PRESENTATION OUTLINE

Our History – 20 Years in the Making

The Present – Boundary Dam Unit 3, CCTF

The Future – Boundary Dam Units 4 & 5

Opportunities
OUR HISTORY
be more acceptable or $31,410,000. I suggest that SaskPower would not become involved in a project that will have a 25 percent risk factor attached to it.

5. **Owner's Costs**

AOSTRA has set a figure of $56,800,000 or 9 percent of total costs. In the IGCC study this was interest charges during construction, owner's on site inspection, and management costs, etc. I suggest maybe 5 percent may be more realistic at $31,410,000.

<table>
<thead>
<tr>
<th>Summary Table</th>
<th>AOSTRA</th>
<th>Revised AOSTRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>$251,100,000</td>
<td>$188,125,000</td>
</tr>
<tr>
<td>General Field Expense</td>
<td>119,900,000</td>
<td>119,900,000</td>
</tr>
<tr>
<td>Interconnection</td>
<td>43,700,000</td>
<td>25,110,000</td>
</tr>
<tr>
<td>Engineering &amp; Home Office</td>
<td>35,620,000</td>
<td>35,620,000</td>
</tr>
<tr>
<td>Licensor</td>
<td>1,790,000</td>
<td>1,790,000</td>
</tr>
<tr>
<td>Licensee</td>
<td>112,690,000</td>
<td>31,410,000</td>
</tr>
<tr>
<td>Risk</td>
<td>564,000,000</td>
<td>402,155,000</td>
</tr>
<tr>
<td>Total Construction Cost</td>
<td>63,400,000</td>
<td>38,010,000</td>
</tr>
<tr>
<td>Other Capital Costs</td>
<td>628,200,000</td>
<td>440,165,000</td>
</tr>
<tr>
<td>Total Installed Plant Cost</td>
<td>$61.00</td>
<td>$43.00</td>
</tr>
</tbody>
</table>

This rough review indicates a price of $43.00 per tonne. If the competition is at $30.00 per tonne I suggest the overall amine process has to become more cost-effective. There may be another $7.00 to $10.00 a tonne reduction in amine process. Another $2.00 to $3.00 with more integration with BDPs, has to come from general field expense, engineering design.
THE PRESENT
Current SaskPower CCS Projects

- Shand Carbon Capture Test Facility (CCTF)
- Boundary Dam Integrated CCS Project
- Other Initiatives
- Aquistore
Boundary Dam Integrated CCS Project

Original Unit #3
• Pulverized coal (lignite)
• 1800 psi 1000/1000F
• 139 MW net
• Minimal environmental controls
• Commissioned 1968

Replacement Unit #3
• New Unit, old box
• 1800 psi 1050/1050F
• 110+ MW
• 1 million t/y CO₂ capture and sales
• Near zero emissions
Boundary Dam Integrated CCS Project

Capture Facility

- Integrated SO2 & CO2 capture process
- 100% SO2 will be captured, converted to sulphuric acid
- 90% CO2 captured and transported for use in EOR
- Flyash will be captured and sold
- Construction of facility is complete, undergoing preparation for start-up
Status of Boundary Dam Integrated CCS Project
Power Plant Refurbishment: Construction Challenge
Steam Generator:
• Replaced and upgraded
• Superheater/reheater
• Low NO\textsubscript{x} burners
• Air Heater Upgrades
• Major Water Wall Replacements

Update for Sept 2013:
• Ready for Hydro Test
Turbine Generator Set:
• Full replacement from existing sole plates
• Provides wide range or process steam flow
• Enhanced efficiency
• Increased maximum nameplate

Update for September 2013:
• Ready for Cold Pull on HE piping
Capture Facility: on time and budget
Operator Training:
- Full process simulator on site and operating
- Completed in excess of 20,000 hours of class room training
- Completed in excess of 2,400 hours of simulator training
# BOUNDARY DAM INTEGRATED CCS PROJECT OUTCOMES

<table>
<thead>
<tr>
<th>Emission Change</th>
<th>Pre-CCS</th>
<th>Post-CCS</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>1094</td>
<td>120</td>
<td>90%</td>
</tr>
<tr>
<td>SO₂</td>
<td>11</td>
<td>0</td>
<td>100%</td>
</tr>
<tr>
<td>NO</td>
<td>1.5</td>
<td>1.1</td>
<td>27%</td>
</tr>
<tr>
<td>PM10</td>
<td>.2</td>
<td>.02</td>
<td>90%</td>
</tr>
<tr>
<td>PM2.5</td>
<td>.1</td>
<td>.03</td>
<td>70%</td>
</tr>
<tr>
<td>Hg</td>
<td>Under Corporate Cap</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Power to Grid**: 110 MW
- **Flyash**: 100% to Market
- **Sulphuric acid**: 100% to Market
- **CO₂**: 90% to Market
Cost Breakdown

Boundary Dam Integrated CCS Project Cost of Electricity

Boundary Dam Integrated CCS Project Capital Cost

- Co2 Capture: 50%
- Emissions Control: 30%
- Power Plant: 20%

Capital: 80%
Fuel: 15%
O&M: 10%
Boundary Dam Integrated CCS - A First Generation Project

- New Generator
- Existing Infrastructure
- 20% Capital Grant
- EOR

= Competitive Low Carbon Electricity
Shand Carbon Capture Test Facility
Shand Carbon Capture Test Facility

- For Commercial validation of amine PCCC systems
- Primary train: 120 tonnes per day
- Secondary train: 7.5 tonnes per day
- Catch and release
- Developed in collaboration with Hitachi Ltd.
- Primary train dedicated to Hitachi technology 2015 and early 2016
- Primary train open for non-Hitachi work mid 2016
- Secondary train available as needed
# Synergistic Relationship

<table>
<thead>
<tr>
<th></th>
<th>CCTF alone</th>
<th>CCTF with BD ICCS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Installed Cost</strong></td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td><strong>Direct Energy Demand</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>CO₂ Quality</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Operating Procedures/impact</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Indirect Energy (host impact)</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Trace Emissions</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Efficacy, Operability</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Consumables and Maintenance</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Uncertainty in all of Above</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>
CCTF “Universal Design”
Supporting Future Technologies

- 304/316 SS construction accommodates all prospective solvents
- Heat Exchangers, pumps, piping sized for wide range of solvent mixes – also upgradeable
- Absorber/desorber internals accessible for easy reconfiguration
- Space allowed for additional process equipment and expansion of tower packings
- High quality process steam provides flexibility
- Advanced measurement and data collection systems
- Zero liquid discharge site and full spill containment
CCTF “Universal Design”
Operability

- Extensive Instrumentation including CEMS
- Dedicated Control and Data System
- HMI in Satellite control room and in PCR
- Simulates “normal” commercial operation
  - typically 8,000 hour run
Shand Carbon Capture Test Facility

BD Large Scale Experience

Need for Viable Options

Hitachi Partnership

High Value Host Site

Carbon Capture Test Facility
Supporting Initiatives
Chemistry Initiatives

- Ultra High Sensitivity Equipment and Protocol for tracking solvents and byproducts through process and at process boundaries

- Experimental and computational approach to explore degradation pathways (Collaboration with U of R)
Performance Testing and Monitoring Plans
Challenges Encountered and Managed
(Every Significant Project Has Challenges)

• Focused engineering vs. exploration of all avenues
  • Focus delivering to the business case

• Procurement Strategies
  • Value - transparency - timeliness

• Construction Productivity

• Management of IP
  • Maintaining proprietary process (commercial) information while objectively sharing critical knowledge with stakeholders
  • Trust

• HSE concerns
  • Many Initial unknowns – most resolved
  • Ongoing Refinements
  • No Insurmountable issues
Health, Safety & Environment

- **Approach:**
  - HAZID/HAZOP
  - Chemical safety - solvent and byproducts
  - Third Party reviews

- **Technical resources:**
  - Engineering
  - Chemistry
  - Biochemistry
  - Operations

- We work with Provincial regulator

- **Toxicity assessments** for each solvent including byproducts

- Adoption of Norwegian (NILU) standards
Health, Safety & Environment

- Engineering design:
  - potential exposures are order of magnitude below accepted standards

- Engineering approach to ALARA concept
  - full containment, dedicated waste management

- Building in-house state of the art capacity for measuring and managing byproducts

- Assembled technical team to document solvent/flue gas interactions
  - work in progress- future benefits

- Ongoing improvements
Perspective Needed

Exogenous nitrosamines

- Cosmetics
- Tobacco & smoke
- Cured meats
- Water
- Pickled foods
- Malt beverages
- …and now
- Carbon Capture

Study

Actual
OPPORTUNITIES
Boundary Dam Generation 2

New Generator + Existing Infrastructure = Competitive Low Carbon Electricity

2nd Generation Technology + EOR
The Commercial Opportunity

- **1st Generation CCS Project:**
  - Optimized for successful demonstration of fully integrated power/CO2 cogeneration

- **2nd Generation CCS Project:**
  - Optimized for
    - Compliance with GHG regulations
    - “Right sizing” of components
    - Focused engineering – real life data available
    - Advanced subsystems designs (e.g. waste management)
    - Reliability, Availability and Maintainability (RAM) experience
    - Best NPV

- 30% lower capital intensity ($/MW) compared to subsidized Demo
BOUNDARY DAM UNITS 4 & 5

THE WORLD’S FIRST UNSUBSIDIZED CCS PROJECT?
Key Decision Points for BD 4 & 5 Project

**Concept**
- Preliminary Concept
- Data Gathering
  - Boundary Dam CCS Assessments
  - Air Emissions Regulations
  - CO₂ Market Evaluations
- Concept/Design Verification
- Preliminary Proposal

**Investment**
- *Initial Investment Decision #1*
  - Ph 1 Engineering
- *Initial Investment Decision #2*
  - Ph 2 Eng., Award #4 Steam turbine
- *Final investment Decision*
  - Final stages of investment
    - Engineering
    - Procurement
    - Construction

Proposals must be competitive at each stage

2019-2023
Boundary Dam Generation 2

New Generators + Existing Infrastructure = Competitive Low Carbon Electricity

2nd Generation Technology + EOR = Competitive Low Carbon Electricity

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Opportunities for Collaboration
SaskPower
Small but focused

Statoil  RWE  Huangeng  Vattenfall  Southern Company  SaskPower
Informing The Commercial Design

- Researchers
- Suppliers
- CCTF
- Boundary Dam
- Industrial Partners
- Test Centers
SaskPower 2nd Generation CCS
(The World’s First Unsubsidized CCS Project)

2020’s
BD 4&5

2010’s
ICCS Demo

2000’s
Shand 2 Oxy

1990’s
Specific

1980’s
General

Collaborating Partners

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