SUMMARY OF THE CHALLENGES ENCOUNTERED FROM INCEPTION TO OPERATION OF THE BD3 RETROFIT

ORGANIZATION

By 2008, SaskPower was no longer organized to manage a "mega" energy project. The last project of this size was the design, engineering and construction of the Shand Power Station that was completed in 1992. The Shand engineering team had long since been disbanded and most team members had retired or left the company.

TECHNOLOGY CHOICE

Making the carbon capture technology choice was particularly problematic because it was difficult to visualize any of the processes under consideration and its integration with the power plant due to lack of scalable engineering data and operational history.

POWER PLANT AND CAPTURE PLANT INTEGRATION

The most complicated part of the design and engineering process was integration of the power plant with the capture plant. This was a custom design and completely new territory as the first project of its kind in the world. Accordingly, the project bore unusual expenses associated with first-time technology risk mitigation. This was expected and was the justification for seeking the C$240 million federal funding. It is expected that these costs will not be incurred on the next similar project.

CHANGE MANAGEMENT AND PROCUREMENT

Change management during design and engineering was a particular challenge that was complicated by procurement requirements:

> The open procurement process necessitated by the public ownership of SaskPower required tight technical specifications for appropriate and timely management of purchasing to avoid unnecessarily extensive lists of bidders and the associated SaskPower workload to evaluate their proposals. Regardless, a longer list of potential options for each piece of equipment than desirable was considered in most instances.

> Each equipment selection inevitably slightly changed the overall engineering design and impacted choices of other pieces of equipment. This could be termed a "ripple effect" that lengthened the time required to complete the engineering design prior to construction approval in December 2010..

> Technology risk for CO_2 capture was mitigated by keeping a tight rein on performance specifications for the integrated equipment in the power plant as well as the capture equipment. Changes in equipment choices, with associated differing performance specifications, made technology risk management difficult.

LENGTHY PROCUREMENT

Procurement processes were often protracted due to multiple levels of approval required each time a piece of equipment was selected. It took approximately 2 years to complete the final design and engineering as a consequence of the procurement time and its impact on overall design.

TECHNOLOGY RISK MANAGEMENT

Risk management during design and engineering meant building a considerable amount of equipment redundancy into the capture plant. The successful operation of the power plant during upsets and trips in the capture plant has meant that some of this equipment was not ultimately required. The associated challenges were:

> to determine how much redundancy was sufficient to effectively manage the technology risk AND satisfy stakeholders, and

> to keep capital costs within reason so that the BD3 ICCS project was affordable.

This was typical for a first-time project leading to a one-time ***cost of performance uncertainty.***

THIRD PARTY REVIEW

The third-party review by R.W. Beck came at a challenging time in mid-2010 when workload was at a high level as the SaskPower team tried to complete the engineering for the project. This led to a very high workload for the engineering team.

SUMMARY OF THE CHALLENGES ENCOUNTERED FROM INCEPTION TO OPERATION OF THE BD3 RETROFIT

CONTINUED

KEEPING OPTIONS OPEN

SaskPower needed to keep technology and equipment options open for an extended period of time until decision makers were comfortable with the recommended course of action. This was typical for a first-time project to ***build technology confidence.***

COMPLEXITY OF "BROWN-FIELD" CONSTRUCTION

SaskPower and its owner's engineer (Stantec) undertook the integration of the power plant and the capture plant using a design-build approach, in order to manage the complex "brown" field construction in the power plant that would have made an EPC approach uncompetitive. There was a significant amount of additional scope that was discovered as the design was progressed.

LOCATION OF BD3 WITHIN THE POWER STATION

Unit 3 is located in the middle of the Boundary Dam Power Station. This complicated the ability to physically move tradespeople and materials around the construction site, necessitating construction of two people elevators and one mechanical elevator, as well as roof-top lunch rooms and roof-top openings that were used solely for the construction period.

IMPACT OF TIMING OF CONSTRUCTION

Construction costs had doubled from 2004–2007 in Western Canada[55]. This was partly due to a shortage of skilled trades labour and many competing "mega" energy projects in the region, as well as record prices for construction materials such as steel.

CORPORATE POLICY CHANGES

Several policies within SaskPower changed during the project period (2008–2014), including: new safety standards (e.g. banning man lifts, asbestos management); a new quality assurance program; and a new procurement process.

MANAGING LABOUR

Due to the high level of competition for skilled labour in Western Canada, SaskPower had to ensure it was an "employer of choice" by effectively managing a myriad of unusual details, including: accommodations, on-site infrastructure, parking, ease of manpower movement at site, etc. Additionally, operator staffing for the capture plant had not been foreseen and had to be undertaken at a time when the skilled labour shortage was at its peak in the early-2010s in Western Canada.

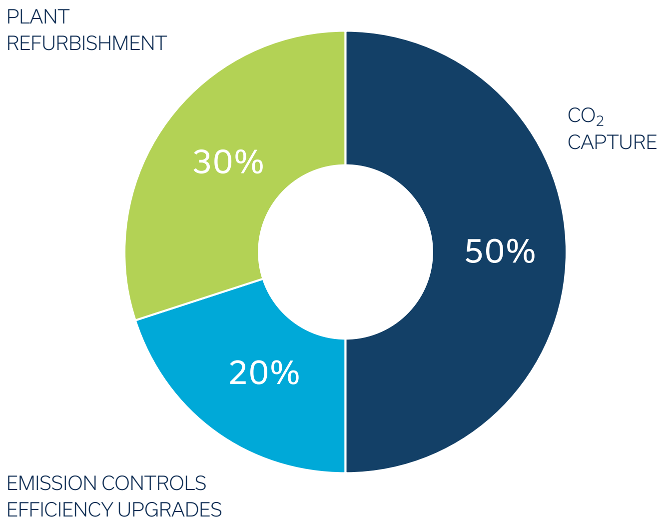
UNFAMILIARITY WITH CAPTURE EQUIPMENT

First-time projects typically require the time to gain experience in the operation of unfamiliar equipment and processes. Added to this was the complication of working with unexpected amine chemistry, which was completely foreign territory for a power company. During 2015–2016, SaskPower is correcting construction deficiencies and building knowledge and understanding about amine-based capture chemistry to help optimize the chemical processes in the capture plant.

MEGA PROJECT INVESTMENT DECISION

A technology decision, and its associated investment approval by stakeholders, is made at a fixed point in time. Technical, business and economic conditions will most likely change from that decision time until the project is completed. However, the company will be held accountable by its shareholders for the investment decision when the facility is operational.

FIGURE 19 | BD3 RETROFIT CAPITAL COST BREAKDOWN



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)

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[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/**

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