

Health and Safety Considerations in Carbon Capture and Storage

Lessons from Boundary Dam CCS Project

September 18, 2025



We protect the owner's interests through the entire project lifecycle

Strategic Advisory

- Public engagement & issues management
- Project development strategies, economics & business case development
- In-house policy & regulation expertise
- High-level education on policy & regulatory impacts for heavy emitters
- Analysis on implications of CCS policy & regulations
- Develop & craft regulatory & policy strategies
- Communications planning & strategy

Technical Services

- CCS Feasibility Studies
 - Execution & support
- CCS FEED Studies
 - Support as Owner's Engineer (HAZOPs, RAM, studies, technical reviews)
 - Third party review
- Specialized CCS Technical Expertise
 - Thermal integration
 - Flue gas characterization
 - Technology screening & selection
 - Regulatory permitting advice
- Project Execution
 - Performance testing & operational transition

Courses & Custom Training

- BD3 CCS Facility site tours
- Customized technical lesson learned workshops
- Course offerings:
 - CCS 101
 - BD3 lessons learned
 - CO₂ capture technologies
 - Transportation & storage
 - Amine chemistry



SaskPower's Boundary Dam Unit 3 CCS Facility (BD3)

World's first fully integrated post-combustion CCS facility

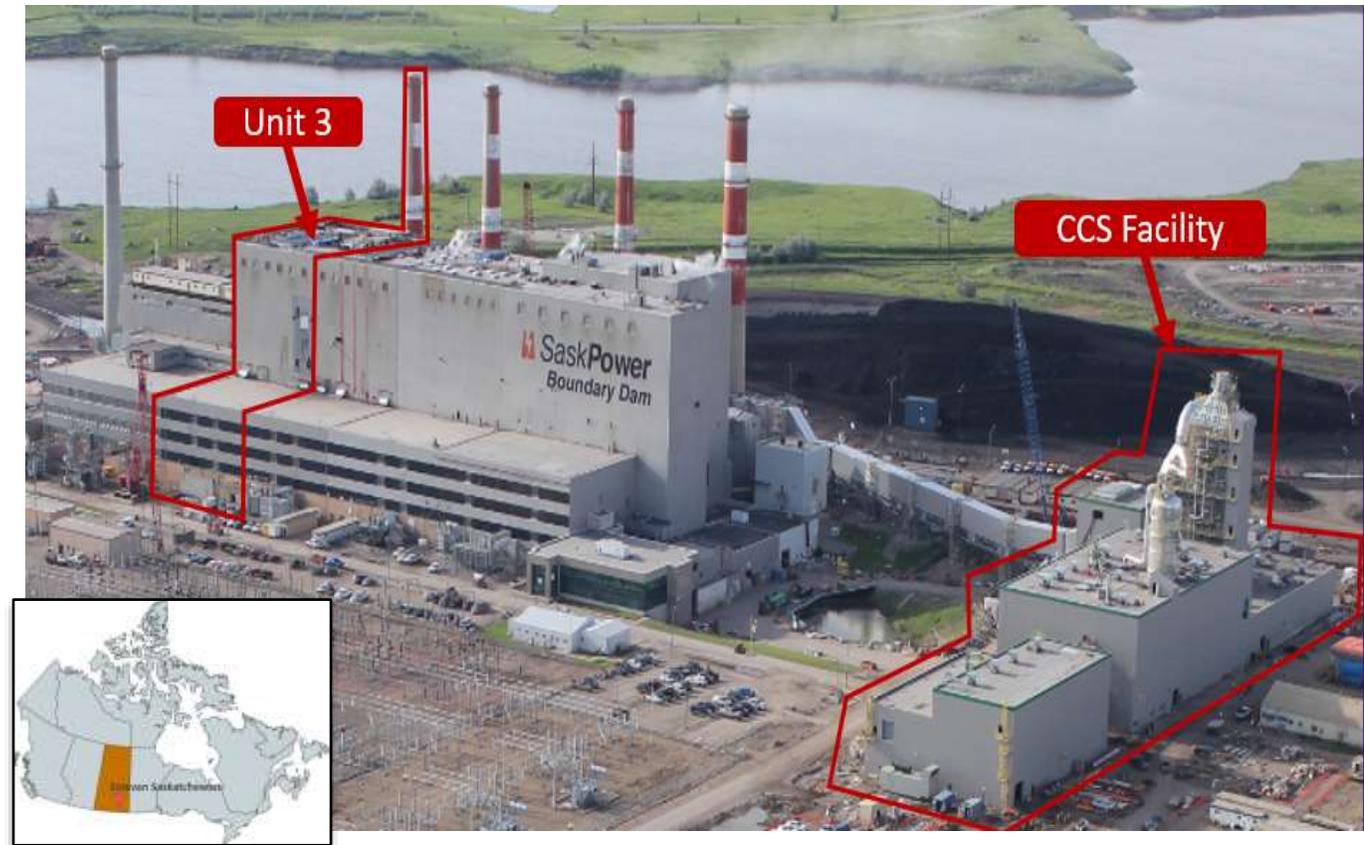
- Extended life of the 45-yr-old Boundary Dam Unit 3
- Located in Saskatchewan, Canada

Total CAPEX: 1.5 Billion Canadian Dollars

- Executed as a two-part project:
 - Power island upgrade (\$600M)
 - CCS retrofit (\$900)
- Aided by 240 CAD million-dollar federal grant

Capture operations began October 2014

- 7 million tonnes of CO₂ captured & stored since 2014
- CO₂ used for EOR and stored in the Aquistore Project

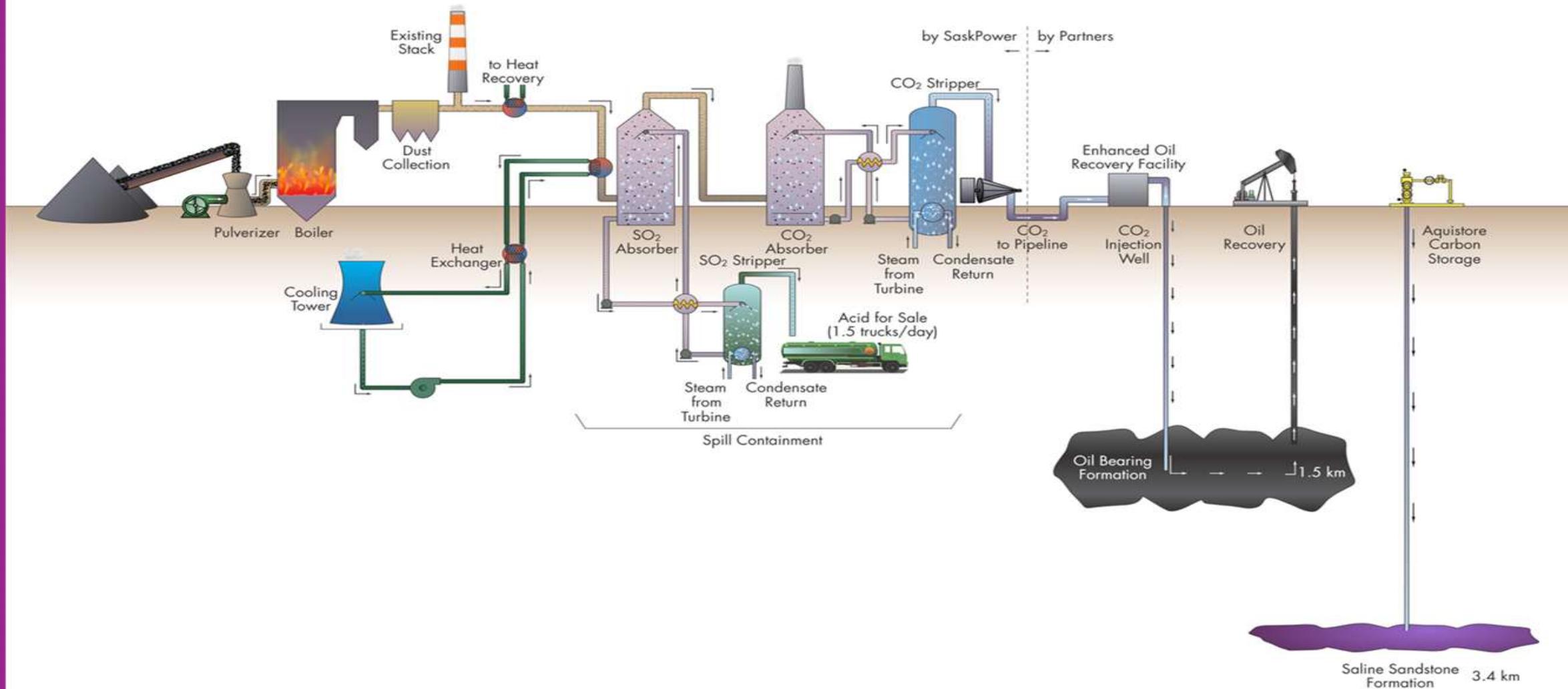


Boundary Dam Power Station and the ICCS Facility

EOR = Enhanced Oil Recovery



Overview of BD3 Integrated CCS Process



Health and Safety Considerations



EVALUATION



EXECUTION



OPERATIONS



- Regulatory Compliance
- Development of OH&S Philosophies

- Training and Competency
- Standard Operating Procedures (SOPs)
- Emergency Response Planning
- Material Safety Data Sheet Development

- Emissions Monitoring
- Performance Monitoring
- Management of Waste Streams
- Management of Change



Regulatory Compliance



EVALUATION

PRE-FEASIBILITY

FEASIBILITY

FEED

1 year

2 years

- Regulatory Compliance
- Development of OH&S Philosophies

- **Challenges for SaskPower**

- Lack of experience in CCS
- Lack of specific regulatory guidelines for amine-based capture
- Proprietary nature of the solvent complicated OH&S effort
- Significant concerns regarding emissions of nitrosamines

- **Adoption of NILU Guidelines**

- Emissions limits for monoethanolamine (MEA) and N-nitrosodimethylamine (NDMA)
- NDMA used as a surrogate model for air emissions

OH&S = Occupational Health & Safety

NILU = The Norwegian Institute for Climate and Environmental Research

Regulatory Compliance



EVALUATION

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2 years

- Regulatory Compliance
- Development of OH&S Philosophies

Risk estimates for NDMA in air in different jurisdictions

Territory	Risk Level	Limit, $\mu\text{g}/\text{m}^3$	Reference
Norway	Below 10^{-5}	0.0003	[1]
USA	10^{-5}	0.0007	[2]
	10^{-6}	0.00007	[2]
Canada	10^{-5}	0.003	[1]
	10^{-6}	0.0003	[1]
WHO	10^{-5}	0.003	[1]
	10^{-6}	0.0003	[1]
UK	-	0.0002	[3]

[1] [CO₂ capture: Health effects of amines and their derivatives – NIPH](#)

[2] [N-Nitrosodimethylamine \(CASRN 62-75-9\) | IRIS | US EPA](#)

[3] [Appendix C: summary of toxicological evidence for MEA and NDMA - GOV.UK](#)



Regulatory Compliance – Lessons Learned



EVALUATION

PRE-FEASIBILITY

FEASIBILITY

FEED

1 year

2 years

- Regulatory Compliance
- Development of OH&S Philosophies

- Prepare for regulatory voids

- Specific emissions of proprietary amines / nitrosamines
- Significant effort to establish safe limits with the regulator
 - Operator-derived Environmental Assessment Levels (EALs) / Proxy chemicals
 - Dispersion modelling studies
 - Inputs: expected rates of emission at the vent (by Licensor)
 - Rate of amine degradation, potential reactions of amines with other components of the flue gas
 - Potential reactions of amines with the atmosphere



Development of OH&S Philosophies



EVALUATION

PRE-FEASIBILITY

FEASIBILITY

FEED

1 year

2 years

- Regulatory Compliance
- Development of OH&S Philosophies

- **Compliance dictates detailed design**
 - Over-engineered for safety vs. CAPEX/OPEX
- **Hazard and Operability Studies (HAZOPs) executed throughout project timeline**
 - Critical for processes new to Operations staff
 - 3D model reviews conducted between EPC and cross-functional teams – formal reviews at 30%, 60%, 90% stages
- **Include your OH&S team in your reviews**



Training and Competency



- Training and Competency
- Standard Operating Procedures
- Emergency Response Planning
- Material Safety Data Sheet

• High-fidelity Plant Simulator – Mid 2012

- Integrated Host Plant, Capture Plant, Aquistore
- Extensive document requirements: H&MB, P&IDs, manuals, spec sheets
- Benefits
 - Improved process knowledge and safety
 - Improved troubleshooting skills
 - Smoother start-ups and shutdowns
 - Fewer abnormal situations/trips
 - Minimized down time due to operator error
 - Better overall training of new operators



Standard Operating Procedures (SOPs)



- Training and Competency
- **Standard Operating Procedures**
- Emergency Response Planning
- Material Safety Data Sheet

• SOP Development

- Detailed OEM manuals and operating procedures were converted to Standard Operating Procedures (SOP's)
- Ensure alignment between Host Plant and Capture Plant

• Task-specific work permits

- Hazard and Risk Assessment (HARA) to be completed before any field work tasks undertaken
 - Dictates PPE required, emergency rescue procedure, etc.

Personal Protective Equipment (PPE)

PPE	Minimum Risk	Low Risk	Medium Risk	High Risk
Hard Hat	•	•	•	•
Hearing Protection	•	•	•	•
Safety Glasses with Side Shields	•	•	•	•
Chemical Goggles and Face shield		•	•	•
Chemical Suit		As per HARA	As per HARA	•
Leather Gloves	•	•	•	•
Viton-Butyl Gloves (Chem Resistant)		As per HARA	•	•
Safety Boots	•	•	•	•
Respirator and Cartridges		As per HARA	As per HARA	•



Emergency Response Planning



EXECUTION

CONSTRUCTION

COMMISSIONING

PERFORMANCE TESTING

3 years

- Training and Competency
- Standard Operating Procedures
- Emergency Response Planning
- Material Safety Data Sheet

• Within Plant Boundary

- Upgraded to include the new hazards in the Capture Plant
 - E.g., amine and SO₂/CO₂ leaks/spills
- Fire fighting procedures updated

• Outside Plant Boundary

- Response plan shared with local authorities
- Emergency crews (i.e., fire/police/ambulance) toured the Capture Plant



Material Safety Data Sheet Development



- Training and Competency
- Standard Operating Procedures
- Emergency Response Planning
- **Material Safety Data Sheet**

- **Virgin Solvent / Seasoned Solvent / Waste**
- **New Safety Data Sheet (SDS) or Hazard Information Sheet may be required**
 - Work with your regulator to understand the requirements
 - Licensor's IP restrictions may impact these processes
 - Who is responsible for developing new SDS's / hazard information sheets?

Absorber Emissions Monitoring



OPERATIONS

OPERATIONAL
EXCELLENCE

OPTIMIZATION

LOOKBACK

- Emissions Monitoring
- Performance Monitoring
- Waste Management
- Maintenance and Inspection
- Management of Change

- **Continuous Emission Monitoring System (CEMS)**

- Fourier-transform Infrared Spectroscopy (FTIR)
 - CO₂
 - H₂O
 - NO
 - NO₂
 - SO₂
 - NH₃
 - HCl/HF
- Oxygen Analyzer
- Total Organic Carbon (TOC) Analyzer
- Stack Temperature and Pressure



Absorber Emissions Monitoring



OPERATIONAL
EXCELLENCE

OPTIMIZATION

LOOKBACK

- Emissions Monitoring
- Performance Monitoring
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• Requirements for Stack Monitoring

- Regulatory – e.g., IED permitting
 - Technology provider's requirements
 - Operator dictated
 - Major operational changes / performance fine tuning
 - Targeting proprietary amines, nitrosamines, other gaseous degradation products
 - CEMS quality assurance: RATA / QAL2
- ## • Ensuring adequate platform for stack testing
- E.g., lighting, probes, sampling kits



IED: Industrial Emissions Directive
RATA: Relative Accuracy Test Audit
QAL2: Quality Assurance Level 2

Absorber Stack Enclosure



- **Stack Testing Safety**

- Dispersion study examining downwash scenarios
- Stack enclosure may be considered
 - Weather protection
 - Space for permanent storage of testing equipment
 - Ambient air monitoring

Ambient Air Monitoring



OPERATIONAL
EXCELLENCE

OPTIMIZATION

LOOKBACK

- Emissions Monitoring
- Performance Monitoring
- Waste Management
- Management of Change

- **Ambient Air Emission Monitoring**

- SO₂, CO₂, NO, O₂

- **Potential for fugitive emissions of nitrosamines**

- ThermoSorb-N cartridge by Ellutia Chromatography Solutions
- HPLC-MS / GC-MS techniques to analyse for specific nitrosamines of concern.

HPLC-MS: High Performance Liquid Chromatography-Mass Spectrometry
GC-MS: Gas Chromatography-Mass Spectrometry

Performance Monitoring



OPERATIONAL
EXCELLENCE

OPTIMIZATION

LOOKBACK

- Emissions Monitoring
- **Performance Monitoring**
- Waste Management
- Management of Change

- **Sample Collection (Liquid)**

- Ensuring optimal retrieval of samples and personnel protection from exposure to hazardous chemicals

- **Laboratory Analysis**

- Licensor's lab
 - Shipment required: Road / Ship / Air
 - Lengthy turnaround time
- Operator owned lab
 - Robust
 - Beneficial for performance fine tuning, troubleshooting
 - Secrecy agreements required. Significant effort to develop



Waste Management



OPERATIONAL
EXCELLENCE

OPTIMIZATION

LOOKBACK

- Emissions Monitoring
- Performance Monitoring
- **Waste Management**
- Management of Change

- **Waste Types**

- Spent solvent, reclaimer waste, used filters, used gloves, lab samples, etc.

- **Waste Management**

- Hazard information sheet or SDS for the waste
- IP requirements led to challenges in classifying waste
- On-site treatment / landfill / incineration / underground injection
- NDA to be signed with third-party waste management firms

IP: Intellectual Property
NDA: Non-disclosure Agreement

Continuous Improvement



OPERATIONAL
EXCELLENCE

OPTIMIZATION

LOOKBACK

- Emissions Monitoring
- Performance Monitoring
- Waste Management
- **Management of Change**

- **Revise as lessons are learned:**

- Accident investigations
- Root cause analysis
- Emission excursions or reductions
- Improving emission measurements
- Changing regulations
- Utilize HAZOP's should any process changes be considered

Goal is to operate the plant efficiently while safely protecting your workers and the environment.



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