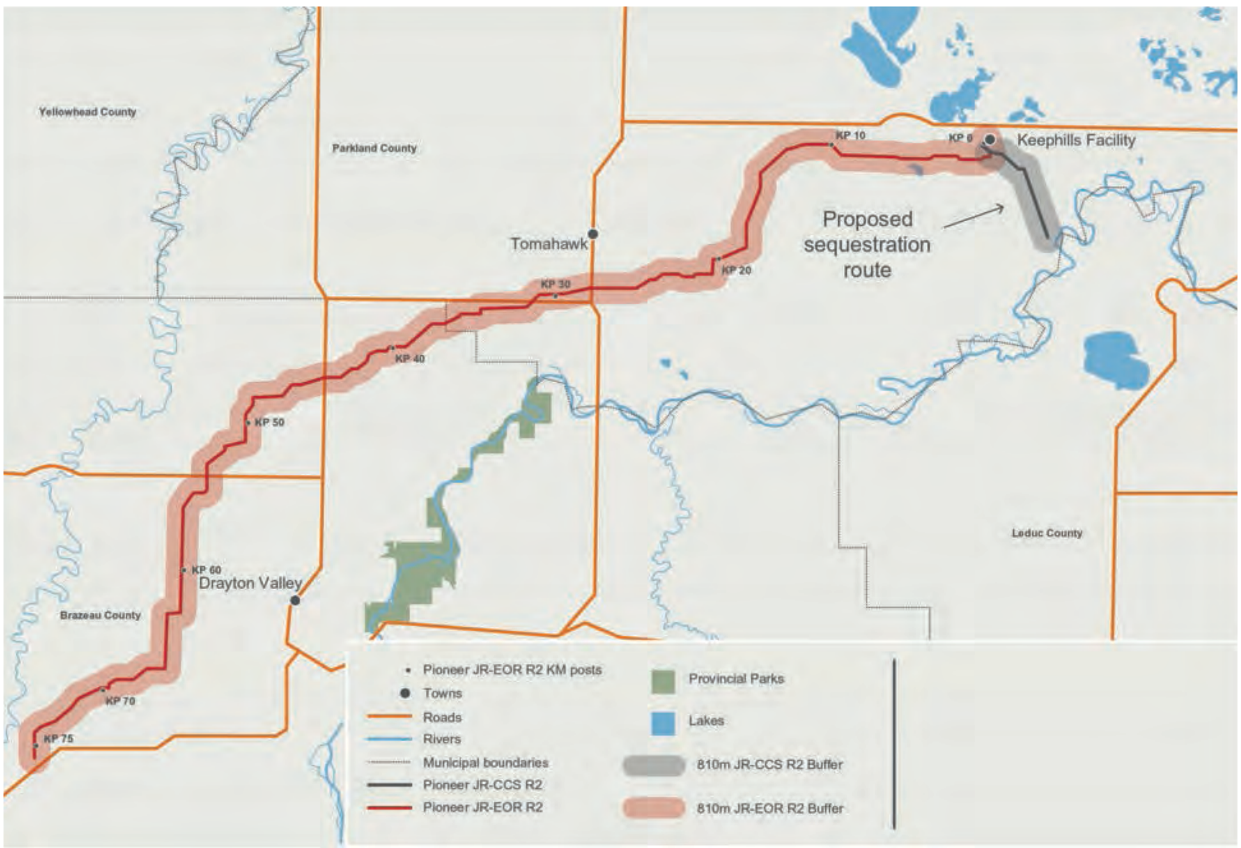
- One NPS 10 (273.1 mm OD) pipeline to transport CO_2 from the Keephills facility to the sequestration wells located southeast of the Keephills facility;
- Product metering facilities and leak detection equipment to ensure safety before being transferred to the well operator Schlumberger;
- A pig launcher at the Keephills facility and a pig receiver at the furthest south well site to launch inspection tools to ensure pipeline integrity

Pipeline Route

The last version of the proposed sequestration pipeline route is below. The Project was in the process of conducting environmental studies, engineering design work, and stakeholder engagements and consultations, when the decision was taken not to proceed with the Project.

fig. 6.0

PROJECT PIONEER PROPOSED SEQUESTRATION PIPELINE ROUTE



Safety

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Project Pioneer would have continuously gathered data and monitored the facilities and pipeline system for leak detection. In the unlikely event of a leak, an alarm system would have alerted control room operators to system changes. If a leak was suspected, valves would automatically close to isolate the section of the pipeline and minimize the release of CO_2 into the atmosphere.

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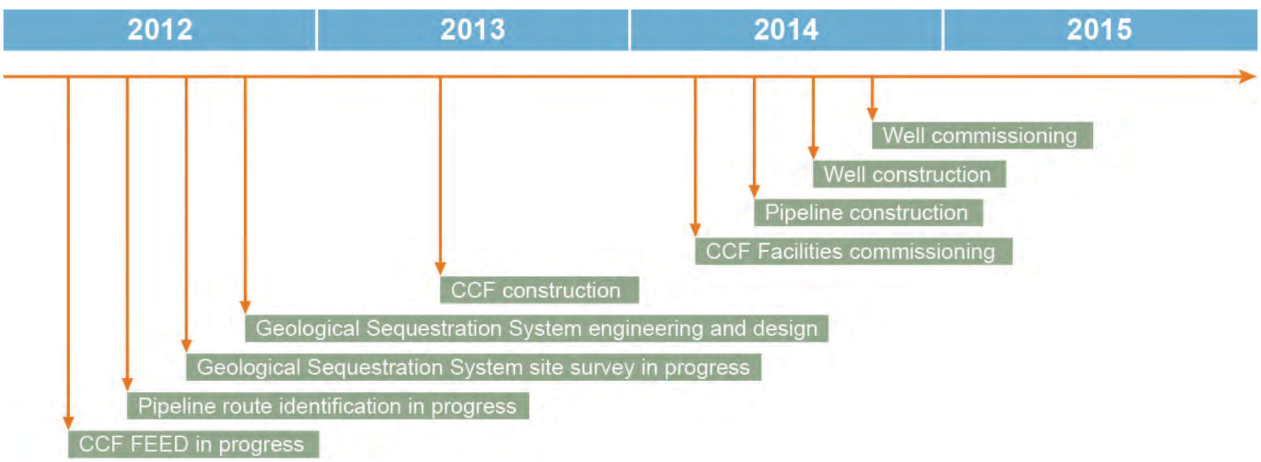
fig. 7.0

PROJECT PIONEER KEY DATES



Approach to Acquiring Non-Objections to Pipeline Routing

It is a requirement of the ERCB approval process that the applicant obtain confirmation of non-objection from those landowners and occupants whose properties are directly impacted by the construction of the pipeline. Approximately 3 to 4 months prior to the anticipated ERCB application filing, the land agents engaged by the Project would have arranged for one on one meetings with the affected owners at which time the pipeline route is reviewed and landowner/occupant questions are addressed. The landowner/occupant is requested to sign a Non-Objection form.

All reasonable efforts are made to address landowner/occupant concerns and obtain the non-objection but occasionally an impasse is reached and the Project reports to the ERCB that a non-objection was not secured from that particular party.

A successful non-objection process requires a comprehensive information package that includes quality mapping of the pipeline route through the affected parcels, a detailed but reader-friendly project description and the expertise that comes from experienced land agents.

Process Considerations and Process Design

CO_2 Capture Facility

The CCF would have been located within the Keephills Power Plant site boundaries. It would have used a large-scale amine process to capture the CO_2 and used compressors to “liquefy” the CO_2 and a pump to achieve the 14.0 MPa (2030 psi) discharge pressure. A molecular sieve dehydration unit was to have been installed after the compressors fourth stage to dry the CO_2.

After the phase of initial plant startup, the CO_2 transported would have been of the following purity:

fig. 8.0

CO_2 PARAMETERS

Parameter	Units	Suggested CO_2 Product Quality[1]
Composition		
CO_2	mol. %	99.955% min.
$N_2/O_2/NH_3$/SOx/Glycol/Inerts	ppmv	< 450 max.
H_2O	ppmv	50 max.[1]
Pressure	MPa	14.0 max.
Temperature	°C	60 max.
Total Flow Rate	Mt/yr	1,170,000

1. *The CO_2 water content will vary from near zero at the start of the molecular sieve run and will be near 50 ppm when the molecular sieve beds are switched/regenerated; a typical average run time is 72 hours.*

The CCF was designed to process and deliver at a constant 134 tonnes/hour, there are situations where the end point EOR customers facilities are unable to accept the full discharge flow rate. In these circumstances, the excess CO_2 would have been diverted to the CCS pipeline and sent to the sequestration wells.

Mechanical Design Considerations and Design of Piping System

fig. 9.0

PIPELINE BUILT TO CANADIAN STANDARDS ASSOCIATION (CSA) SPECIFICATIONS

- The design would have been fully compliant with the relevant design codes including Canadian Standards Association (CSA) Z662, “Oil and Gas Pipeline Systems” and the Alberta Pipeline Act and Regulations;
- The design would incorporate a route that is fully compliant with the requirements of Energy Resources Conservation Board (ERCB) Directive 56 as it relates to public consultation and stakeholder engagement;
- A route that has undergone review for environmental protection as well as constructability to reduce the impact of pipeline construction on landowners and stakeholders;
- The maximum absolute operating pressure (MAOP) of the pipeline would have been 14.8 megapascals (MPa) or 2,150 pounds per square inch gauge (psig) which is able to use PN 150 or American National Standards Institute (ANSI) 900 valve/flange/fitting design;
- For the least conservative pipe wall thickness (standard cross country pipelining), the allowable stress level as per CSA Z662 would not have exceeded 72% (80% stress for the location factor multiplied by 90% design factor);
- For the most conservative pipe wall thickness (railway crossings), the maximum allowable stress level as per CSA Z662 would not have exceeded 50% (62.5% stress for the location factor multiplied by 80% design factor);

- The pipe would have fully met the material restrictions for high vapour pressure and CO_2 pipelines as defined by CSA Z662. This included proven ductility and fracture control properties suitable for the intended service. The pipe that was selected was Nominal Pipe Size (NPS) 10 CSA Z245.1 Grade 359 Category II with a wall thickness of 11.8 mm. This low carbon steel with proven notch toughness would have given the properties required to meet and exceed code requirements;
- Pressure, temperature and valve position was to have been transmitted from the valve assembly location to the Supervisory Control and Data Acquisition System (SCADA) host. In addition, emergency connections would have been installed on both sides of the valve to allow de-pressuring of a section of the pipeline;
- The minimum depth of cover for the entire pipeline would have been a minimum of 1.2 meters throughout, with the exception of crossings that may have required to be deeper. Cover depth would have met CSA Z662 requirements as a minimum, but also would have met specific requirements set out in crossing agreements.

Safety Considerations and Design of Safety into the System

- At Class Location 2 and greater, block valves are required to be installed at a maximum distance of approximately 15 kilometers as per Clause 4.4.4 of CSA Z662.
- The valves would have been placed at Class Location boundaries to be compliant with the requirements of Clause 4.4.5 of CSA Z662.
- The code reads “For HVP and carbon dioxide pipelines, sectionalizing valves shall be located outside cities, towns, and villages, at the transition from Class 1 to a higher class location” to prevent issues in areas where there are 11 or more dwellings within a 200 m by 1,600 m area adjacent to the right-of-way.
- As specified in the Alberta Pipeline Act and Regulations a leak detection system would have been implemented for the proposed diluents pipeline. In general, it would have followed the “Recommended Practice for Liquid Hydrocarbon Pipeline System Leak Detection” as shown in Annex E of CSA Z662.
- The pipeline would have the ability to isolate flow remotely, using intermediate block valves to limit release volumes in the event of an upset or for scheduled maintenance.

3.0

LESSONS LEARNED FROM OTHER CO_2 PIPELINES

The majority of existing CO_2 pipelines are found in North America, primarily in the United States, where there is more than 30 years of experience in operating buried CO_2 pipelines.

In Canada, the main CO_2 pipeline is one that transports CO_2 from a North Dakota coal gasification plant to Weyburn, Saskatchewan for enhanced oil recovery. This pipeline has operated safely and without incident for a decade.

A U.S. Department of Energy report stated that, “The design, permitting, construction, and operation of CO_2 pipelines are comparable to natural gas pipelines because they both transport a pressurized gas and utilize a similar carbon steel pipe design.”

According to a 2008 U.S. Congressional Research Service Report for Congress, “Many analysts consider CO_2 pipeline technology to be mature, stemming from its use since the 1970s for EOR and in other industries.” The report added that, “to date, CO_2 pipelines in the United States have experienced few serious accidents…there were 12 leaks from CO_2 pipelines reported from 1986 through 2006…Based on the limited sample of CO_2 incidents, analysts conclude that, mile-for-mile, CO_2 pipelines appear to be safer than the other types of pipeline regulated by OPS (Office of Pipeline Safety).”

With this positive experience to date, industry and governments are working to ensure future CO_2 pipelines build on that success. Globally, an industry project led by DNV, a global leader in risk management services, has developed the first set of CO_2 pipeline standards for design and operation of CO_2 pipelines. And in Canada, government and industry groups continue to work to develop policies and regulations, address safety issues, and advance the technologies needed to ensure safe construction and operation of future CO_2 pipelines.

TransAlta™

www.projectpioneer.ca

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CONTACT US

Don Wharton – Vice President of Sustainability & Policy
TransAlta Corporation
Calgary, Alberta, Canada
Don_Wharton@TransAlta.com

Stacey Hatcher – Knowledge Transfer Specialist
Project Pioneer
Calgary, Alberta, Canada
Stacey_Hatcher@TransAlta.com