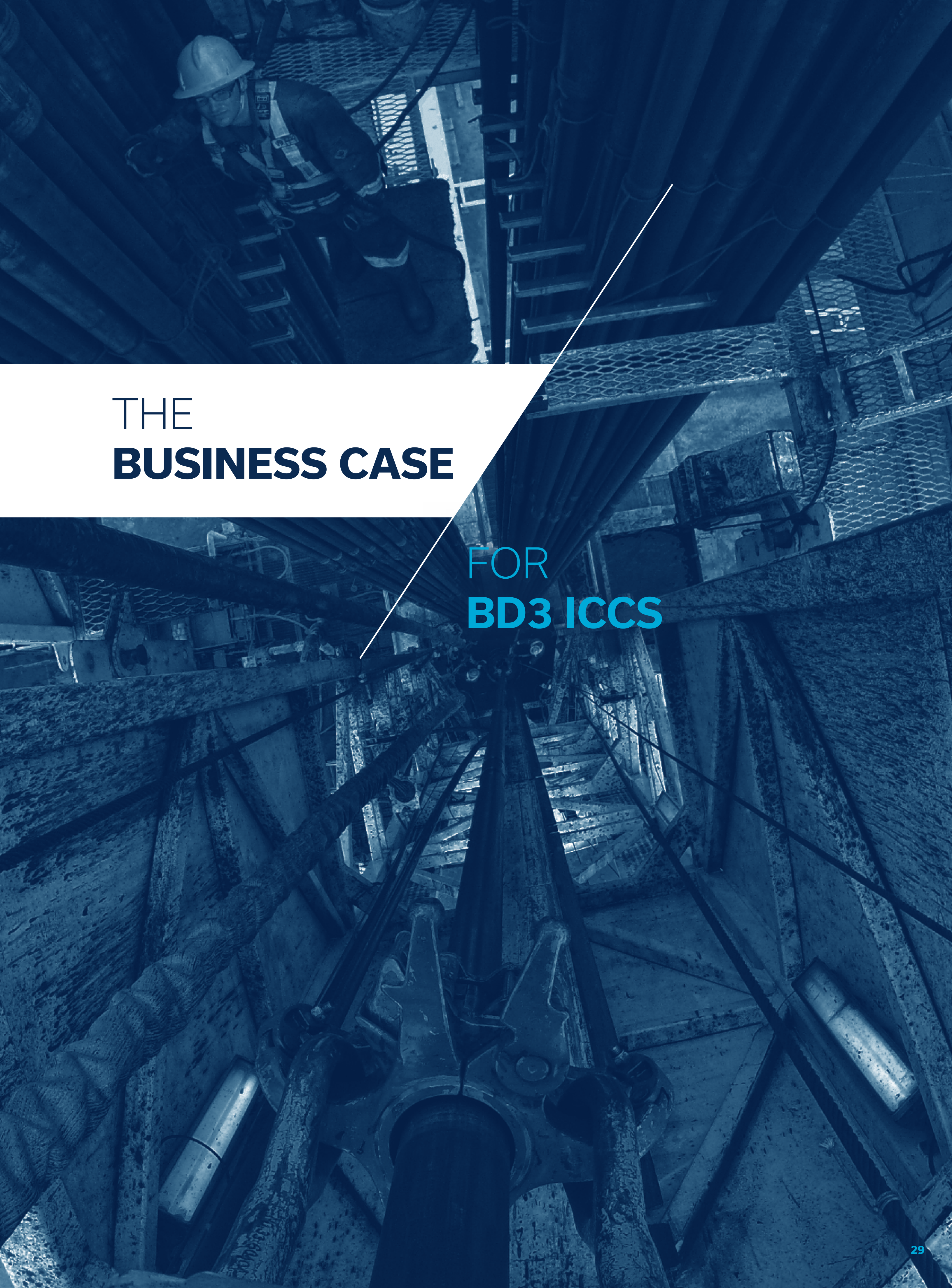
THE **BUSINESS CASE** FOR **BD3 ICCS**

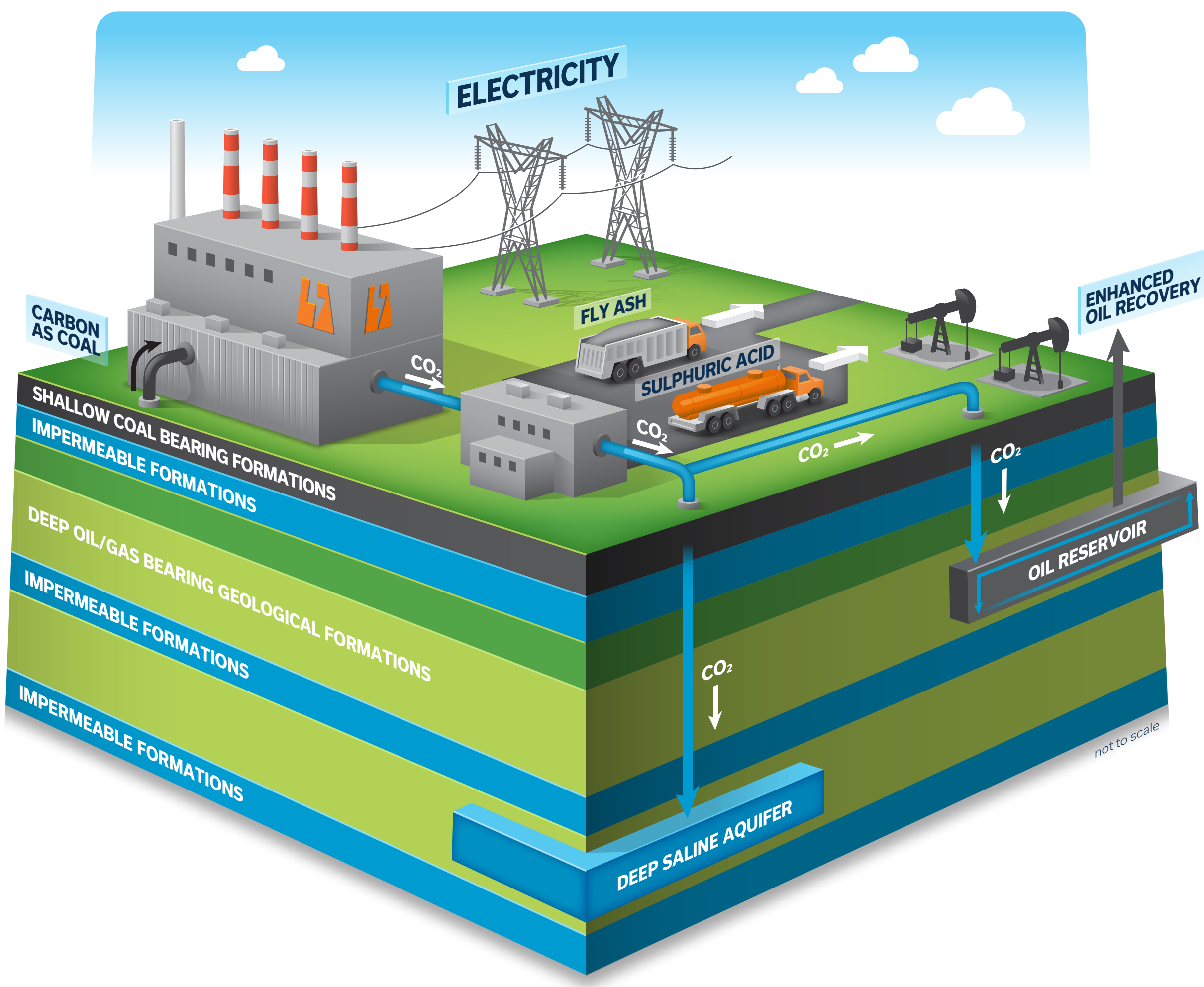


THE IMPACT OF BY-PRODUCTS

In its simplest form, the business case for the BD3 retrofit to convert to clean coal power generation boils down to making valuable by-products (CO_2, sulphuric acid and fly ash) to meet regional market demands, in addition to power generation [Figure 13]. Those very by-products had been determined from economic forecasts to have competitive pricing in Saskatchewan and the northern USA at the time the decision to construct the BD3 retrofit was made in late 2010/early 2011.

The projected, highly competitive market for by-products is expected to span the useful operating life of the retrofitted plant (i.e. 30–35 years), thereby offsetting a major part of the capture plant investment cost. The economic evaluation of the BD3 design(s) assumed that the capture plant would be operated at 85% capacity, and would produce 1 M tonnes per year of supercritical, high-purity CO_2 or approx. 3250 tonnes per day. This economic scenario could be characterized as the yield of a zero net present value for the Integrated Carbon Capture and Storage Project (ICCS) at BD3. A key component of the business case of BD3 was the rare injection of federal funding (C$240 million), that represented approx. 20% of the capital cost of the retrofit, and helped to offset the cost of engineering and design of the retrofit since it was a "first time ever" project in Canada.

FIGURE 13 | USING COAL TO GENERATE POWER AND VALUABLE BY-PRODUCTS



In fact, so huge was the forecasted potential for CO_2 sales volume and price over the next few decades in the southeastern Saskatchewan region, it was not essential to have a long-term CO_2 sales contract in place to support the approval of construction of the project by CIC in early 2011. Market demand was effectively 100% assured. However, well before the first delivery of carbon dioxide by SaskPower in October 2014, the entire volume of CO_2 was sold to Cenovus under a ten-year contract[41]. Cenovus planned to use the CO_2 for its EOR operation at the Weyburn oil field. It seems entirely likely that should the value of CO_2 rise over time due to increased demand by the local oil industry, SaskPower would actually realize an unplanned financial gain from the BD3 retrofit that couldn't be predicted when the capital expenditure was approved in 2011.

The business case for the BD3's ICCS retrofit boils down to making valuable by-products, namely CO_2, sulphuric acid and fly ash, for off-taker markets.

REALIZING CONTINUED VALUE FROM EXISTING **INFRASTRUCTURE**

What made the economic case so compelling for generation of power from clean coal using an existing power plant versus the unfavourable economics of power from a newly-built clean coal power plant was the sunk cost in existing infrastructure. The BD3 power plant was constructed in 1970, when skilled labour was plentiful and materials, like steel, were inexpensive. The prices of labour and materials were quite the opposite around 2010 when the business case for BD3 was finalized. Furthermore, as a consequence of SaskPower's long-term employment of skilled power engineers at Boundary Dam Power Station, there would likely be a suitable pool of workers in the region to staff the retrofitted power plant when it was completed. The situation could well be quite different at a new power station elsewhere in the Province.

In all likelihood, an aged, existing power plant incorporating technology targeted for conversion to clean power would have reached or nearly reached the end of its planned useful life, and its capital cost could be close to full depreciation, when a decision would have to be made about retrofit vs. retirement. Retrofitting presented a golden opportunity to install new power generation technology and equipment that would provide reliable and efficient service equivalent to a newly-built power plant without the associated infrastructure costs. Additionally, installation of new power generating equipment would also be an opportunity to more effectively and efficiently deploy thermodynamic integration of the power plant with the capture unit rather than integration of carbon capture equipment with an unmodified, though relatively new, power plant, such as Shand.

TIMING AND CONSIDERATIONS FOR A CAPITAL INVESTMENT DECISION

As stated previously, it is important to realize that the business case for BD3 was made in 2009–2010, when natural gas prices were higher than when the BD3 retrofit began generating power in June 2014. Those high natural gas prices made the comparison more favourable for the clean coal retrofit of BD3 versus a newly built NGCC power plant which supported the go-ahead decision for construction [Figure 14].

Intangibles that were difficult to pinpoint financially were also considered, given SaskPower's public ownership status, that included:

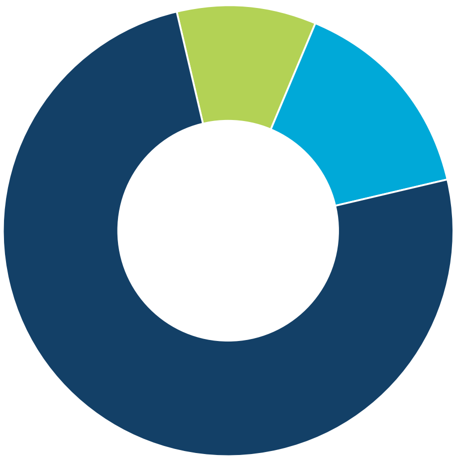
- better environmental footprint,
- positive socio-economic package, and
- a valuable learning opportunity.

The latter factor was particularly important for a first-time project like BD3 ICCS. The project would include insights upon which SaskPower and its partners could improve in the next old coal plant conversion project(s) to do the retrofit better, faster and cheaper.

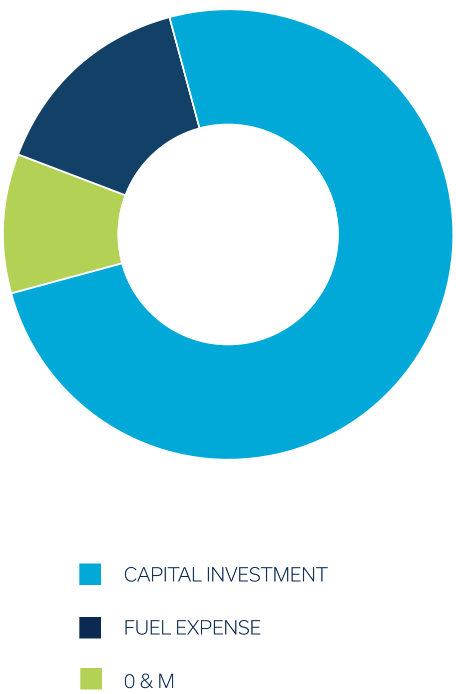
It is important to note that as a publicly-owned utility, SaskPower is not a profit-driven organization. It is an electricity-rate-driven enterprise that considers the lowest cost next option to supply its customers with power, reliably and sustainably. Consequently, if two roughly equivalent options have the same rate impact, other considerations come into play such as socio-economic benefits. So while the aforementioned "side benefits" may make clean coal a better outcome than natural gas, SaskPower's role is to firstly quantify the economic, reliability, and sustainability values and then to supplement that information with pertinent socio-economic information to support the investment decision by the Government of Saskatchewan. To be clear, the decision to proceed with the BD3 ICCS project was the most strategic and sustainable choice at the time it was made.

FIGURE 14 | COMPARING THE COST OF NGCC WITH CLEAN COAL AND CCS (2009–2010)

BASELOAD NATURAL GAS COST OF ELECTRICITY



BD3 CARBON CAPTURE COST OF ELECTRICITY



CONTINUED ACCOUNTABILITY FOR MAJOR PUBLIC INVESTMENT DECISIONS

> The decision to proceed with the BD3 ICCS project was the most strategic and sustainable choice at the time it was made

Narrowing in on a generation supply technology choice is not only difficult from investment, engineering and operating perspectives (see "Retrofitting an Aging Coal-Fired Power Plant"), but it is even more complicated when investors (shareholders or citizens in the case of a public utility like SaskPower) question the decision many years later when circumstances will undoubtedly have changed. The point in time when a technology choice is made is the only time when anyone can logically compare alternatives, such as NGCC or wind combined with simple-cycle gas power backup, AND any investment decision will be made a few years before the installation can be completed and operational.

By the time a power plant is operational, the economic and technical conditions for the project will most likely have changed and can potentially make its choice look poor relative to newer information. Almost certainly, the comparative cost of various fuel sources will have changed. This proved to be the case for BD3 as we can see from recent criticism of the project from a number of quarters, principally ENGOs[42].

Any debate about a power generation investment must also consider the complete suite of power generation capacity being operated by the utility. SaskPower's entire fleet clearly demonstrates that the power utility has a diverse power mix that ensures environmental and economic sustainability for many decades to come.

At the time SaskPower decided to pursue post-combustion capture in 2009–2010, retrofitting BD3 to convert it into a clean coal power facility was comparable to the cost of building another NGCC power plant, which would entail the shutdown of the original BD3 power unit. By the time power was generated from the upgraded BD3 in June 2014, natural gas prices had slumped and NGCC looked rosy in comparison to the retrofitted BD3 power unit. The total C$1.24 billion budget for the BD3 retrofit to incorporate CCS that was announced in April 2011 was overrun past plan, reaching C$1.467 billion[43] for reasons that will become apparent to the reader later in this report. The upgrade of the power plant was seriously over budget, while the capture plant cost was slightly over budget. The entire project schedule was delayed by several months compared to the original plan.

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

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[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**

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[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.

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[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

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