EXPLORING THE FATE OF CO_2 AT BRITISH COLUMBIA'S PLANNED FORT NELSON CARBON CAPTURE AND STORAGE PROJECT

Peter Crockford[1] and Kevin Telmer[1]

ABSTRACT

The geochemical reactions involved in injecting fluids into reservoirs remain poorly understood, yet this information is critical to the success of carbon capture and storage (CCS) projects. Remarkably, no standard methodology exists to estimate storage capacity for CCS, largely because of the inadequacy of thermo-kinetic databases needed to model geochemical processes at the pressures, temperatures, and salinities of deep reservoir conditions. Thermodynamic and kinetic constants and coefficients, reactive surface area estimates, and understanding of pore-scale physical processes that control geochemical reactivity are particularly lacking. This information is required to predict long-term CO_2 trapping. The University of Victoria is aiming to develop this information by performing high-quality research on a case-by-case basis.

In collaboration with the Ministry of Energy, Mines and Petroleum Resources and Spectra Energy, researchers at the University of Victoria are performing laboratory experimental work to measure empirical and site-specific thermo-kinetic properties of reservoir materials from the planned Fort Nelson CCS project. These results and a conceptual model based on field data will be integrated into the project to produce a reactive transport simulation to predict the fate of the injected CO_2.

Crockford, P. and Telmer, K. (2009): Exploring the Fate of CO_2 at British Columbia's planned Fort Nelson Carbon Capture and Storage Project; Geoscience Reports 2009, *BC Ministry of Energy, Mines and Petroleum Resources,* pages 1–4.

[1]University of Victoria

CCS IN BRITISH COLUMBIA: A VIABLE OPTION TO REDUCE CO_2 EMISSIONS

There is broad understanding in the scientific community that rising concentrations of anthropogenic greenhouse gases will change our climate and produce an estimated warming of the planet up to 4°C this century (IPCC 2007). CO_2 is the most abundant greenhouse gas and is thought to be responsible for 76.6% of the enhanced greenhouse effect (IPCC 2007). In 2008, the province of British Columbia emitted an estimated 70.3 Mt of CO_2 (Figure 1), representing nearly 9% of the 780 Mt of CO_2 estimated to have been emitted by Canadians (Environment Canada 2005). While the global energy market waits for development of renewable energy forms, CCS is a technology available to British Columbia that can help the province to achieve it's goal of reducing emissions to 46.4 Mton CO_2 per year (Figure 1).

CCS lowers greenhouse gas emissions by capturing CO_2 and other gases from point-source emitters such as gas-fired power plants and injecting them into the subsurface, where they remain for millennia. CCS is not new—it has been used for a different purpose and at a smaller scale for decades by the oil and gas industry to enhance oil recovery (a technology called EOR) and for the disposal of acid gas (CO_2 and H_2S). Because it is already available and is cost effective, CCS has become an important component to emission reduction strategies of governments and the private sector all around the world. For British Columbia, CCS has great potential to lower emissions because of the presence of several large CO_2 point sources near its numerous potentially good geological storage sites (Figure 2). In particular, British Columbia's natural gas industry, which is expected to grow 50% to 200% over the next 10 to 15 years, is a good candidate for CCS because of its large and relatively pure point sources of CO_2, which are co-located with suitable storage reservoirs (principally deep saline formations).

Government, industry, and academia are cooperating to take advantage of British Columbia's CCS opportunities. A large CCS project at Fort Nelson is in the feasibility stage. It is a collaborative effort involving mainly the British Columbia Ministry of Energy, Mines and Petroleum Resources and Spectra Energy, a natural gas producer. The Plains CO_2 Reduction Partnership (PCOR) and the University of Victoria are also involved, bringing needed institutional capacity and research expertise to the project. The target for the CCS project is Spectra's Fort Nelson sour-gas H_2S processing plant (Figure 2), which emits significant volumes of CO_2 during the processing of raw gas.

The Fort Nelson area is an ideal location for CCS. This area has a large number of candidate CCS sites with suitable stratigraphy—thick shaly aquitards, ideal for sealing in CO_2 for the long term. Northeast British Columbia is also

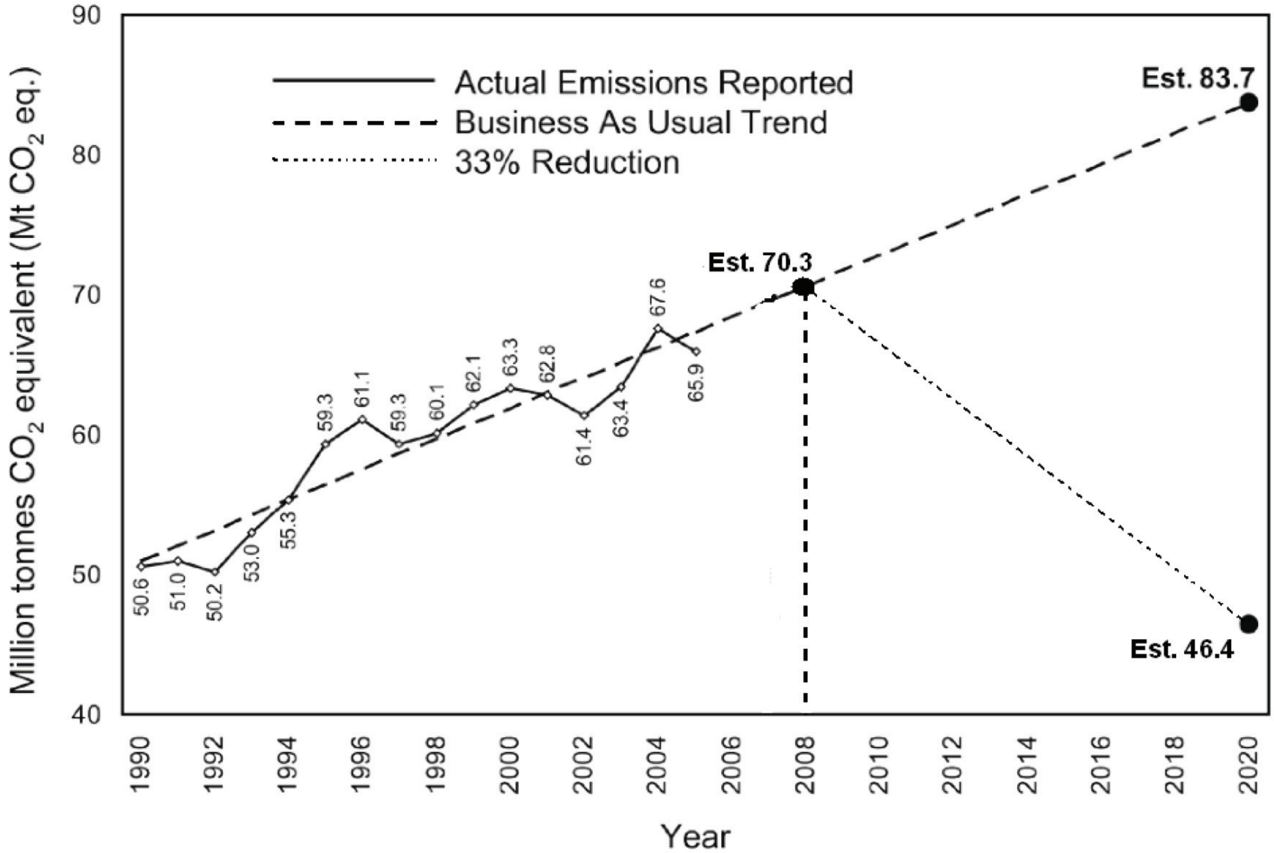

Figure 1. Global measured CO_2 values up to 2003 along with the "Business As Usual" trend to 2020 and British Columbia's 2020 reduction target. Figure adapted from Hartling 2008.

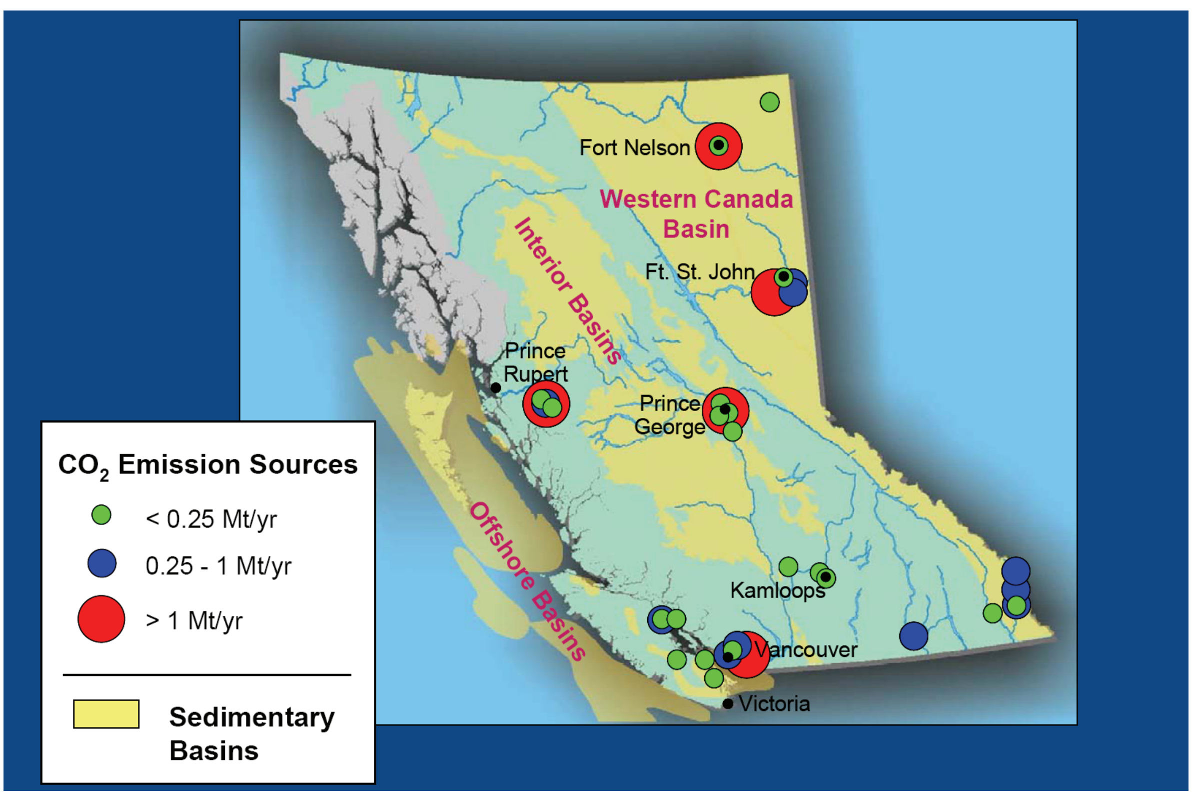

Figure 2. Map of British Columbia showing the largest point source emitters. (Hartling 2008).

a tectonically stable area with a low probability of earthquakes that could fracture rocks and cause leakage.

If successful, the Fort Nelson project will inject about 1 Mt of CO_2 into the subsurface every year and become one of the world's largest CCS operation. This single project could reduce British Columbia's CO_2 emissions by a significant 2.5% and play a pivotal role in British Columbia's reduction goal of 33% by 2020.

THE FORT NELSON CCS PROJECT: RESEARCHING THE GEOCHEMISTRY OF CO_2 IN THE DEEP AQUEOUS ENVIRONMENT

Geochemical knowledge will assist in estimating the storage capacity, limitations on injection rates and injection methods, and contamination risks associated with leakage. Storage capacity is controlled by porosity, permeability, and the pressure and temperature field of the reservoir. These, however, are affected by geochemical reactions that cause mineral precipitation and dissolution and shifts in gas solubility that feedback on the pressure and temperature and ultimately the potential CO_2 injection rate.

University of Victoria research is focusing on the geochemistry of the saline formation environment during and after CO_2 injection to determine which geochemical reactions will occur and at what rates. This information will be coupled with reservoir flow dynamics to estimate where in the aquifer these reactions will be occurring. Both experimental and computer modeling approaches will be taken. Laboratory experiments will be performed at the pressure and temperature range of the proposed CCS location in the Fort Nelson area. These experiments will be performed on brine and rock samples from the proposed reservoir. The laboratory results will also be used to create and refine physical constants in thermodynamic and kinetic databases, which will dictate the accuracy of a mathematical model of the reservoir system.

Fieldwork will be performed at the drill site to collect samples and perform measurements of parameters such as temperature, pressure, and alkalinity of the formation brine. These data can be used in follow-up studies that will track the evolution of these parameters of the saline aquifer.

Samples will be analyzed and experiments run at the School of Earth and Ocean Sciences, University of Victoria. Using the new state-of-the-art laboratories, samples of brine and rock will be placed under aquifer conditions. An acid-gas mixture of supercritical CO_2 and H_2S will be introduced in a reaction vessel at the P-T conditions of the Fort Nelson aquifer. The system will be sampled through ports over a 90-day period to detect the rates of changes in brine chemistry and alterations in the aquifer rock. The rock will be analyzed for changes in porosity and permeability, and the brine composition will be compared to the initial composition before CO_2 introduction. Changes in brine composition combined with petrological work on rock materials will allow mineral precipitation and dissolution rates to be determined. By measuring samples over several intervals, kinetic information will also be generated. Some of this work will address some of the deficiencies in this field today, such as quantification of reactive surface area and geochemical interactions.

More research is required to gain information about the reactivity of the CO_2 phase of the system. The injected CO_2 does not always immediately dissolve into solution or precipitate into minerals—for at least the injection period (25 to 50 years). The majority of CO_2 may reside as a separate phase on top of the formation brine because of its lower density (Figure 3). The reactions that occur in this part of the system are also very important to investigate. Processes such as brine desiccation, where the H_2O of the brine evaporates into the CO_2 layer, and reactions between the CO_2 phase and the rocks may also be important in estimating the overall storage capacity of the reservoir. The university will be performing experiments to look at these reactions as well.

To extrapolate results from the laboratory to the reservoir and from short time scales to long, reactive transport modeling will be performed. Results from the laboratory will be used to replace thermodynamic and kinetic terms in modeling databases with site-specific data. This is essential for developing a realistic and practical model. However, not all reactions that will occur in the aquifer can be observed in the laboratory because of the slow kinetics of

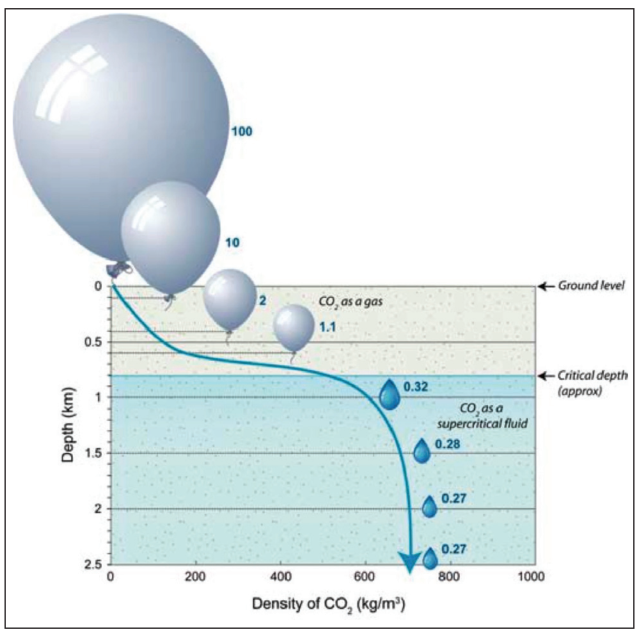

Figure 3. Graphic depiction of CO_2 density changes with depth. Figure taken from CO_2 CRC (2008).

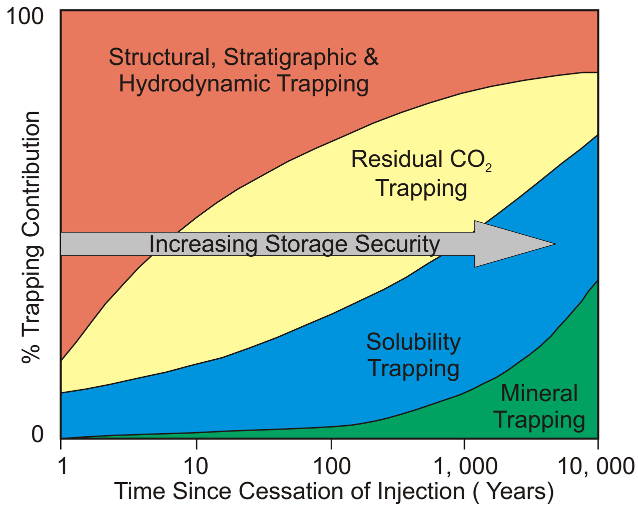

Figure 4. Dominant CO_2 trapping mechanisms over 1- to 10,000-year timescales. Figure from Benson and Cook (2005).

some reactions (Figure 4). Modeling software will be used to predict long-term products as they may be reasonably estimated by chemical equilibrium—a task that software is fairly good at, given the proper initial input chemistry. Fluid dynamics at the aquifer scale are also not replicable in the laboratory, and so scaling factors will be researched.

As well, when CO_2 is injected into the aquifer, gradients of CO_2 concentration and pH will be created around the injection site. Such a chemical distribution cannot directly be emulated in a laboratory reaction vessel and therefore will require computer modeling. By using a model to determine where in the aquifer reactions will be occurring, we will be able to better predict the long-term distribution of CO_2 and the geochemical reactions participating in trapping it in long-term storage.

Predicting the long-term fate of the injected CO_2 will help the Fort Nelson CCS project transition from the planning stages to implementation. As well, the data collected will be useful to the CCS community in implementing projects globally.

CONCLUSIONS

CCS is a rapidly expanding technology that will be a major player in the 21st century as a transitional solution in one of our greatest environmental challenges—the reduction in greenhouse gases emitted into the atmosphere. If implemented in the near future, the Fort Nelson CCS project will be the largest of its kind globally and make a significant contribution to British Columbia's efforts at reducing carbon emissions. However, in order to ensure the long-term viability of the project, it is important to characterize the geochemical environment that will be used for CO_2 storage to be able to estimate potential injection rates and storage capacity. Laboratory and modeling work at the University of Victoria has been designed to help quantify these parameters.

REFERENCES

Benson, S., and Cook, P., eds. (2005): Underground geological storage, in Carbon Dioxide Capture and Storage, Special Report of the Intergovernmental Panel on Climate Change (IPCC), *Cambridge University Press*, Cambridge, pages 195-276.

Environment Canada website http://www.ec.gc.ca/

Hartling, Alf (2008a): Carbon Capture and Storage in British Columbia; in Geoscience reports 2008, *BC Ministry of Energy, Mines and Petroleum Resources*, pages 25-31.

Hartling, Alf (2008b): Geological Aspects of CO2 Sequestration, Northeast British Columbia, Canada, *Search and Discovery*, Article #80010, http://www.searchanddiscovery.com/documents/2008/08073hartling/index.htm

IPCC (2007): Climate Change 2007, Synthesis report. An assessment of the Intergovernmental Panel on Climate Change, A. Allali, R. Bojariu, S. Diaz, I. Elgizouli, D. Griggs, D. Hawkins, O. Hohmeyer, B. Pateh Jallow, L. Kajfez-Bogataj, N. Leary, H. Lee & D. Wratt (eds), *Cambridge University Press*, Cambridge, 52 pages.

Price, Jeffrey, and Smith, Brian (2008): Geologic Storage of Carbon Dioxide – Staying Safely Underground, *International Energy Agency (IEA) Greenhouse Gas R & D Programme*, Cheltenham, UK, 28 pages.