PLANNING FOR THE FUTURE: SASKPOWER'S CCS RESEARCH ACTIVITIES

FOR MORE THAN THREE DECADES, SaskPower has been conducting internal research and supporting external research to develop and validate new technologies to mitigate environmental impacts associated with GHGs, SO_2, NO_X, mercury, and particulates. These undertakings have included:

- Providing a custom-built facility at Boundary Dam to facilitate the demonstration of promising amine-based capture technologies by the International Test Centre for CO_2 Capture at the University of Regina.
- Founding and supporting the Oxyfuel Combustion technology development program at CanmetENERGY in Ottawa, Canada[57].
- Financial support and technical participation in the IEAGHG Weyburn-Midale CO_2 Monitoring and Storage Project (2000–2012).
- Founding and supporting the Canadian Clean Power Coalition (CCPC) (early 2000s to present), an organization dedicated to investigation and advancement of technologies related to clean use of coal for power generation.
- Being the founding funder of the Aquistore deep saline aquifer CO_2 geological storage monitoring project (2009–2017) managed by the Petroleum Technology Research Centre in Regina, SK. This project is currently monitoring the geological storage of CO_2 from BD3 as of April 2015. That daily injection volume is expected to increase over time as injectivity improves.
- Initiating and managing the Emissions Control Research Facility (ECRF) at the Poplar River Power Station near Coronach, SK. Mercury control technologies were validated at this facility prior to being implemented. During the design and engineering of BD3, SaskPower recognized that there was a paucity of validated data to support new capture technologies and thereby reduce the risk of scale up and other uncertainties. ECRF may be part of advancing and maturing some of those technologies.

THESE EFFORTS have not been simply about developing new technologies but have been more importantly about reduction of the risk of decision making for future clean coal power plant technology and equipment options. Providing venues to demonstrate and validate technologies has the advantages of:

- reducing capital and operating costs;
- improving reliability and operability;
- enhancing and reinforcing understanding;
- building knowledge and know-how; and
- assuring stakeholders about the risks associated with choosing new technology.

The SaskPower Carbon Capture Test Facility is validating new power systems developed by Mitsubishi Hitachi as its first project to be completed by the end of 2016.

Consequently, since 2012 SaskPower has ramped up its clean coal technology development activities in support of finding and proving the next best CO_2 capture technology. Additional new activities include:

1 It has designed, constructed and is operating the Carbon Capture Test Facility (CCTF) at the 300 MW Shand Power Station, which officially opened in June 2015.

The facility incorporates a 2-meter diameter CO_2 absorption tower capable of capturing 120 tonnes per day of the gas. This is at engineering validation scale.

The facility is validating new power systems developed by Mitsubishi Hitachi as its first project to be completed by the end of 2016.

It will continue to test vendor technologies on a confidential basis in future years and will also consider non-confidential testing in collaboration with other partners.

The facility will ensure that future SaskPower projects will benefit from a selection of validated commercial technology that will considerably reduce the risk of commercialization and provide the essential data to design and engineer the associated full-scale facilities.

Since the facility is part of a full-scale power plant, there will be the opportunity to evaluate entire systems upstream of carbon capture and their impacts on capture technologies. This will present an opportunity to adjust each piece of equipment and monitor the impact on the entire power generation system. For instance:

WHAT would be the power levers?

WHAT would the capture levers?

HOW would we need to optimally integrate both sides of the power plant to, for example, reduce steam consumption in capture?

HOW would we manage flue gas? Fly ash?

2 The ECRF continues to be operated at Poplar River to validate other emissions control technologies.

3 Tracking and troubleshooting amine chemistry is an ongoing process at two field laboratories (Boundary Dam and Shand) and at the Central Amine Chemistry Laboratory in Regina. The goals of this research are to understand degradation mechanisms and reaction pathways to mitigate "bad actors" like SO_3 and other flue gas constituents that impact both SO_2 and CO_2 amine-based capture processes, and to understand the formation and toxicity of nitrosamines in the amine capture system to help mitigate their formation and/or develop appropriate disposal strategies. SaskPower is also collaborating in complementary work at the University of Regina.

4 An annual SaskPower Symposium on Post-Combustion Capture for Coal-Fired Power Generation has been held twice in Regina during 2013 and 2014[58]. SaskPower will also be hosting the 2015 IEAGHG PCCC3 Conference. These have been/will be public knowledge and information exchange vehicles to maximize collaboration and information exchange, while minimizing any unnecessary duplication of effort.

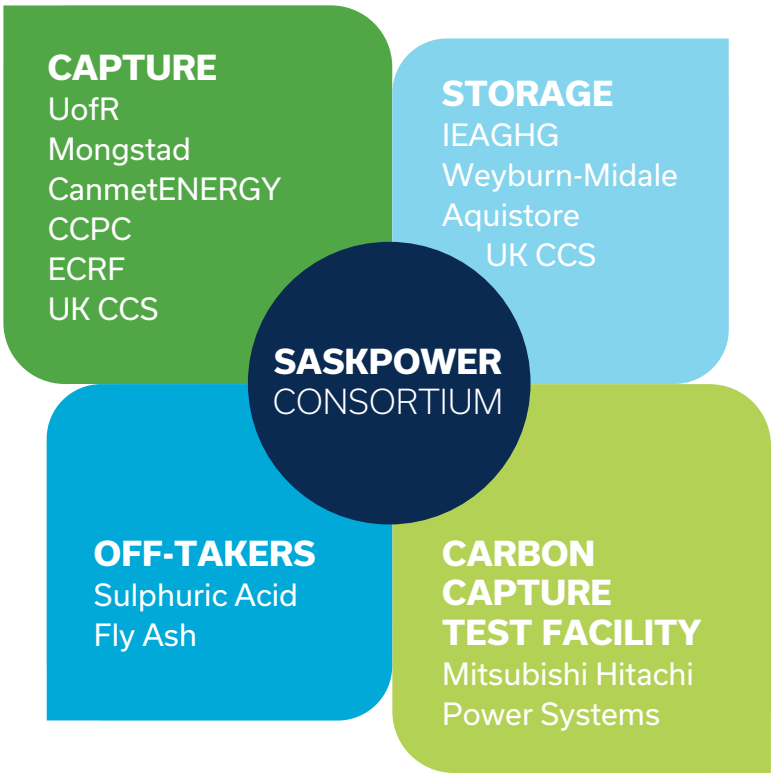
5 SaskPower intends to share non-commercial insights and data from designing, constructing and operating the PCC facility at BD3, the only fully cost-validated model for clean coal power generation combined with integrated commercial CCS technologies in the world. This will be the site for "ground truthing" the details of integrated amine-based post-combustion CO_2 capture. Although the mechanics of cooperation remains a subject of discussion, there is interest in collaboration with technology vendors and various research organizations such as the University of Regina[59], the UK CCS Research Centre[60], CO_2 Technology Centre Mongstad, and others.

6 SaskPower is contemplating a new CCS Consortium that may include opportunities to collaborate in the following areas, providing the necessary alignment between participants can be achieved:

- Technology
- Research
- Procurement
- Supplier management
- Project management
- Training
- Regulatory affairs
- Government relations

All of the aforementioned activities are timely given the need to make a technology decision for BD4 and BD5 by 2019, should it be decided in two years' time that the units will be retrofitted rather than decommissioned.

FIGURE 21 | SASKPOWER'S STRATEGIC CCS INITIATIVES AND RELATIONSHIPS



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+CO_2+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.

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[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.