Potential for Nuclear Energy in Alberta's Oil Sands

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Overview

- The Canadian oil sands industry consumes large quantities of natural gas to supply its energy needs and produce hydrogen
  - The EUB expects Alberta crude bitumen production to reach 2,330 Mb/d by 2012, a 2.8-fold increase from 2002
  - This would require about 1,400 MMcf/d of natural gas in 2012 - more than 10% of current Alberta gas production
- Results in substantial GHG emissions
- In situ projects are large energy consumers
- The industry is working hard to reduce energy requirements and/or find alternative energy sources - Nuclear is one option

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CERI's Study

In response to this issue, Atomic Energy of Canada Limited (AECL) contracted the Canadian Energy Research Institute (CERI) to compare the economics of nuclear and gas-fired options to supply steam to an oil sands reservoir using SAGD

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Study Objectives and Scope

- **Objectives**
  - **Compare the economics of a modified Advanced Candu Reactor (ACR-700) with a gas-fired facility, to supply steam to a hypothetical SAGD project located in north-eastern Alberta**
  - **Perform the comparison at a pre-feasibility level**
- **Scope**
  - **The study focussed on comparative economics - it did not examine other issues that might be associated with nuclear development**
  - **Follow-up studies may be carried out**

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Supply Cost

- The economic comparison was made using supply cost methodology
- Supply cost is the constant dollar price that would recover all costs including:
  - Capital
  - Operating costs
  - Return on investment
- Supply cost is calculated using discounted cash flow techniques
- Supply costs for both the nuclear and the gas-fired options were calculated before tax

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The ACR-700

- Evolutionary development of familiar CANDU technology with innovations for improvement of economics, operations and safety
- Gross output of 1983 MW_t and 728 MW_e in its normal configuration
- Slightly enriched uranium fuel
- Light water coolant
- Compact core design

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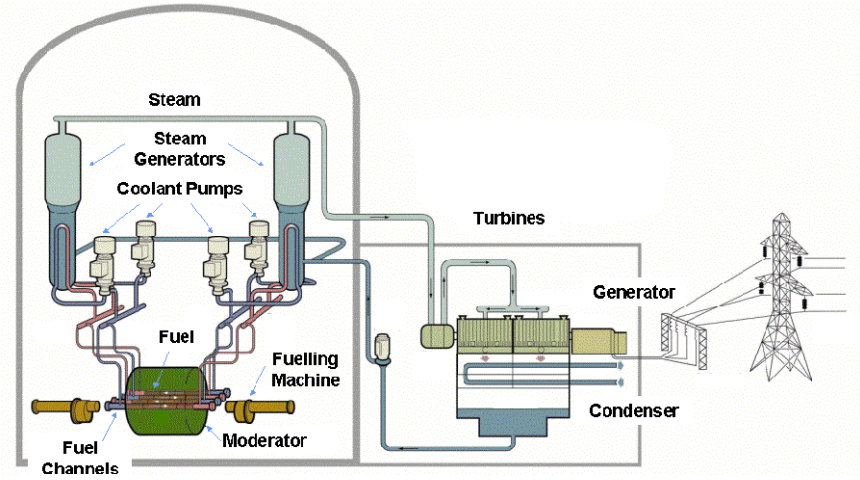
Typical Layout for an ACR-700 Nuclear Power Plant



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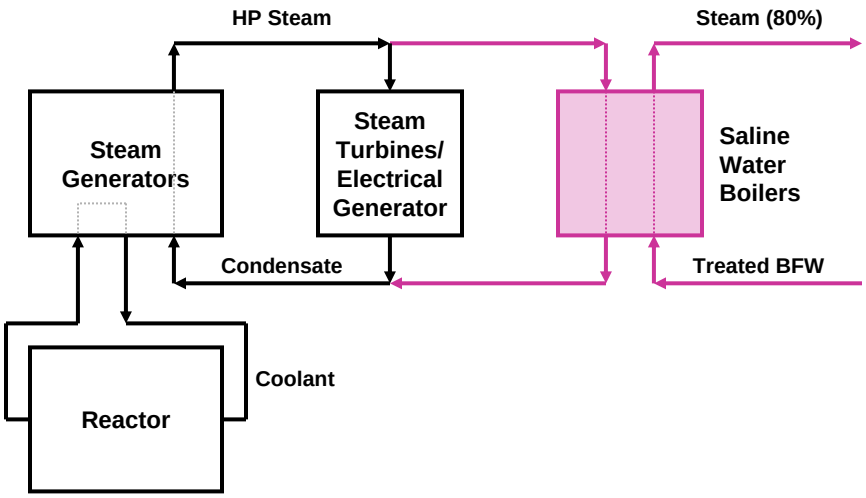
ACR-700 Configuration for this Study



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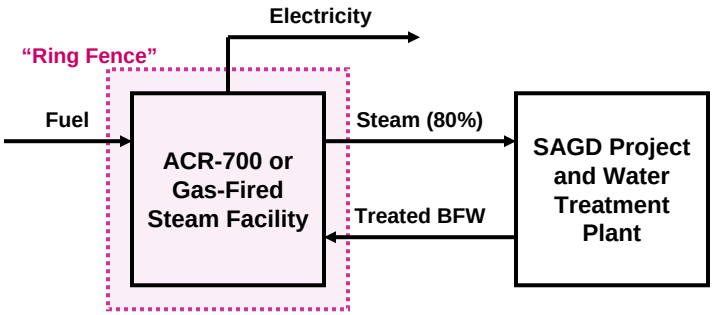
"Ring Fence"

The study compared the supply cost of steam generation within a "Ring Fence". It did not examine the economics of the SAGD facility.



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ACR 700 Nuclear Facility

- **78,020 m^3/d steam capacity**
  - **80% quality steam; 3.0 MPa**
  - **390 Mb/d of 100% quality steam after separation**
  - **157 Mb/d of SAGD bitumen at a 2.5 SOR**
- **100 MW net electrical capacity**
- **Costs ($2002)**
  - **Capital: $1,400 million**
  - **Annual O&M (including fuel): $83 million**
  - **Annual spent fuel management: $8 million**
- **On-stream date: April 1, 2011**
- **No GHG emissions**

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Gas-Fired Facility

- 78,020 m^3/d steam capacity and 103 MW net electrical output
  - Alstom 11N2 Gas Turbine with electrical generator and HRSG (116.5 MW_e ISO rating)
  - 21 OTSGs (36.33 kg/s steam capacity per unit)
- Costs ($2002)
  - Capital: $230 million
  - Annual O&M: $8.5 million
  - Annual fuel: $256 million
- On-stream date: April 1, 2011
- Substantial GHG emissions - 3.0 Mt/a

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Energy Price Assumptions

- Natural Gas
  - NYMEX: US$3.50/MMBtu
  - Plant Gate: C$4.25/GJ
- Electricity
  - Plant Gate: C$50/MWh

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Steam Supply Costs - Base Case (C$/t)

	Nuclear Option	Gas-Fired Option
Costs		
Fixed Capital	6.71	0.96
Working Capital	0.09	0.01
Fuel	included	9.70
Spent Fuel Management	0.28	0.00
Other Operating Costs	3.07	0.33
Subtotal	10.15	11.00
Credits		
Electricity Sales	1.54	1.58
Total Supply Cost	**8.61**	**9.42**

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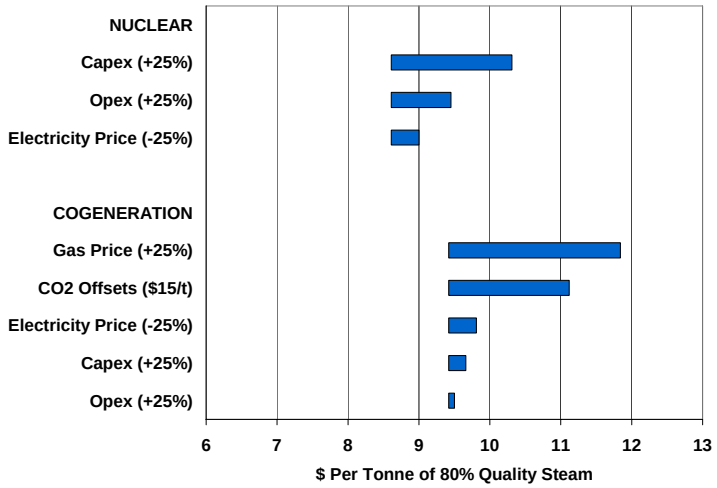
Supply Cost Sensitivities



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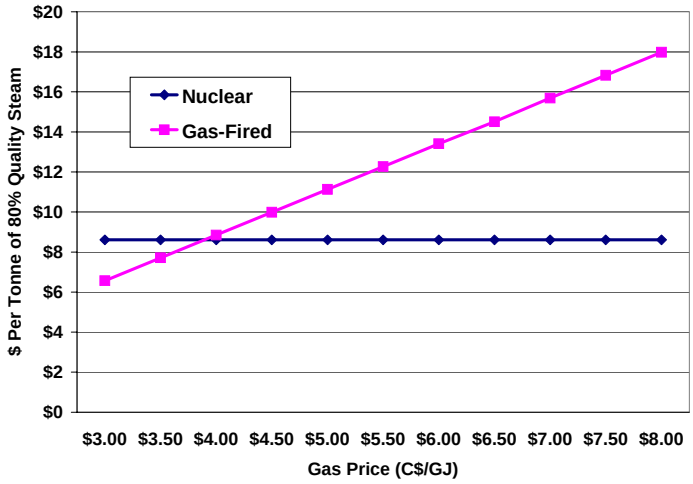
Natural Gas Price Sensitivity



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Important Considerations

- Project Scale
  - Staged Production/Risk Profile
  - Requires Long-Term Commitment
- Steam Distribution
- Water Supply
- Design Optimization
  - Steam/Electricity Balance
  - Opportunity to Generate Hydrogen?

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Public Concerns

- A nuclear proponent would need to address public concerns regarding:
  - Safety
  - Terrorism
  - Proliferation
  - Long-term management of radioactive wastes
  - Reliability
- These issues were not addressed in the CERI Study

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Conclusions

- An ACR-700 nuclear facility could be an economically competitive source of steam
- Steam supply cost from a nuclear facility is very sensitive to capital cost
- Steam supply cost from a gas-fired facility is very sensitive to natural gas price and possible Kyoto compliance cost
- The large size of nuclear facility would require a correspondingly large SAGD project
- Public concerns would need to be addressed

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