Relevant • Independent • Objective

Energy and Hydrogen for Alberta's Oil Sands

Oil Sands Supply and Infrastructure Conference

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Canadian Energy Research Institute

February 10, 2005
Calgary, Alberta

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Canadian Energy Research Institute

- Calgary-based, independent, non-profit energy research organization established in 1975 by government and industry partners
- Mission is to undertake independent, high-quality economic research on energy and related environmental issues and policies to assist Canadian business and government organizations

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Presentation Overview

- Oil Sands Supply Outlook
- Oil Sands Natural Gas Usage
- Energy and Hydrogen Supply Options
- Is There a Role for Nuclear?
- Conclusions

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CERI's Oil Sands Supply Outlook

- Oil Sands Supply Outlook
  - Potential Supply and Costs of Crude Bitumen and Synthetic Crude Oil in Canada, 2003 - 2017
- CERI Study No. 108
- Released March 3, 2004

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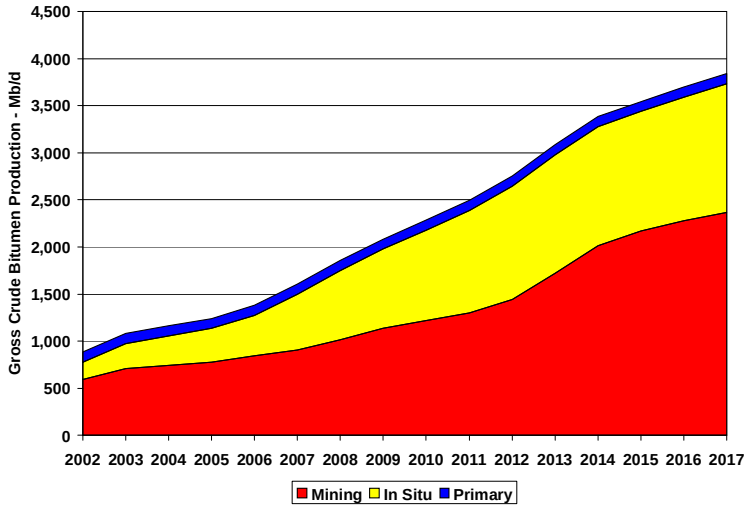
Unconstrained Bitumen Supply Projection



Source: CERI Oil Sands Supply Outlook; March 2004

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Source: CERI Study No. 108

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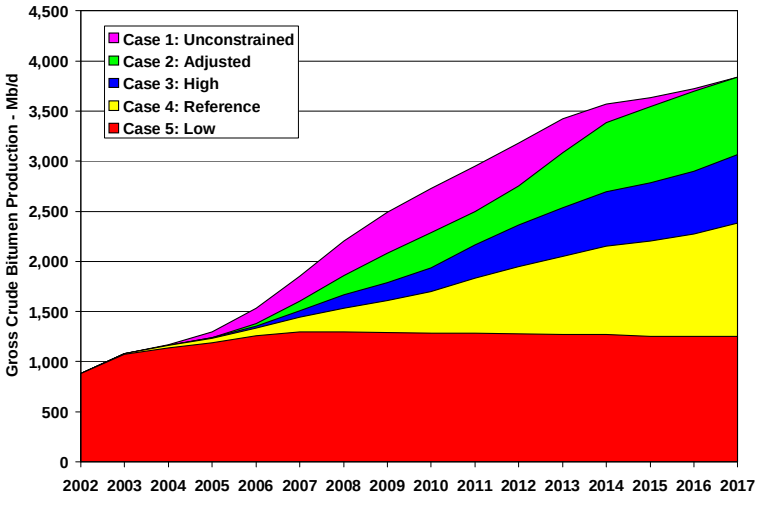
All Supply Projections



Source: CERI Oil Sands Supply Outlook; March 2004

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Supply Outlook in 2017 (million b/d)

	SCO	Bitumen	Total
Unconstrained	2.0	1.5	3.5
High (US$32/b)	1.6	1.2	2.8
Reference (US$25/b)	1.3	0.9	2.2
Low (US$18/b)	0.8	0.3	1.1

Source: CERI Oil Sands Supply Outlook; March 2004

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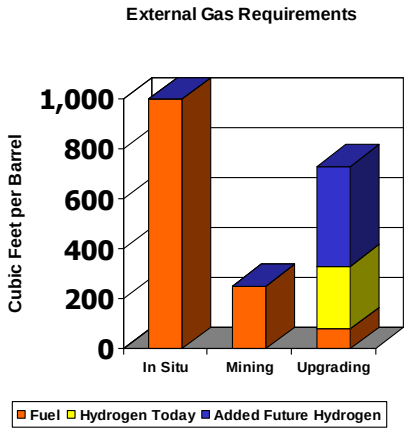
Oil Sands External Natural Gas Requirements



- Thermal in situ projects are very large energy consumers – Gas use depends on recovery performance
- Gas use for upgrading is higher for production of higher quality synthetic crude oil

Source: Oil Sands Technology Roadmap

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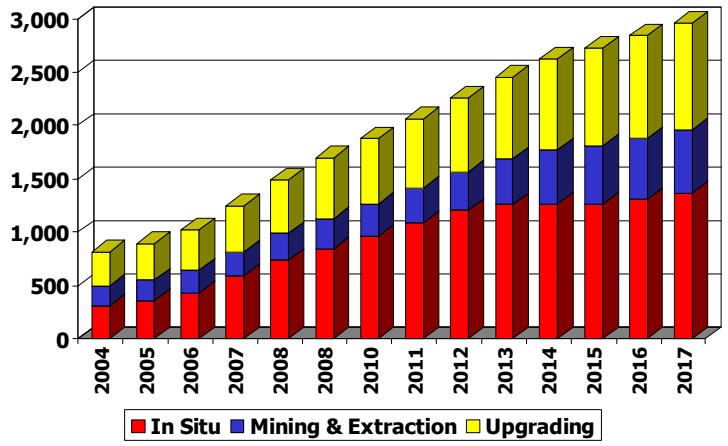
Unconstrained Natural Gas Demand (million cf/d)



Source: CERI Oil Sands Supply Outlook; March 2004

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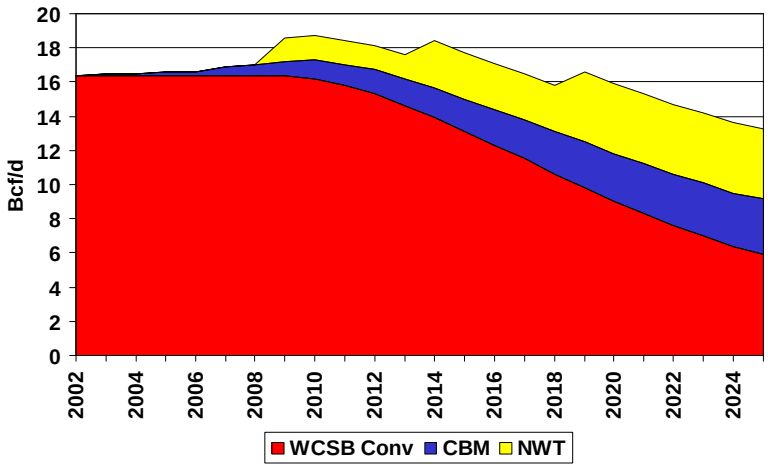
Projected Western Canadian Natural Gas Production



Source: CERI Study No. 107

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Source: CERI Study No. 107

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Implications

- The oil sands industry is competing for supply with other North American natural gas consumers
- Strong demand for North American natural gas and supply shortages will sustain current high natural gas prices
- High prices are providing incentives for:
  - Examination of alternative fuels
  - Further efficiency improvements/ conservation
  - Development of new recovery technologies

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Sources of Energy

- Today
  - Combustion of process gases
  - Combustion of purchased natural gas
  - Combustion of coke (limited)
  - On-site generation of electricity
  - Purchase of off-site electricity (primarily thermal)
- Alternatives
  - Combustion of liquid hydrocarbon fuels
  - More extensive combustion of coke
  - Combustion of coal, whole bitumen or bitumen residues
  - Gasification of coal, coke, or bitumen residues
  - Purchase of off-site electricity (i.e., nuclear, hydro)

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Sources of Hydrogen

- Today
  - Steam-methane reforming (natural gas)
- Alternatives
  - Gasification of coal, coke, or bitumen residues
  - Hydrolysis of water
    - Nuclear
    - Other?

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Other Options

- Energy Conservation
  - Low-pressure SAGD
  - Mining and extraction process improvements
  - Upgrading process improvements
- New Technologies
  - In Situ
    - Hybrid thermal-solvent processes
    - VAPEX
    - THAI
  - Mining and extraction

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Energy Supply Options

Source	Technology	Infrastructure	Potential Supply	Fuel Price/Cost	GHG Emissions (w/o capture)	Other Emissions (w/o capture)
Natural Gas Combustion	Proven	Established	Limited	High/Volatile	Low	Low
Liquid Hydrocarbon Combustion	Proven	Must be Developed for Off Site	Limited	High/Volatile	Moderate	Moderate
Coke/ Residuum Combustion	Proven	On Site	Substantial	Low	High	High
Coke/ Residuum Gasification	Proven	On Site	Substantial	Low	High	High
Pulverized Coal Combustion	Proven	Must be Developed	Substantial	Low	High	High
Coal Gasification	Proven	Must be Developed	Substantial	Low	High	High
Nuclear (Steam and Electricity)	Proven	Must be Developed	Substantial	Low	Zero	Zero

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Hydrogen Supply Options

Feedstock/ Source	Process	Technology	Cost	GHG Emissions (w/o capture)	Other Emissions (w/o capture)
Natural Gas	Steam Methane Reforming	Proven	Moderate	Low	Low
Coal, Coke, Bitumen Residuum	Gasification	Proven	High	High	High
Nuclear	Hydrolysis	Requires Some Further Development	High	Zero	Zero

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CERI/AECL Nuclear Steam Generation Study

- 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 are being considered

Source: CERI SAGD Nuclear Study; April 2003

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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

Source: CERI SAGD Nuclear Study; April 2003

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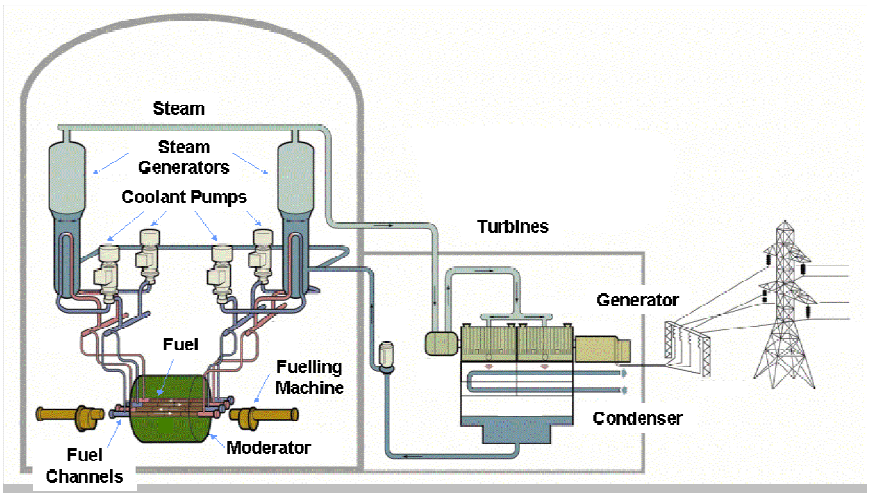
Typical Layout for an ACR-700 Nuclear Power Plant



Source: AECL

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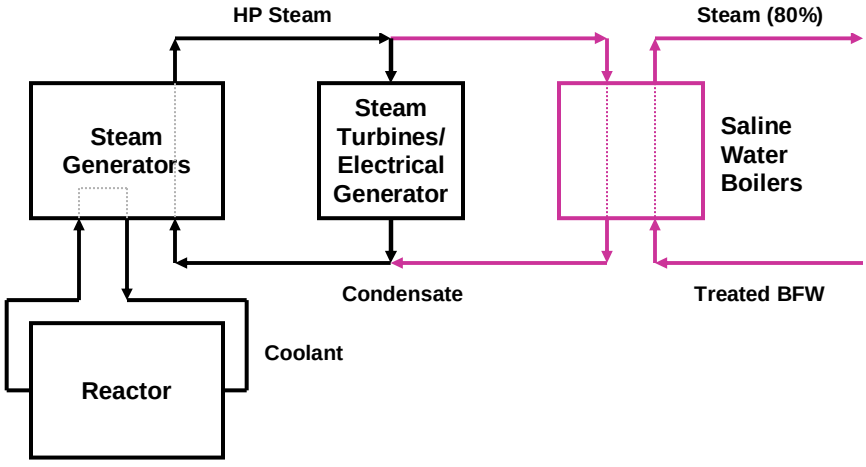
ACR-700 Configuration for this Study



Source: CERI SAGD Nuclear Study; April 2003

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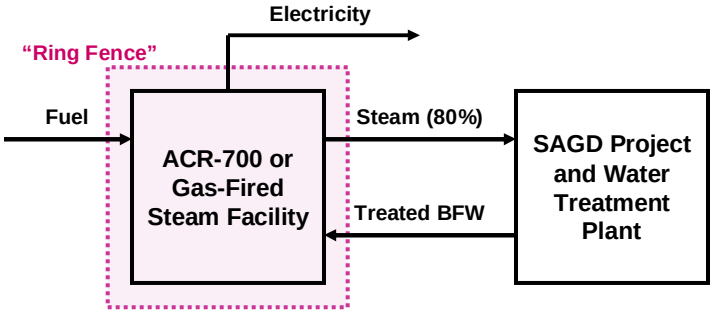
"Ring Fence"

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



Source: CERI SAGD Nuclear Study; April 2003

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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**

Source: CERI SAGD Nuclear Study; April 2003

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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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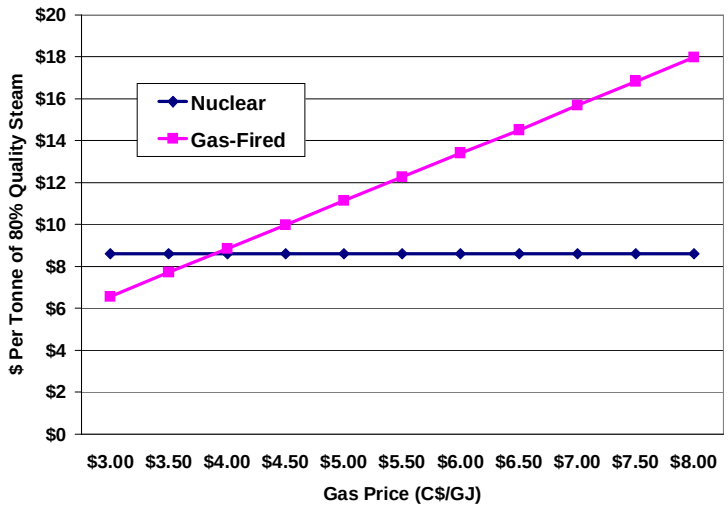
Source: CERI SAGD Nuclear Study; April 2003 WWW.CERI.CA

Natural Gas Price Sensitivity



Source: CERI SAGD Nuclear Study; April 2003

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Other Considerations

- Technical Issues
  - Staged production and risk profile
  - Steam distribution
  - Water access
  - Capital cost
  - Design optimization
    - Steam
    - Electricity
    - Hydrogen
- Public Concerns
  - Safety
  - Terrorism
  - Disposal of spent nuclear fuel

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Conclusions

- Natural gas is an expensive source of energy and hydrogen for the oil sands industry
- There is considerable incentive for the industry to:
  - Reduce energy use
  - Find alternative sources of energy
- Several promising alternatives are either available or are being developed

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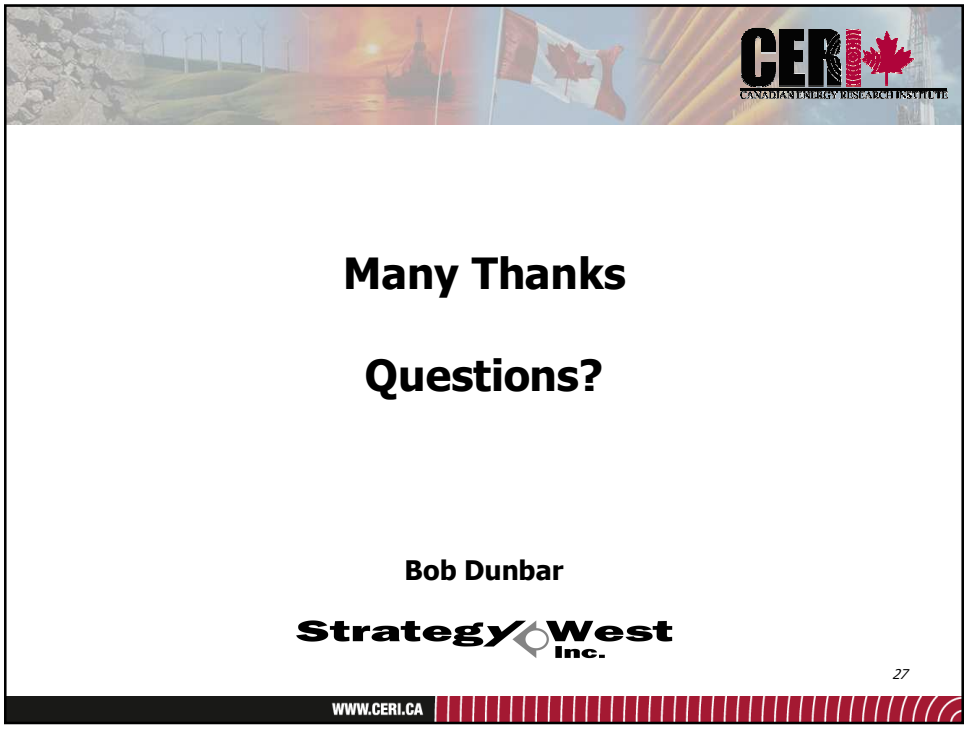
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Many Thanks
Questions?
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