CANDU® Plants for Oil Sands Application

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Overview

• Major ongoing long term expansion of Alberta's oil sands production capability is underway.
• Extraction and upgrading are energy intensive. Oil Sands facilities require a 300% increase in energy supply by 2020.
• Depletion of natural gas reserves, green house gas (GHG) emissions and price escalation are major concerns.
• Nuclear reactors are proven large scale thermal energy producers.
• Nuclear plants provide a sustainable solution for oil sands industry energy requirements, and do not produce GHG emissions.
Canadian Crude Oil Production

Total Canadian Production

Total Oil Sands Production

In-Situ

Mining

Thousand Barrels Per Day


2000 3000 4000 5000
Areas of Opportunity

• Bitumen/Oil Extraction
  - Steam Assisted Gravity Drainage (SAGD)
  - Carbonate
  - Mining

• Upgrading/Processing
  - Hydrogen
  - Electricity
  (Projects could be combinations of above)
SAGD - Overview of Technology

Steam Chambers

Cap Rock (shale & glacial till) 250m thick

Unrecovered Heavy Oil

Each barrel of bitumen requires 2.5 – 4.0 barrels of steam

SAGD Process

~ 200m

~ 1 kilometer

40m
Simplified SAGD Configuration
SAGD - Potential Configurations

- **Option 1**: Limited amount of electricity (150-200MWe), the remainder steam
  - Hybrid design
  - Flexible in energy product delivery (steam/electricity ratio)

- **Option 2**: No electricity generation, all steam
  - Simpler design
  - Reduced water requirement
  - Favorable thermodynamics (best economics)
SAGD Design Concept for CANDU 6
(Steam and Electricity)

Main steam 4.7 MPa

CANDU SG

HPT

LPT

Condenser

187°C

Feedwater System A

Feedwater Pump B

Drain Tank

Reboiler

Drain Cooler

Process steam 3.5 MPa

Blowdown

Process water pump

Process water tank

Process water 170°C
SAGD Design Concept for ACR 1000 (Steam Only)

Main steam 6.0 MPa

CANDU SG

Feedwater Pump

215°C

Drain Tank

Feedwater Pump

Process water tank

Process water pump

Process water 170°C

Process steam 4.5 MPa

Reboiler

Blowdown

Drain Cooler
Design Challenges(1)

• Coexistence with Oil Sands Operator
  – Energy demand dependant on oil sands operations
  – Process steam/return water link
  – SAGD complexity

• Steam Transport
  – Distance, delta P, pipe size and isolation etc.

• Reboilers
  – Detailed design, fouling and cleaning etc.
  – Heat sink for upset conditions and isolation requirements

• Cooling Water
  – Distance and availability
  – Water return temperature
Design Challenges(2)

• Electrical Power
  – Grid reliability
  – Plant operational stability

STUDIES INDICATE THE NPP APPROACH IS TECHNICALY AND ECONOMICALY FEASIBLE
Carbonates - Background

- Carbonate zones have bitumen locked in rock-like formations similar to Colorado oil shales
- Significant development effort over the last 30 years
- Extraction Technology is highly protected
  - Use of electrical heaters in 1000 feet long vertical tubes to heat rock formations
  - Takes up to three years of heating up to 600°C to separate gas and light oil from the rock (so-called in-situ conversion)
- Requires large amounts of base-load electricity
- Oil extracted by conventional oil pumps
Simplified Flow Diagram of H₂ Production System

- **RECTIFIER**
  - DC POWER

- **ELECTROLYSER MODULE**
  - WATER
  - WATER
  - COOLANT (RECYCLED)
  - NITROGEN PURGE GAS

- **GAS PURIFICATION**
  - H₂
  - HEAVY WATER

- **USER**
Electrolysis Modules

- Standard electrolysis modules simplify shipment, installation and servicing
Cost Comparison – Natural Gas and Nuclear Power for Steam Generation

The graph shows the cost comparison between natural gas and nuclear power for steam generation. The x-axis represents the gas price (C$/GJ) ranging from $4.00 to $12.00. The y-axis represents the cost per tonne ranging from $5 to $31.

- **Natural Gas Steam Supply** is represented by a blue line starting from the origin and increasing linearly.
- **Nuclear Upper Bound** is represented by a pink horizontal line.
- **Nuclear Lower** is represented by a red horizontal line.

At higher gas prices, natural gas becomes costlier than nuclear power, which remains relatively constant. This indicates that nuclear power might be a more cost-effective option in scenarios with relatively high gas prices.
Summary

- Each oil sands project is somewhat unique.

- Secondary side design adaptation for specific projects will be needed.

- Nuclear power plants are competitive and reliable. They have no CO$_2$ emissions and therefore offer a sustainable long term solution for oil sands energy requirements.