GENERIC APPLICABILITY

OF THE BD3 ICCS BUSINESS CASE

AT THIS POINT, you are likely pondering the following question: "How do I transfer the business model from BD3 ICCS to a different power plant and likely a different jurisdiction?"

The reality is that, in Canada at least, coal-fired power plants are quickly becoming stranded assets that must either be turned off or converted to clean coal with carbon capture and storage over the next two decades, with the oldest plants (pre-1966) to be retired by December 31, 2015 if CCS retrofitting plans have not been filed with the Government of Canada. Those are the requirements of the new GHG Regulations under CEPA for coal-fired power generation in Canada.

If it makes technical and economic sense to retrofit End–of–life power plants with CCS to generate power cleanly, it seems a logical step to continue to reap the benefits of infrastructure investments made in the 1960s to 1990s, an era when a large number of big-budget coal-fired thermal power plants were built, particularly in Western Canada where lignite coal was plentiful and could be economically mined. Most of the coal-fired power plants built from 1970 onward employed very similar technologies and equipment that would make the application of the BD3 ICCS business case particularly suitable.

The following are some considerations that must be taken into account when considering the adaptation of the BD3 ICCS business model to a particular power plant in a particular jurisdiction:

REGULATORY

WHAT, if any, GHG emissions and air quality regulations apply and what would be the targeted emissions levels? How would these impact your technology choice(s)? How would your technology choice(s) impact dates for construction and commissioning a retrofit?

WOULD there be room to negotiate with your regulator to come up with creative solutions that meet the same GHG reduction goals, objectives and outcomes?

FINANCIAL

WHAT, if any, carbon tax or incentive(s) apply(ies) to your situation?

There might be "first-time" funding available in your jurisdiction if you proposed a leading project. **WOULD** there be any government grants that you could use to offset design, engineering, capital or operating costs that might improve the economics of your business case?

WHAT type of innovative financing could you employ? For instance, would it make sense to contemplate a public-private partnership (P3)?

WHAT would be the capital and operating costs of alternative power generation such as NGCC? This would include the cost of fuel (such as natural gas) vs. coal, including future pricing forecasts.

HOW MUCH redundancy would you require in your power and capture plants to satisfy the risk management requirements of your company? How would this impact capital cost?

MARKET

WOULD there be unsatisfied demand for CO_2 in your region and would the market pricing be sufficient to pay enough for the capture plant to offset all or part of its cost when coupled with any applicable carbon tax or incentive? That CO_2 market must ensure the CO_2 would be sequestered from the environment to be a viable GHG emission mitigation option (i.e. CO_2 enhanced oil or natural gas production).

WHAT potential market would exist for other by-products such as sulphuric acid and fly ash?

WOULD your jurisdiction be a regulated or an unregulated electricity market? This would be an important consideration in forecasting future prices for electrical power.

TECHNICAL DESIGN

WOULD you have skilled and experienced internal engineering teams to manage technology choices and oversee design and engineering work? If not, could you broker strong and healthy relationships with appropriate engineering companies?

WHAT would be your technology choices?

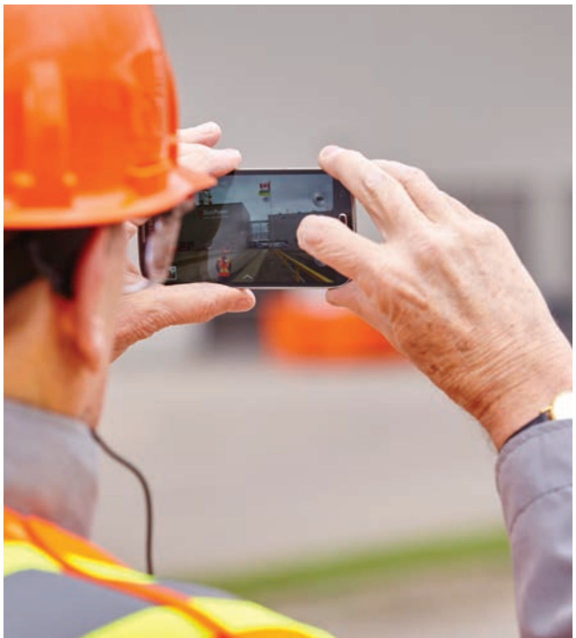
WOULD your company value reliability, maintainability, and operability? If yes, how would these be impacted by technology maturity and therefore your capture technology options?

WOULD you have a reference plant to provide a basis for operational forecasts?

WHAT would be the risk tolerance of your organization and how would that impact technology choices and their required maturity in terms of operational track record?

WHAT would be the minimum number of changes that could be made to the power plant to optimize efficiency when a capture plant would be "tacked on", that would necessitate a reduction in power generation efficiency (i.e. parasitic load that would reduce net power generated and available to consumers)?

WOULD there be an opportunity to design the retrofit so that it would be appropriate for modular construction? Would there be a regional location for module manufacture that would make transportation costs reasonable?



"How do I transfer the business model from BD3 ICCS to a different power plant and likely a different jurisdiction?"

CONSTRUCTION

WHAT would be the availability of appropriately skilled and experienced labour in your jurisdiction? If there were labour shortages or intense competition for labour in critical areas, these would likely lead to higher construction costs. How could you effectively manage the associated labour risks?

WOULD you have sufficient internal experience to manage a "mega" energy construction project?

WOULD there be experienced, reputable construction or EPC firms willing and able to work in your jurisdiction?

WOULD there be modularization yards within reasonable transportation distance from your site?

NOTE: This is not an exhaustive list of considerations. Each power utility must consider its own set of peculiar jurisdictional limitations, regulations and CO_2 market conditions plus any potential geological storage options.

ABBREVIATIONS

This is not a comprehensive list.

BD3 – Boundary Power Plant Station Unit 3

CCS – Carbon Capture, Transportation and Storage

CCPC – Canadian Clean Power Coalition

CCTF – SaskPower's Carbon Capture Test Facility (at Shand Power Station)

CEPA – The Canadian Environmental Protection Act

CIC – Crown Investments Corporation of the Government of Saskatchewan (owner of all Crown corporations such as SaskPower)

CO_2e – The climate forcing factor associated with a greenhouse gas expressed as "carbon dioxide equivalents". For example, the climate forcing factor of methane (CH4) is 21 times the factor for CO_2. Hence, one methane molecule is equivalent to 21 carbon dioxide molecules in terms of greenhouse impact on the climate.

C$ – Canadian Dollars

EC – European Commission

ECRF – SaskPower's Emissions Control Research Facility (at Poplar River Power Station)

EOR – Enhanced Oil Recovery

EU – European Union

GHG – Greenhouse Gas

GWh – Giga-Watt-Hour, the energy unit of total power generation

ICCS – Integrated Carbon Capture and Storage, which is the name of the combined BD3 power plant retrofit project and the geological storage of its captured CO_2.

IEAGHG – IEA Greenhouse Gas R&D Programme

MW – Mega-Watt, the energy unit used for power-generating capacity

PCC – Post-Combustion Capture

$PM_{2.5}$ – Fine Particulate Matter found in the air that is less than or equal to 2.5 mm (micrometres) in diameter and normally only observed by electron microscope. This material is often associated with energy combustion and the fine particulate matter is believed to cause serious health issues upon entering lungs of air-breathing animals.

PM_{10} – Coarse Particulate Matter found in the air that is less than or equal to 10 (mm) micrometres in diameter. It can be seen with the human eye in the air as soot, dust, dirt and liquid droplets. This material is often associated with energy combustion.

PTRC – Petroleum Technology Research Centre, a non-profit R&D corporation located in Regina, Saskatchewan

R&D – Research and Development

QA/QC – Quality Assurance and Quality Control

SE - Southeast

SaskPower – Saskatchewan Power Corporation

REFERENCES

[1] 2014 SaskPower Annual Report

[2] SaskPower's fiscal year runs from January 1 to December 31.

[3] From 2010–2014, SaskPower invested C$4.7 billion in capital assets (upgrades, new construction)

[4] Canada Gazette, Vol. 146, No. 19 — September 12, 2012 (Government of Canada)

[5] Provided by SaskPower

[6] **http://www.ir.gov.sk.ca/coal**

[7] The Encyclopedia of Saskatchewan. The Oil and Gas Industry. **http://esask.uregina.ca/entry/oil_and_gas_industry.html**

[8] Melzer, Stephen, 2012. Report for the National Enhanced Oil Recovery Initiative, Center for Climate and Energy Solutions Carbon Dioxide Enhanced Oil Recovery (CO_2 EOR): Factors Involved in Adding Carbon Capture, Utilization and Storage (CCUS) to Enhanced Oil Recovery

[9] From Leasing Mineral Rights: "Unitization of a producing field: The purpose of unitization is to produce oil or gas more efficiently and effectively by bringing together an area involving a large number of sections. Unitization is used where the industry feels that a large portion of the oil and gas can be produced with fewer wells. Upon unitization, an owner within the boundaries of the unitized field is entitled to participate in production, even though no well is located on his land. The provisions of a lease may therefore permit "pooling," in which case you receive a portion of the royalty, based on the number of acres you put in the pool. The lease may permit "unitization," which converts your royalty into a "tract factor," based on a complex formula. Even though unitization in the vast majority of cases provides a better total income for the mineral owner, an owner should not grant the right to unitize automatically; nor should he leave it up to the company's discretion. Because participation in a unit is not based on the number of acres you have in the unit but is determined by the company, based on geological factors, you should very carefully assess your position. For example, while you may hold five per cent of the area in a unit, you may be allocated only two per cent of the production."

[10] **http://www.economy.gov.sk.ca/PR-IC11**

[11] Pan Canadian was a subsidiary company of Canadian Pacific Railway until it merged with Alberta Energy Company in 2002 to form EnCana Corporation, an independent oil and gas corporation. In December 2009, Cenovus Corporation split from EnCana to operate as an independent integrated oil company, including all of the oil assets from the original firm. EnCana continues to operate the natural gas assets of the original firm and is a leading independent Canadian natural gas producer.

[12] Numac Energy Inc. was incorporated in Alberta in 1971 and was an independent oil producing company until it was purchased by Anderson Exploration Inc. in early 2010. Anderson was subsequently purchased by Devon Energy (USA) to form Devon Canada Corporation in late 2010. Numac, in partnership with Nexen Inc., operated a CO_2–EOR pilot at its Elswick Midale oil leases in 2001 using trucked CO_2 from the Air Liquide plant in Medicine Hat, Alberta. It ultimately decided not to proceed with full-scale operation of CO_2–EOR due to various technical issues it encountered during the pilot as well as poor economics due, in part, to the lack of a pipelined source of CO_2. The Elswick oil field is one of many potential CO_2–EOR targets in SE Saskatchewan.

[13] **http://www.economy.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=10290,10289,3384,5460,2936,Documents&MediaID=26122&Filename=SPRI+CO2+Pilot+Injection+Test.pdf**

[14] **http://www.ucsusa.org/global_warming/science_and_impacts/impacts/early-warning-signs-of-global-1.html#.Va6YMnnbKTM**

[15] **http://unfccc.int/kyoto_protocol/items/2830.php** ; The agreement came into force in 2005 upon ratification by 55 signatory parties belonging to the UNFCCC. Those signatories include Canada but notably exclude the USA as of mid-2015.

[16] Clift, R. and J. Seville (Editors), 1993. Proceedings of the Second International Symposium on Gas Cleaning at High Temperatures. University of Surrey, UK. Springer Science and Business Media. P. 129.

[17] **https://en.wikipedia.org/wiki/Integrated_gasification_combined_cycle**

[18] **http://www.nrcan.gc.ca/energy/coal/carbon-capture-storage/4307**

[19] **http://www.nrcan.gc.ca/energy/coal/carbon-capture-storage/4333**

[20] **http://cornerstonemag.net/exploring-the-status-of-oxy-fuel-technology-globally-and-in-china/**

[21] Tanner, C. S., Baxley, P. T., Crump, J. G., & Miller, W. C. (1992, January 1). Production Performance of the Wasson Denver Unit CO_2 Flood. Society of Petroleum Engineers. doi:10.2118/24156-MS

[22] Beliveau, D. A. (1987, November 1). Midale CO_2 Flood Pilot. Petroleum Society of Canada. doi:10.2118/87–06-05

[23] The Midale and Weyburn oil fields are operated in the same geological formation, along with several surrounding oil leases/ operations. Each of the two oil fields is owned by approximately 30 owners but each field was "unitized" in the 1960s to support water flooding infrastructure investment. Each unitized oil field is operated by one major oil company on behalf of the owners. Pan Canadian was an owner of part of the Midale oil field and consequently had access to the CO_2–EOR pilot program undertaken by Shell Canada.

[24] **http://www.dakotagas.com/CO_2_Capture_and_Storage/Pipeline_Information/index.html**

[25] Apache Canada began a commercial CO_2–EOR flood at Midale in 2006 using approx. 1800 tonnes per day of CO_2 supplied by DGC. At that time Apache Canada contributed data and sponsorship to the renamed IEAGHG Weyburn-Midale CO_2 Monitoring and Storage Project.

[26] Hitchon, Brian (Editor), 2012. Best Practices for Validating CO_2 Geological Storage: Observations and Guidance from the IEAGHG Weyburn Midale CO_2 Monitoring and Storage Project. Chapter 1. Updated data from Cenovus and PTRC as of 2014.

[27] Approximately one-third of the CO_2 injected in a given oil production cycle is "lost" to the reservoir. The uncertainty prior to the IEAGHG Weyburn CO_2 Monitoring Project beginning its work was, "Where does the CO_2 go?"

[28] **http://ptrc.ca/projects/weyburn-midale**

[29] **http://www.canadiancleanpowercoalition.com/**

[30] **http://www.SaskPower.com/our-power-future/our-electricity/our-electrical-system/cory-cogeneration-station/**

[31] **http://www.canadiancleanpowercoalition.com/index.php/ccpc-materials/ccpc-reports-phase/phase-i/**

[32] Wilson, M. and M. Monea (Editors), 2004. IEAGHG Weyburn CO_2 Monitoring and Storage Project Summary Report 2000–2004. From the Proceedings of the 7th International Conference on Greenhouse Gas Control Technologies, September 5–9, 2004, Vancouver, Canada. Petroleum Technology Research Centre, Regina.

[33] **http://hub.globalccsinstitute.com/sites/default/files/publications/151303/co2-stored-underground-ieaghg-weyburn-midale-co2-monitoring-storage-project.pdf**

[34] **http://www.environment.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=1273,1272,929,928,926,240,94,88,Documents&MediaID=619&Filename=2007-052_project_description.pdf**

[35] By this time, CO_2 sequestration in deep saline aquifers associated with "acid gas reinjection" at natural gas producing operations was an accepted practice, e.g. StatOil's Sleipner field. See Tore A. Torp and John Gale, Proceedings of the 6th Conference on Greenhouse Gas Control Technologies, 2003, Volume 1, p. 311–316.

[36] **http://www.pm.gc.ca/eng/news/2008/03/25/pm-and-saskatchewan-premier-announce-major-carbon-capture-and-storage-project**

[37] **http://www.publications.gov.sk.ca/details.cfm?p=56895**

[38] **http://www.SaskPower.com/our-power-future/our-electricity/our-electrical-system/boundary-dam-power-station/**

[39] **http://www.shell.com/global/products-services/solutions-for-businesses/globalsolutions/shell-cansolv/shell-cansolv-solutions/co2-capture.html**

[40] **http://www.shell.com/global/products-services/solutions-for-businesses/globalsolutions/shell-cansolv/shell-cansolv-solutions/so2-co2.html**

[41] Johnstone, Bruce, 2012. From Regina Leader-Post and Saskatoon StarPhoenix newspapers. "SaskPower, Cenovus sign CO_2 supply deal". December 20, 2012.

[42] There are many sources of ENGO criticism of the BD3 ICCS Project. One example from the Sierra Club of Canada is embedded in the newspaper article noted in reference 51.

[43] Zinchuk, B., 2015. Pipeline News. "Report critical of Boundary Dam suggests the answer is wind". April 1, 2015.

[44] **http://large.stanford.edu/courses/2010/ph240/vasudev1/**

[45] See for example: Lefebvre, R., Elena Simonova, and Liang Wang. July 2012. Issue in Focus. Certified General Accountants (Canada). "Labour Shortages in Skilled Trades – The Best Guestimate?" http://ppm.cga-canada.org/en-ca/Documents/ca_rep_2012-07_labour-shortage.pdf

[46] **https://en.wikipedia.org/wiki/R._W._Beck,_Inc. Due to various acquisitions since 2009, R.W. Beck is now part of Leidos Engineering LLC, www.leidos.com/engineering**

[47] **http://www.babcock.com/products/Pages/Subcritical-Radiant-Boilers.aspx**

[48] **http://www.snclavalin.com/en/**

[49] **http://www.mhps.com/en/products/generator/**

[50] **http://www.stantec.com/**

[51] **http://www.cenovus.com/operations/oil/docs/rafferty-landowner.pdf**

[52] Johnstone, B., 2014. Regina Leader-Post. "CCS best bet to stop climate change." October 4, 2014.

[53] Wu, Ying and John J. Carroll (editors), Acid Gas Injection and Related Technologies, Advances in Natural Gas Engineering, 2011. John Wiley & Sons. P. 170.

[54] **http://www.tcmda.com/en/**

[55] **http://www.oilsandsken.com/huge-challenge-facing-oil-and-gas-companies/**

[56] **http://www.ferc.gov/industries/gas/indus-act/lng.asp**

[57] **http://www.nrcan.gc.ca/energy/coal/carbon-capture-storage/4333**

[58] **http://SaskPowerccs.com/2015-symposium/symposium/**

[59] **http://www.co2-research.ca/index.php/about-us/**

[60] **https://ukccsrc.ac.uk/**

[61] Hitchon, Brian (Editor), 2012. Best Practices for Validating CO_2 Geological Storage: Observations and Guidance from the IEAGHG Weyburn Midale CO_2 Monitoring and Storage Project.

[62] Private communication with the PTRC.