2008 Long Term Acquisition Plan

BC hydro

APPENDIX F2

Powertech Labs Inc. Coal-Fired Generation CCS Report

POWERTECH LABS INC.

TECHNOLOGY SUMMARY

CLEAN COAL POWER GENERATION BY CO_2 SEQUESTRATION

Project: 17478 -34

March 05, 2008

Prepared for:
2008 Long-Term Acquisition Plan Resource Options Update
Energy Planning
BC Hydro

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

Policy Action No. 20 of the 2007 Energy Plan stipulates that coal-fired generation must meet a zero greenhouse gas (GHG) emission standard "through a combination of 'clean coal' fired generation technology, carbon sequestration and offsets for any residual GHG emissions". This report is written to address the current status of coal-fired generation with carbon capture and sequestration (CCS) to determine whether CCS should be included as a commercial option[1] in the 2008 Long-Term Acquisition Plan Resource Options Update (2008 LTAP ROU).

Total coal resources in British Columbia (BC) are estimated at about twenty-three billion tonnes. Coal-fired generation produces emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_X), mercury, fine particulate matter (PM) and carbon dioxide (CO_2). Technology involving a new coal energy process that reduces emissions from coal-fired generation is termed "***Clean Coal Technology***" (Department of Energy, USA). Clean coal technologies available presently have high efficiency in pollution control (more than 90%), which will result in significant reductions in SO_2, NO_x and PM emissions (National Resource Canada, 2006). However, these technologies do not address the capture and sequestration of CO_2 emissions from coal-fired generation.

The following sections summarize the current state of CCS from coal-fired generation with an emphasis on technology, cost, adaptation in BC, and critical factors/barriers that need to be addressed. Based on following analysis, it is recommended that BC Hydro not include coal-fired power generation with CCS as a commercial technology option in 2008 LTAP ROU. However, BC Hydro should continuously monitor developments in this area and include coal-fired power generation with CCS as a commercial option when appropriate.

2.0 TECHNOLOGY

The CCS system includes three stages:

- Carbon Capture: CO_2 is separated and captured from power plant emissions.
- Carbon Transportation: CO_2 is transported by pipeline or other gas carriers from a captured facility to the storage facility.
- Carbon Storage: CO_2 is injected in a suitable storage reservoir.

2.1. CO_2 Capture

Emission of CO_2 in coal-fired generation can be captured during post-combustion, pre-combustion or by oxy-fuel combustion.

[1] For purposes of this report, the following definition of commercial operation has been adopted: "generation technology that is readily available in commercial markets and in commercial use (not demonstration use only), as evidenced by at least 3 generation plants generating energy for a period of not less than 3 years, to a standard of reliability generally required by good utility practice". This is the definition of "proven technology" used in BC Hydro's electricity acquisition processes.

Post-combustion capture technology has been established for over sixty years in chemical and oil industries for removal of hydrogen sulphide and CO_2 from gas streams. Typically CO_2 capture during post-combustion involves two stages; first, flue gas is passed through an absorber/scrubber where a solvent removes most of the CO_2 through chemical reactions. The CO_2 rich solvent proceeds to a stripper where it is heated to release the CO_2. Before post-combustion capture technology can be installed with confidence on a large (300 to 500 MW) coal-fired power plant, current expertise and machinery must be scaled up. For example, the largest industrial, non coal-fired application of post-combustion capture technology captures 800 tonnes of CO_2 per day, whereas a 500 MW coal-fired power plant would require capture of roughly 9000-10 000 tonnes of CO_2 per day, assuming 90% capture (EPRI, 2007). The energy needed to run the stripper stage would require diversion of steam from a steam turbine reducing the net power output by 29% and raising the cost of electricity by 50% (National Energy Technology Laboratory, 2007a).

In pre-combustion CO_2 capture, the coal is processed with oxygen and steam under pressure to form a synthesis gas consisting of CO_2, carbon monoxide and hydrogen. Hydrogen is fired directly to a turbine to produce electricity. The pre-combustion CO_2 would be separated for storage. This technology can only be used in plants including a gasification unit, such as Integrated Gasification Combined Cycle (IGCC). To date, neither IGCC nor any other clean coal gasification technologies have been demonstrated with CCS.

In oxyfuel-combustion, the combustion process takes place in oxygen enriched setting. The air separation unit supplies the oxygen, which combusts with the input flue gas in an oxygen-rich environment, resulting in CO_2 concentration of greater that 80% which can be further concentrated using physical gas purification techniques. Oxy-fuel combustion for power generation is in the demonstration phase and has been demonstrated at a 500 kW test rig (Monckert et al., 2007).

2.2. CO_2 Transportation

Oil companies have been injecting CO_2 into deep geological formations for more than 30 years to help recover additional petroleum from fields depleted during initial production. Enhanced oil recovery is currently supported by approximately 4800 km (3000 miles) of dedicated pipelines in North America. As a supercritical fluid (denser as liquid but gas-like viscosity), CO_2 can be transported through this dedicated pipeline. For example, a 325 kilometer pipeline delivers approximately 3,000 tonnes of CO_2 per day from a synfuels plant in Beulah, North Dakota to a CO_2-based Enhanced Oil Recovery project at Weyburn, Saskatchewan.

2.3. CO_2 Storage

After capturing and transporting CO_2 from a coal-fired power plant, CO_2 must be stored securely and cost-effectively for centuries or longer to reduce GHG emissions overall. Scientists have focused their CO_2 sequestration technology development efforts in:

- The oceans; and
- Underground geological formations.

The ocean represents a large potential sink for sequestration of CO_2. However, the idea of ocean storage of CO_2 has aroused objections from environmental communities and development has not yet progressed to the pilot stage.

Geological sequestration involves the injection of CO_2 into underground reservoirs that have the ability to securely contain it over longer periods of time. Most likely CO_2 underground storage sites will be deep geological formations where porous sediments have been covered by impermeable cap rock that is able to hold the CO_2 in place. To maintain CO_2 in a supercritical state, target reservoir formation will need to be located at depths greater than 0.8 km (half a mile). Potential candidates are deep saline formations where sandstone and carbonated rocks (limestone or dolomite) that have numerous voids that are partially filled with brine. Deep oil and natural gas fields also make attractive candidates for storage sites. Careful storage system design, together with methods for early detection of leakage (preferably long before CO_2 reaches the land surface) are ways of reducing hazards associated with diffused leakage of the gas from deep geological storage.

There are two natural gas and one oil production projects in operation linking CO_2 capture and geological storage: the offshore Sleipner natural gas processing project in Norway, the Weyburn Enhance Oil Recovery project in Saskatchewan, Canada and the In Salah natural gas project in Algeria. These projects store about 3000 tonnes per day of CO_2. A 500 MW coal-fired power plant would require storage of roughly 9000-10 000 tonnes of CO_2 per day. In addition, legislative and regulatory clarity would be required to address ownership of the pore space as CO_2 spreads out underground, and the assumption of liability over the lifetime of the CO_2 storage.

2.4. Technology Development

A CO_2 capture and sequestration system of a coal-fired power plant is made up of number of individual technology component that are currently in different stages of development as summarized in the Table below:

Sequestration component	Technology	BCH Technology Development Continuum					
		Invention	Basic Research / Proof of Concept	Prototype Development	Field Test, Demos & Verification	Niche Application & Supported Commercial	Commercial Application and Full Integration
Capture	Post Combustion				→		
	Pre Combustion				→		
	Oxyfuel			→			
Transportation	Carbon Pipeline						→
Ocean Storage	Deep Dissolution or Pooling on Sea Floor		→				
Storage	Enhanced Oil Recovery (EOR)						→
	Underground Storage				→		

To develop large-scale near zero emission coal-fired generation demonstration projects, governments around the world are injecting billions of dollars through a number of programs. The U.S. Department of Energy is planning to conduct large volume carbon storage demonstration tests through a carbon sequestration regional partnership program between 2007 and 2017. Clean coal-fired generation plants with near zero emission technology (CCS) may be constructed in another three to five years and the commercial viability of these pilot projects may be known by 2017 or later:

- Rio Tinto/BP Alternative Energy Partnership - 500 MW Carson project, California. A permit application is to be submitted to the California Energy Commission during 2008;
- Energy Northwest - Port Kalama, Washington State IGCC complex to produce its own synthesis gas to fuel two, 300 MW power plants (one owned by public power interests and the other under private financing and ownership). The regulator, the Washington State Energy Facility Site Evaluation Council, rejected Energy Northwest's application for site certification on the basis that there was a failure to assure that the Port Kalama project could comply with Washington State greenhouse gas emission laws. Energy Northwest has announced it will amend its development plans and continue to pursue the project;[2]
- FutureGen Alliance - 275 MW power plant, plant location in U.S. to be determined. On 30 January 2008 the U.S. Department of Energy, which was slated to fund about 75% of the cost of the FutureGen project, proposed a major restructuring of the project due to increased project costs;[3]
- Xcel Energy - 300 MW Colorado project.;
- NRG Energy - 680 MW Huntley IGCC project, Tonawanda, New York. Financing and other arrangements have not yet been worked out;
- NRG Energy - 125 MW Parish plant project, near Houston, Texas; and
- SaskPower – 100 MW, 1.4 billion demonstration project that would entail the rebuilding and repowering of a coal-fired facility at Boundary Dam, Saskatchewan over a seven year timeline. SaskPower recently announced that new funding in the federal budget means that it can proceed with this demonstration project. SaskPower also recently cancelled plans to construct a 300 MW near-zero emissions pulverized coal unit because the estimated project cost of $3.8 billion made the project economically unviable.[4] .

These pilot projects aim to sequester at least 90% of the CO_2 emissions with potential for 100% sequestration. According to EPRI, new coal-fired power plants with 90% CO_2 emission capture and storage is expected to be commercially available by 2022.

---

[2] "State rejects proposal for coal plant in Kalama", *The Columbian*, 28 November 2007; "Energy Northwest will pursue $1.5 billion plant in Kalama", *The Columbian*, 29 November 2007; Energy Northwest, "Energy Northwest adjusting power plant plans", 10 January 2008, at www.energy-northwest.com/news/2008/documents.

[3] See U.S. Department of Energy, "DOE Announces Restructured FutureGen Approach to Demonstrate Carbon Capture and Storage Technology", 30 January 2008, www.fossil.energy.gov/news/techlines/2008/08003-DOE-Annouces_Restructured_FutureG.html. See also FutureGen Alliance, 31 January 2008 *News Release*, www.futuregenalliance.org/news/doe_proposal_fact_checl_013108.stm.

[4] SaskPower, 27 February 2008 *News Release*, at www.saskpower.com/aboutus/news/?p=368.

2.5. Cost

When today's technologies for CCS are eventually integrated into new coal-fired power plants, the total CO_2 capture cost is expected to be about 50% to 60% of the total cost of electricity. The cost of transporting CO_2 80 kilometers (50 miles) for storage in a geological formation and monitoring over 30 years is estimated to be about 10% of the total CO_2 capture cost.

The resulting 20 year levelized cost of electricity, including the cost of capture, transport, storage and monitoring, for a IGCC power plant is expected to be about $106 US per MWh and for a Supercritical pulverized coal combustion (PCC) is expected to be about $117 US/MWh at a discount rate of 10% and fuel cost of $1.8 per MMBtu of coal (National Energy Technology Laboratory, United Sates Department of Energy, 2007b). All these costs are stated in 2007 US dollars. Since neither IGCC nor PCC power plants have yet been built at a full scale with CCS, the above costs of electricity from these power plants cannot be state with a high degree of confidence at this time (IPCC Special report, 2005).

3.0 CO_2 SEQUESTRATION TECHNOLOGY ADAPTATION IN BRITISH COLUMBIA

3.1. Potential

Based on preliminary assessment, geological sequestration of CO_2 emission from coal-fired power plants is suited for regions such as northeastern BC. The experience of acid-gas injection in northeastern BC is a good example. In that locale, CO_2 may be sequestered by stratigraphic structural trapping in depleted oil and gas reservoirs, by solubility trapping in oil reservoirs, brine formation, and by absorption trapping in coal beds (Bachu, 2002). In general, northeastern BC has favorable condition for CO_2 sequestration in oil and gas reservoirs and deep saline aquifers. In addition to the potential storage reservoirs in northeastern BC, there are several other sedimentary basins such as Quesnel Trough, Nechako and Bowser Basin in BC that could be potential locations for CO_2 storage. Given the lack of oil and gas exploration and production in these basins, very limited information is available to assess suitability for geological storage of CO_2. Further studies would need to be performed to understand the properties and behavior of CO_2 at the temperature, pressure and stress conditions found in BC sedimentary basins to evaluate the viability of CO_2 sequestration.

In cases where a suitable geologic reservoir for secure CO_2 storage does not directly underlie coal-fired power plants, the captured CO_2 will need to be transported to a separate location through dedicated pipelines for injection into an underground storage. CO_2 pipeline technology is similar to that used for natural gas. Transportation routes such as the Alaska Highway, the Heritage Highway, numerous other local roads and railroads must be crossed to construct pipelines from coal-fired power plants to reservoirs in northeastern BC. In determining the feasibility of CO_2 pipelines in BC, it would be necessary for proponents to consider the specific physical obstacles than have to be overcome to both construct and operate/maintain the pipeline.

3.2. Applicable Legislation

Legislation currently governing the development of coal-fired power plants with CO_2 sequestration in BC includes the BC *Environmental Assessment Act* for coal-fired generation facilities greater than 50 MW and the *Environment Management Act* for air emission and liquid effluent discharges. Such power plants may or may not trigger the *Canadian Environmental Assessment Act* (*CEAA*). However, a pipeline component may trigger *CEAA* due to the necessity of completing in-stream work or length of pipeline clearing required.

Potential projects may face delay due to regulatory uncertainty associated with CO_2 sequestration. For example, there is currently no liability regime in place to govern responsibility for CO_2 leakage once stored. Existing laws and regulations regarding oil and gas operations, pollution control, waste disposal, drinking water, treatment of high-pressure gas and subsurface property rights may be relevant to CO_2 storage (IPCC Special report, 2005). In October 2007, the US Environmental Protection Agency announced that it intends to develop CO_2 storage regulation. The International Energy Agency (IEA) in partnership with the Carbon Sequestration Leadership Forum (CSLF) announced on January 14, 2008, the formation of the Network of CCS Regulators. The Network, to be launched in spring of 2008, will be comprised of regulators from a variety of arenas of expertise, and from local, state/provincial, national, regional and international levels. The IEA has identified the following key regulatory issues that will be addressed in and through the Network: establishing jurisdiction among different agencies, property rights for CO_2 storage and transportation, transport issues, environmental risk mitigation, monitoring and verification methodologies for CO_2 retention in storage sites. Finally, the Canada-Alberta ecoENERGY Carbon Capture and Storage Task Force recommended public funding for the development of legislation or regulation necessary for CCS. These legislation/regulations allocating liability and setting out monitoring standards, and public acceptance, likely need to be addressed before CCS can be applied on a commercial scale in BC.

4.0 CONCLUSIONS

Based on the above study, the following conclusions have been reached:

- At this time, the state of key components of CCS technology is such that it cannot be considered in commercial application of coal-fired generation. Although pilot plants are being considered and pursued, the viability of these technologies on a commercial application scale may not be known until 2017 or later.
- There is uncertainty with respect to the cost of CCS, and what impact CCS will have on a large coal-fired generation facility's efficiency.
- Although there are some geological sites in BC that may prove suitable for CO_2 storage, there is limited information available to assess the suitability for geological storage at this time. Further studies would need to be performed to understand the properties and behavior of CO_2 at the temperature, pressure and stress conditions found in sedimentary basins in BC.

- There are legal/regulatory and public acceptance issues that likely need to be addressed before CO_2 capture and storage technology can be considered in a commercial scale in BC.

The following Table provides the estimated commercial application and full integration timeline based on technology development at this time.

		Estimated Commercial Application and Full integration Time line			Remarks
		Today - 2010	2010- 2020	2020 – Beyond	
Capture	Post combustion and Pre combustion capture		✓		Currently there are several pilot coal-fired power plants with these capture technologies in feasibility or development stage and estimated to be in service between 2012 and 2015. Commercial viability may not be known until 2017 or later.
	Oxyfuel combustion			✓	This technology has only been demonstrated at the scale of test rigs and currently there are no planned coal-fired power plants with this technology.
Transportation	Carbon Pipeline	✓			Mature technology, currently supported by approximately 4800 km of dedicated pipelines in North America.
Ocean Storage	Deep Dissolution or Pooling on Sea Floor			✓	Development has not yet progressed to the pilot stage.
Storage	Enhanced Oil Recovery (EOR)	✓			Mature technology, CO_2 is injected to help recover additional petroleum from fields depleted during initial production.
	Underground storage		✓		Currently there are several pilot coal-fired power plants with CO_2 storage technology in feasibility or development stage and estimated to be in service between 2012 and 2015. Several sedimentary basins in BC could be potential locations for CO_2 storage. Further studies would need to be performed to understand the properties and behavior of CO_2 at the temperature, pressure and stress conditions found in BC sedimentary basins in order to evaluate viability of CO_2 sequestration. Allocation of liability, monitoring standards and public acceptance likely need to be addressed before carbon storage can be applied on a commercial scale in BC.

Based on above, it is recommended that BC Hydro not include coal-fired power generation with CCS as a commercial technology option in 2008 LTAP ROU. However, BC Hydro should continuously monitor developments in this area and include coal-fired power generation with CCS as a commercial option when appropriate.

5.0 REFERENCES

1. Bachu, S., 2002. “Suitability of the Subsurface in Northeastern British Columbia for Geological Sequestration of Anthropogenic Carbon Dioxide”. Alberta Geological Survey.
2. EPRI, 2007. “ CO_2 Capture and Storage”, Journal Electrical Power Research Institute.
3. IPPC Special Report, 2005. “Carbon Dioxide Capture and Storage”. A special report of working group III of the Intergovernmental Panel on Climate Change.
4. Monckert, P., Reber, D., Maier, G. and Scheffknecht, G., 2007. “Operation of a Retrofitted 0.5MWth PF Combustion Facility under Oxyfuel Condition – An Experience report”. Clearwater Clean Coal Conference, USA.
5. National Energy Technology Laboratory, 2007a. “Carbon Sequestration Technology Roadmap and Program Plan”. Office of Fossil Energy, United Sates Department of Energy.
6. National Energy Technology Laboratory, 2007b. “Cost and performance Baseline for Fossil Energy Plants”. Office of Fossil Energy, United Sates Department of Energy.
7. National Resources Canada, 2006. “Technology Roadmap Networking Meeting”. Ottawa, Ontario, Canada.