Canadian Clean Power Coalition: Current Status of Clean Coal Technologies

Presented to

Nova Scotia Energy R&D Forum 2006
Antigonish, NS

May 25, 2006

CANADIAN CLEAN POWER COALITION

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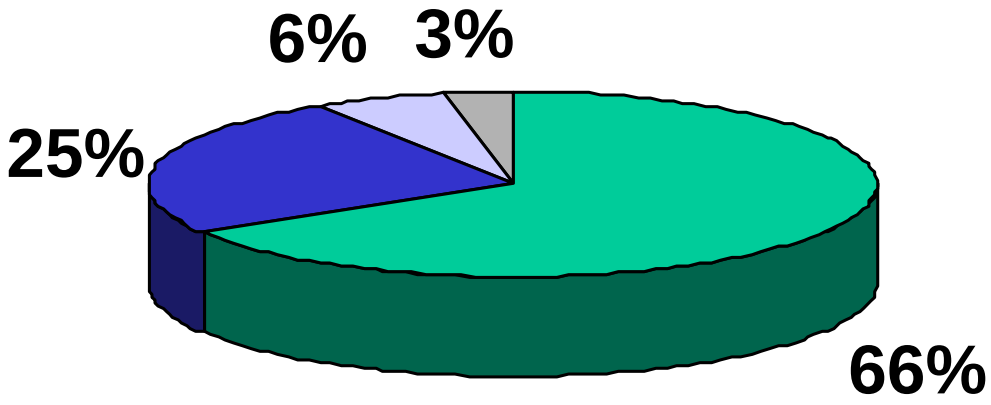
EnergyINet
Unlocking Tomorrow's Energy

www.canadiancleanpowercoalition.com

Presentation Outline

- Canadian Clean Power Coalition Overview
- Phase I Studies
- Phase II Status
  - Gasification Technologies
  - ASC Technologies

Canada's Fossil Fuel Energy Reserves



The Canadian Clean Power Coalition

- Formed in 2000
- A national association of Canadian coal and coal-fired electricity producers
- Represents over 90 percent of Canada's coal-fired electricity generation
- Industry/government partnership
- Objective is to demonstrate that coal-fired electricity generation can effectively address all environmental issues projected in the future, **including CO_2**

www.canadiancleanpowercoalition.com

Current Coalition Participants

- ATCO Power Canada Ltd.
- Basin Electric Power Cooperative (North Dakota)
- EPCOR Utilities Inc.
- EPRI (Electric Power Research Institute)
- Luscar Ltd.
- Nova Scotia Power Inc.
- Saskatchewan Power Corporation
- TransAlta Corporation

In addition, in Phase I, IEA (GHG and CCC) and Ontario Power Generation Inc. participated

Government Participation

- Natural Resources Canada
- Alberta Energy Research Institute
- Saskatchewan Industry and Resources

CCPC Goal: Build and Operate a Clean Coal Demonstration Plant

- Construct and operate a full-scale demonstration project to remove greenhouse gas and all other emissions of concern from a coal-fired power plant by 2012
- Provide flexible fuel capability– bituminous, sub-bituminous, lignite, and petroleum coke
- To accomplish this at a competitive cost of power

CCPC Plan

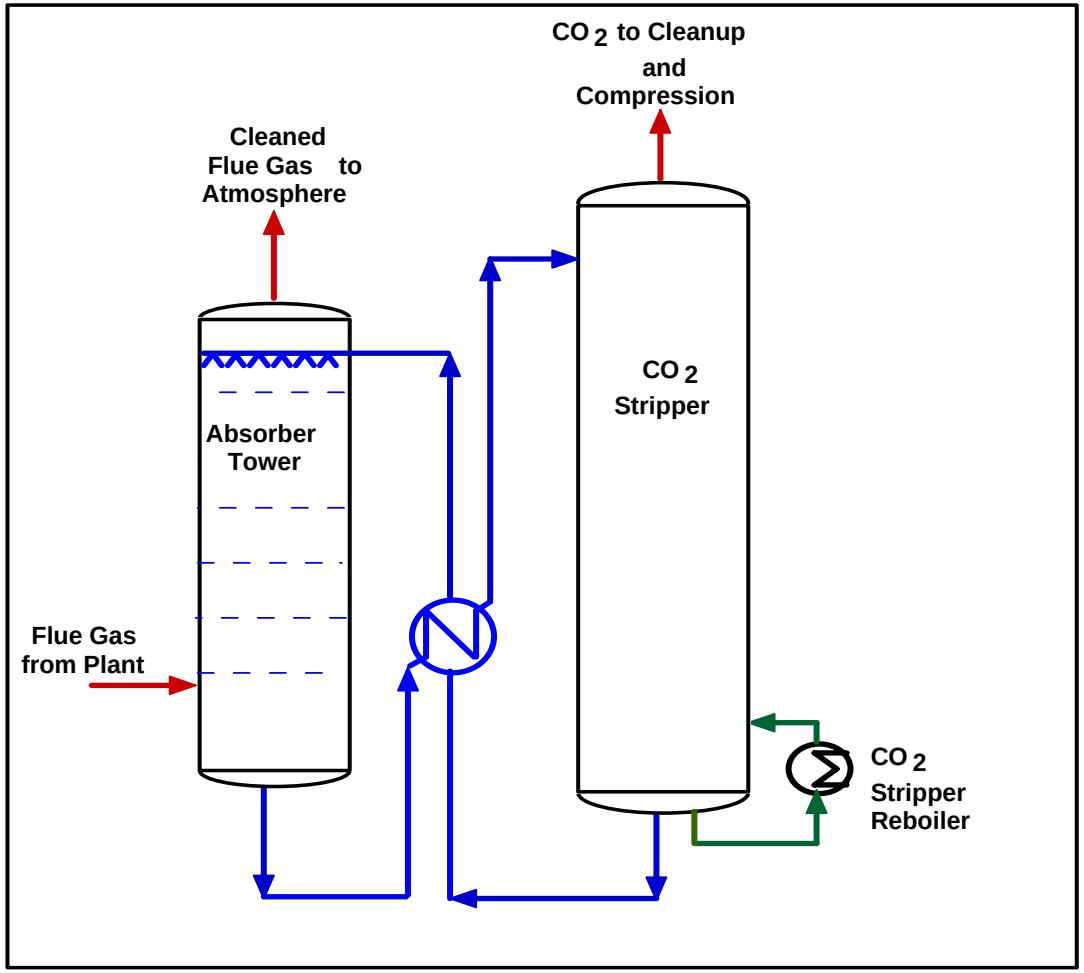
- 2000: Formation & planning
- 2001 - 2003: Phase I technology studies
- 2004: Results assessment and Phase II formation
- 2004 - 2006: Phase II optimization studies

2006: Status assessment & commitment to demo project

2007 - 2011: Design & construction

2012: Operation

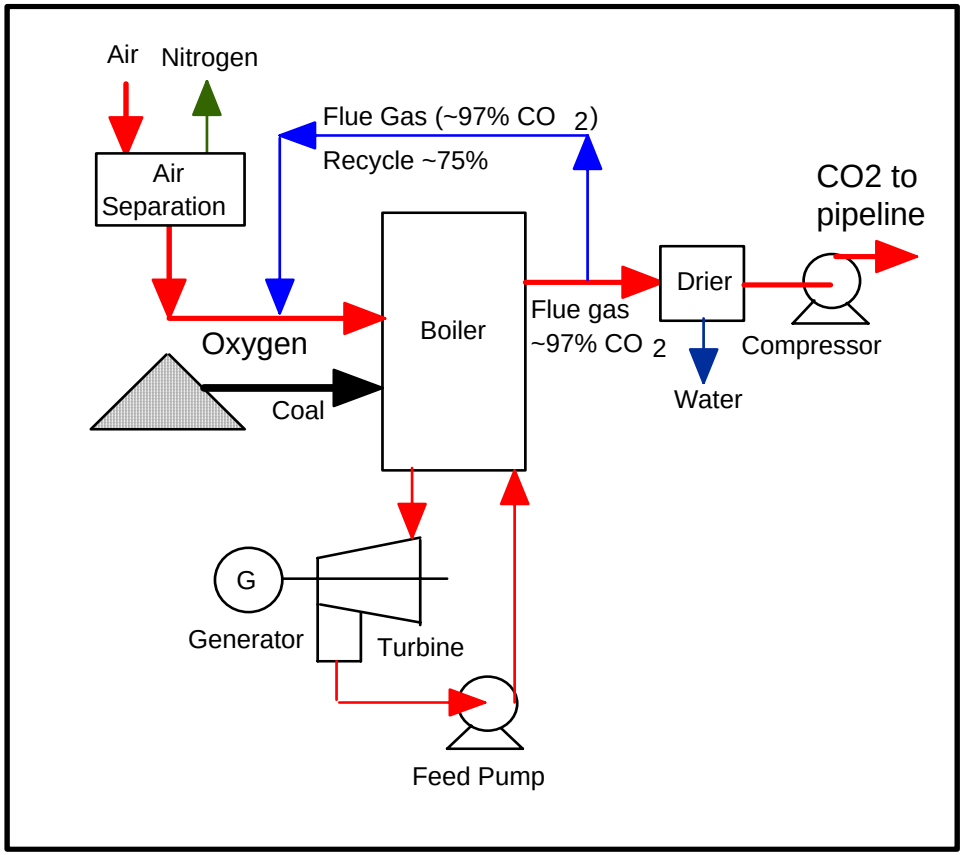
Flue Gas Amine Scrubbing



Issues

- High amine regeneration heat load
- Fate of mercury in amine system

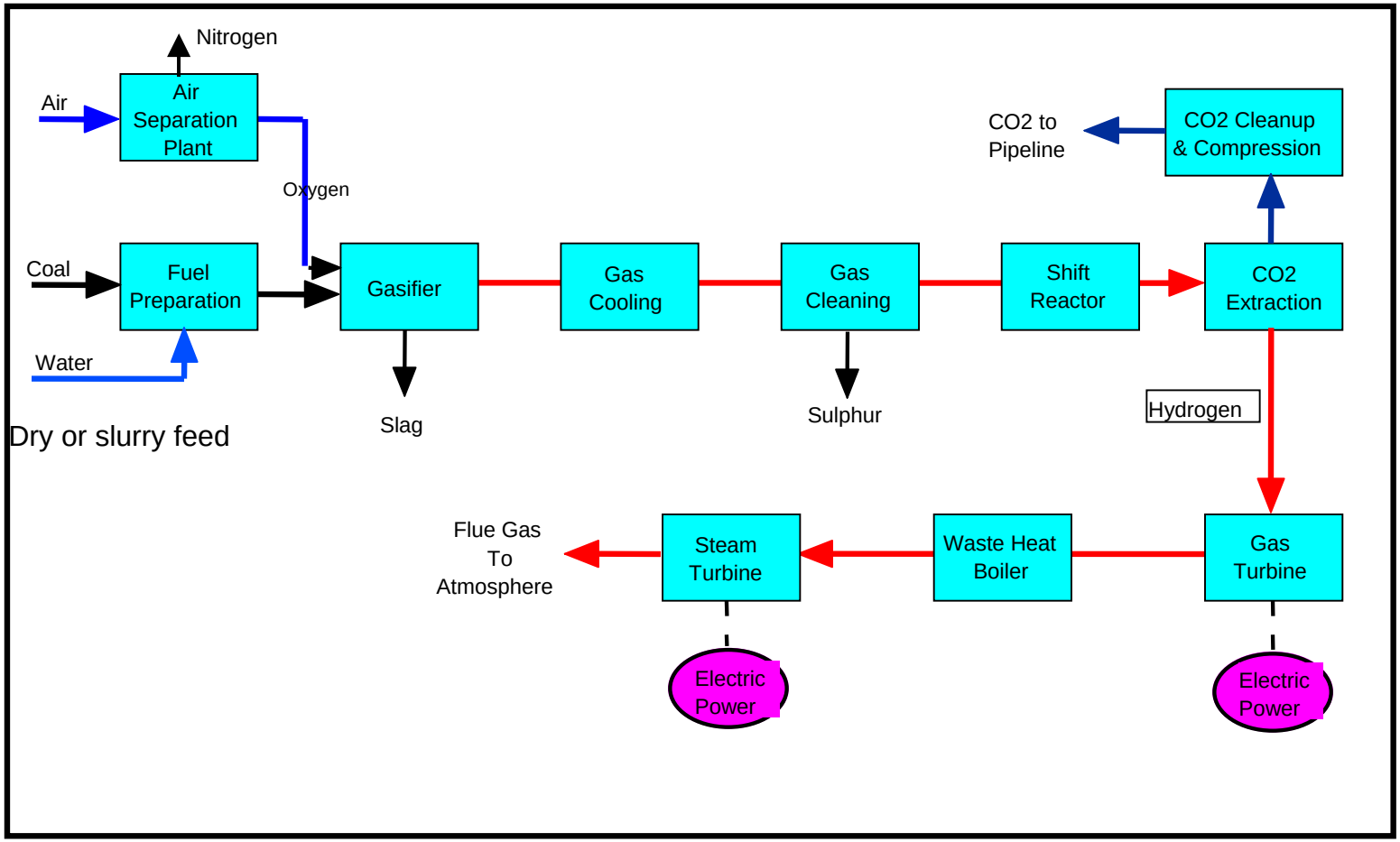
CO_2/O_2 Combustion



Issues

- Boiler performance with recycle flue gas
- Air entrainment
- Shaft power for ASU
- Quality of CO_2

Coal Gasification- IGCC with CO_2 Capture



IGCC Issues

- Gasification characteristics of bituminous, sub-bituminous and lignite coals
- Gasifier feed systems: wet vs dry vs CO_2 slurry
- Syngas composition, clean-up, fate of mercury
- Purity specifications of captured CO_2
- Reliability of gasification plant to meet power generation service factors
- Integration of plant components to minimize capital costs and optimum performance

Emissions Control Study

- Looked at retrofit emission control for NOx, SOx, Hg, particulates and all other pollutants
- Excluded CO_2
- Allows net costs for CO_2 to be calculated by comparison with the other studies

CO_2 Utilization & Storage Evaluation

- Reviewed prior work on EOR & ECBM use in western sedimentary basin
- Separate study for Nova Scotia to examine potential for ECBM in coal beds
- Evaluation of storage options in deep saline aquifers and depleted reservoirs

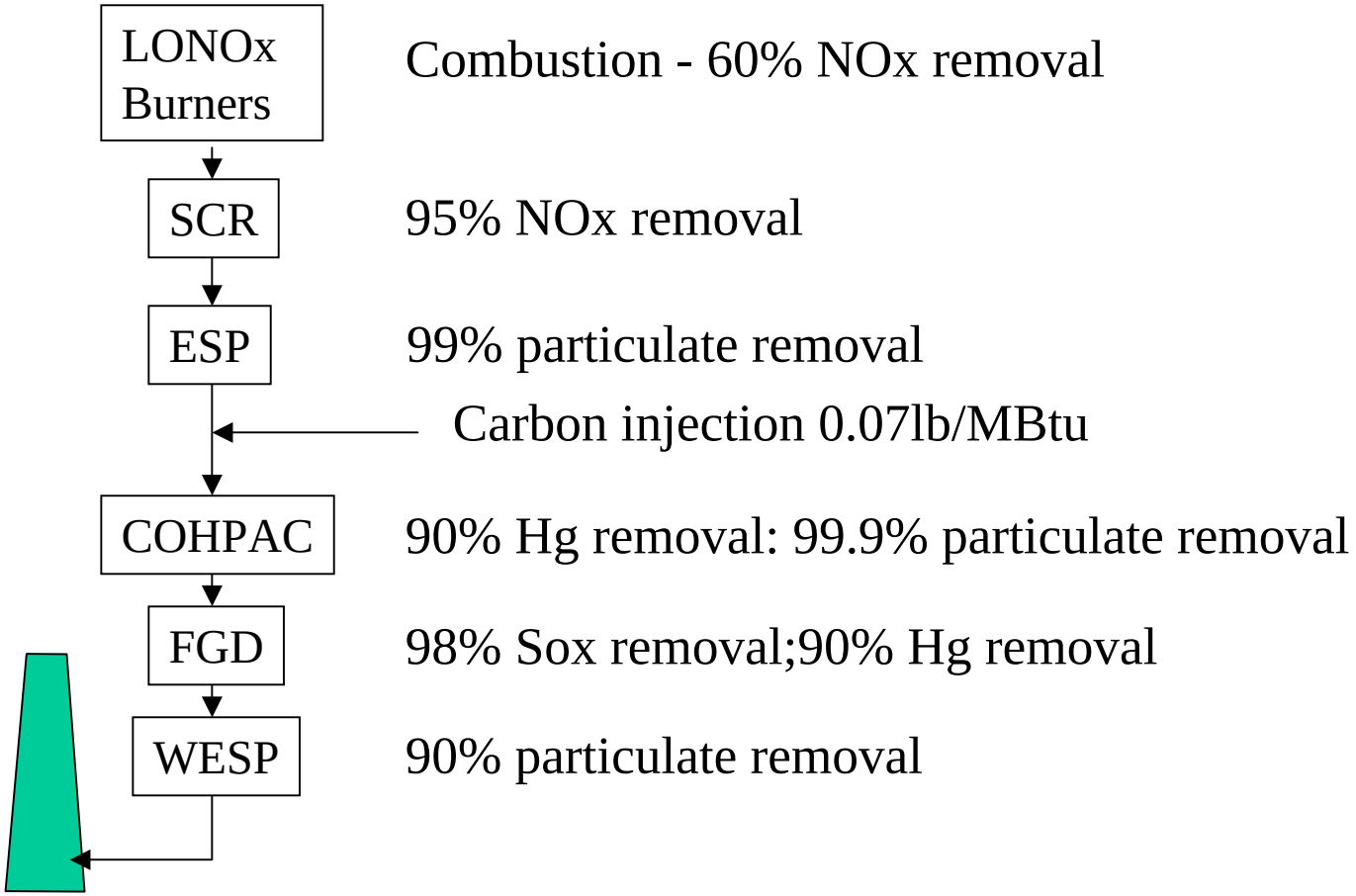
Plants selected for comparative evaluation

- Trenton # 6, a 150 MWe bituminous coal fired power plant located in Nova Scotia
- Shand, a 300 MWe lignite coal fired power plant located in Saskatchewan
- Genesee, a 400 MWe sub-bituminous coal fired power plant located in Alberta

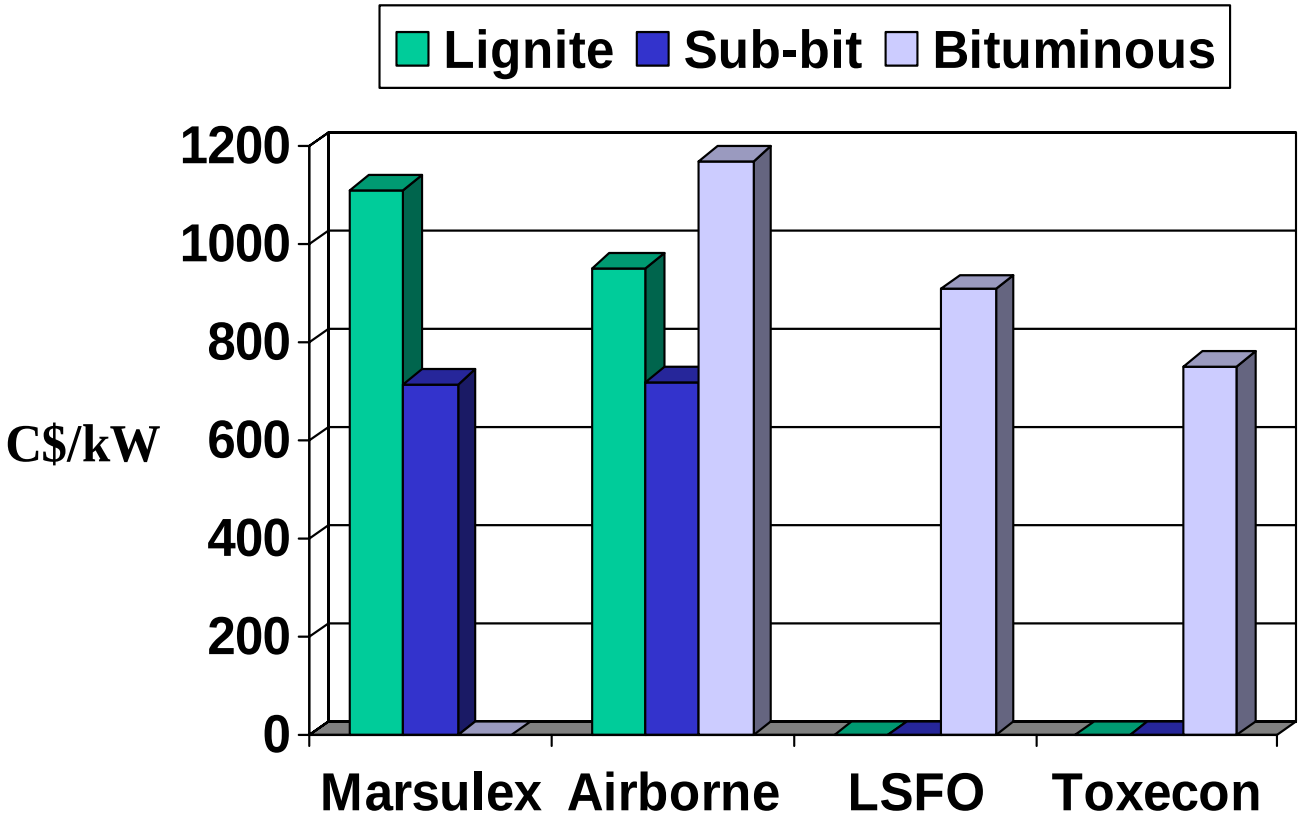
Target Emission Levels-Comparison with Natural Gas Combined Cycle (NGCC)

Type	Units	Lignite	Sub-bit	Bitumi-nous	NGCC
NOx	Gram/MWh net	27.6	27.6	27.6	27.6
SOx	Ng/Joules fired	0.7	0.7	0.7	0.7
$PM_{10, 2.5}$	Ng/Joule fired	2	2	2	2
Mercury	Pg/J	0.5	0.3	0.3	N/A
CO	ppm @ 3% O2	40	40	40	45
SO3	ppmv	5	5	5	N/A
NH3	ppmv	1	1	1	1
Heavy Metals **Se** **As** **Cd**	Mg/Nm^3	 6 6 2	 6 6 2	 6 6 2	

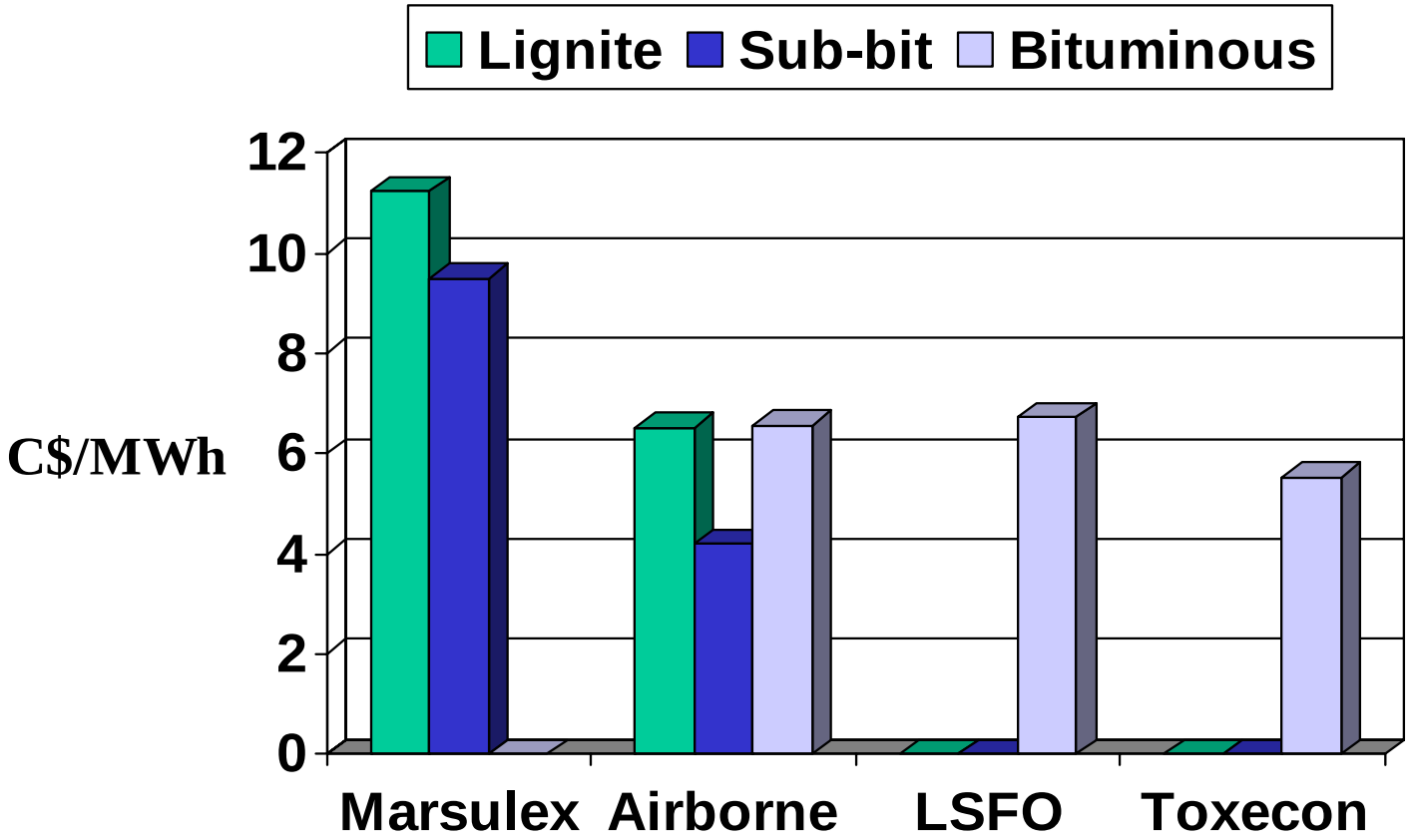
Evaluation of Retrofit Plants for all Emissions Except CO_2



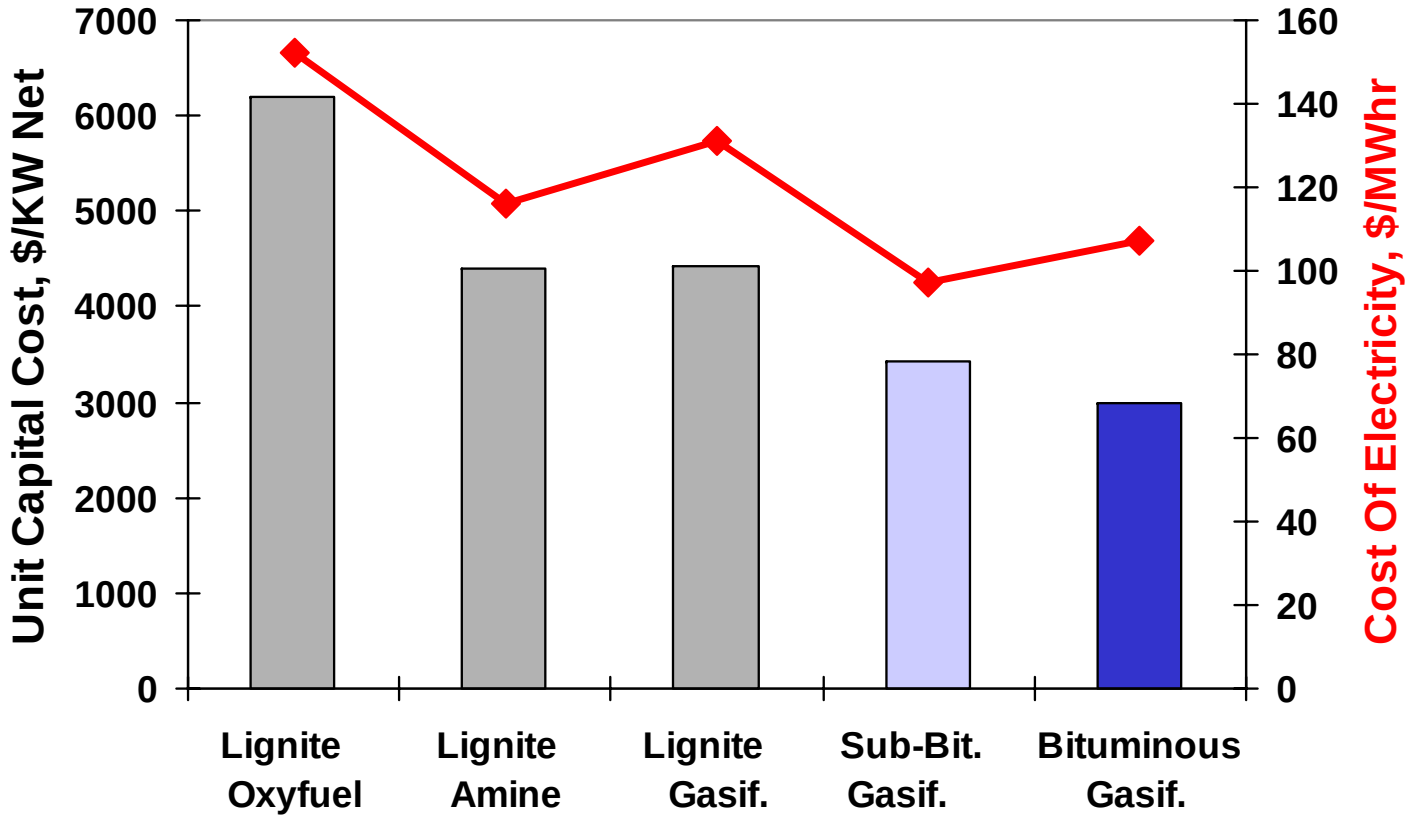
Retrofit Plants for all Emissions Except CO_2 - Capital Costs



Retrofit Plants for all Emissions Except CO_2 - O&M Costs



Unit Capital Cost & Cost of Electricity Comparisons for 90 % CO_2 Capture



CO_2 Storage and Utilization Options in Western Canada

Parameter	Enhanced Oil Recovery	Enhanced Coal Bed Methane Recovery	Storage in Depleted Reservoirs	Storage in Deep Saline Aquifers
Status	Commercial	Pilot	Commercial	Commercial
Capacity Limits	6-7 projects	None	➢50 projects	None
Breakeven Cost*, $/t	38	10	-4	-

*** Breakeven cost is the maximum that the operator could pay to achieve a zero NPV at a 15% discount rate**

CCPC – Phase I Results

- Texaco Quench evaluated for Pittsburgh # 8 and sub-bituminous coal but Texaco declined to provide data for lignite. Shell selected for lignite.
- Fluor has improved the design of their Econamine (MEA) process for flue gas removal of CO_2 reducing the energy penalty from ~1750 to ~1185 Btu of steam/lb of CO_2.
- Although the cost of CO_2 avoided is lower for IGCC than for amine scrubbing for the bituminous and sub-bituminous coals at grass roots plants the differential is less than with previous studies
- For lignite Shell IGCC with pre combustion CO_2 removal was worse than amine scrubbing. All current commercial gasification technologies have poor performance with low rank and high ash coals
- Oxyfuel (O_2 with recycle CO_2) was evaluated to have a significantly higher COE than amine scrubbing for a grass roots plant.

CCPC Phase II

- Goal is to fill in technical uncertainties before moving to a firm project.
- Covers the following scope:
  - Gasification technology evaluation to develop better technology for low rank western Canadian coals.
  - Amine scrubbing & CO_2/O_2 combustion optimization with advanced supercritical steam cycle.
- Upgrading of the coal prior to burning or gasification, by drying or blending with petroleum coke or other residues, will be evaluated.
- Business case development covering multiple cases:
  - Alberta: coal, bitumen and petcoke gasification
  - Saskatchewan: lignite and petcoke gasification
- Polygeneration of power, hydrogen, steam and CO_2 will be evaluated.

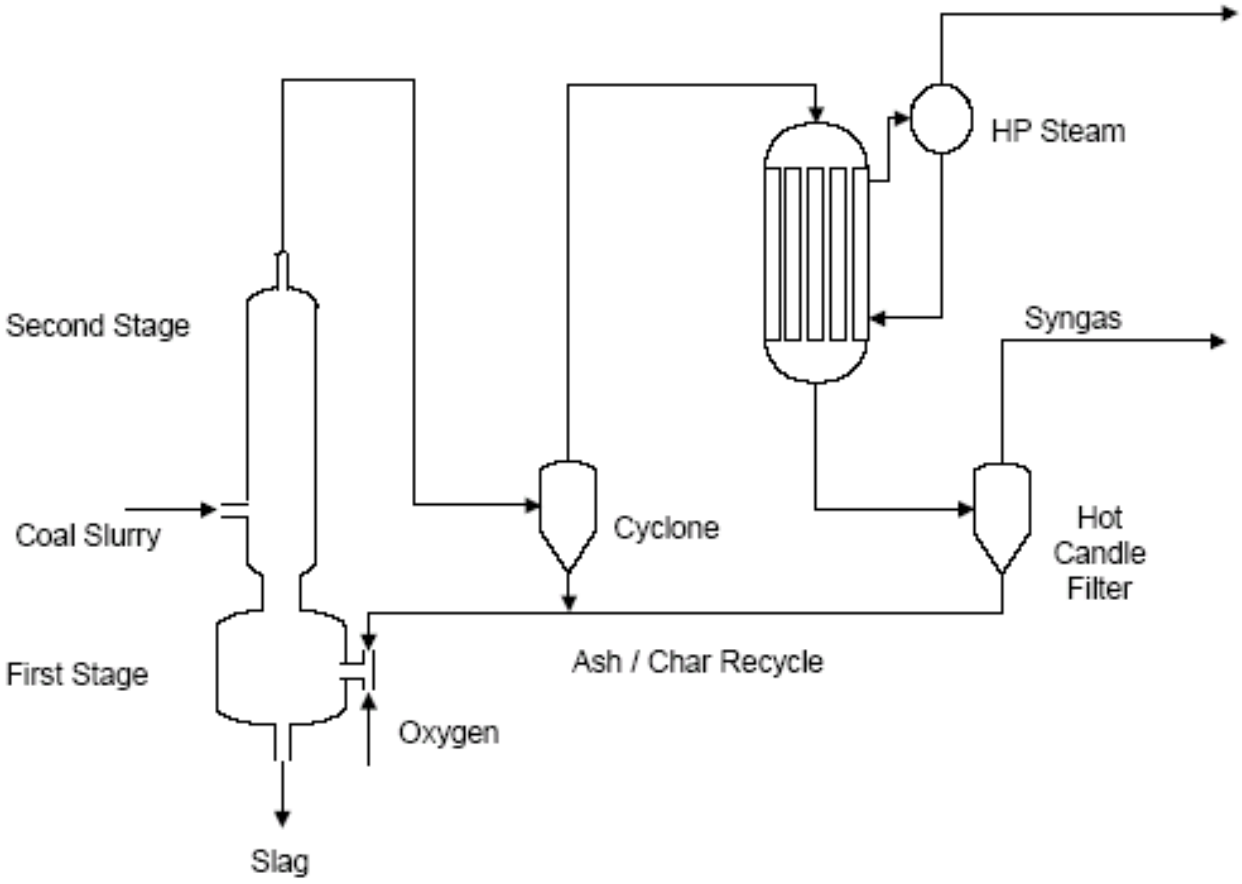
Gasification Technologies Considered

- British Gas Lurgi
- *ConocoPhillips **
- EAGLE
- *Future Energy **
- GE Energy
- High Temperature Winkler
- Sasol-Lurgi
- Shell
- KBR Transport Gasifier

** Selected for development of performance and cost estimates*

ConocoPhillips

Entrained Slagging Transport Reactor (ESTR)



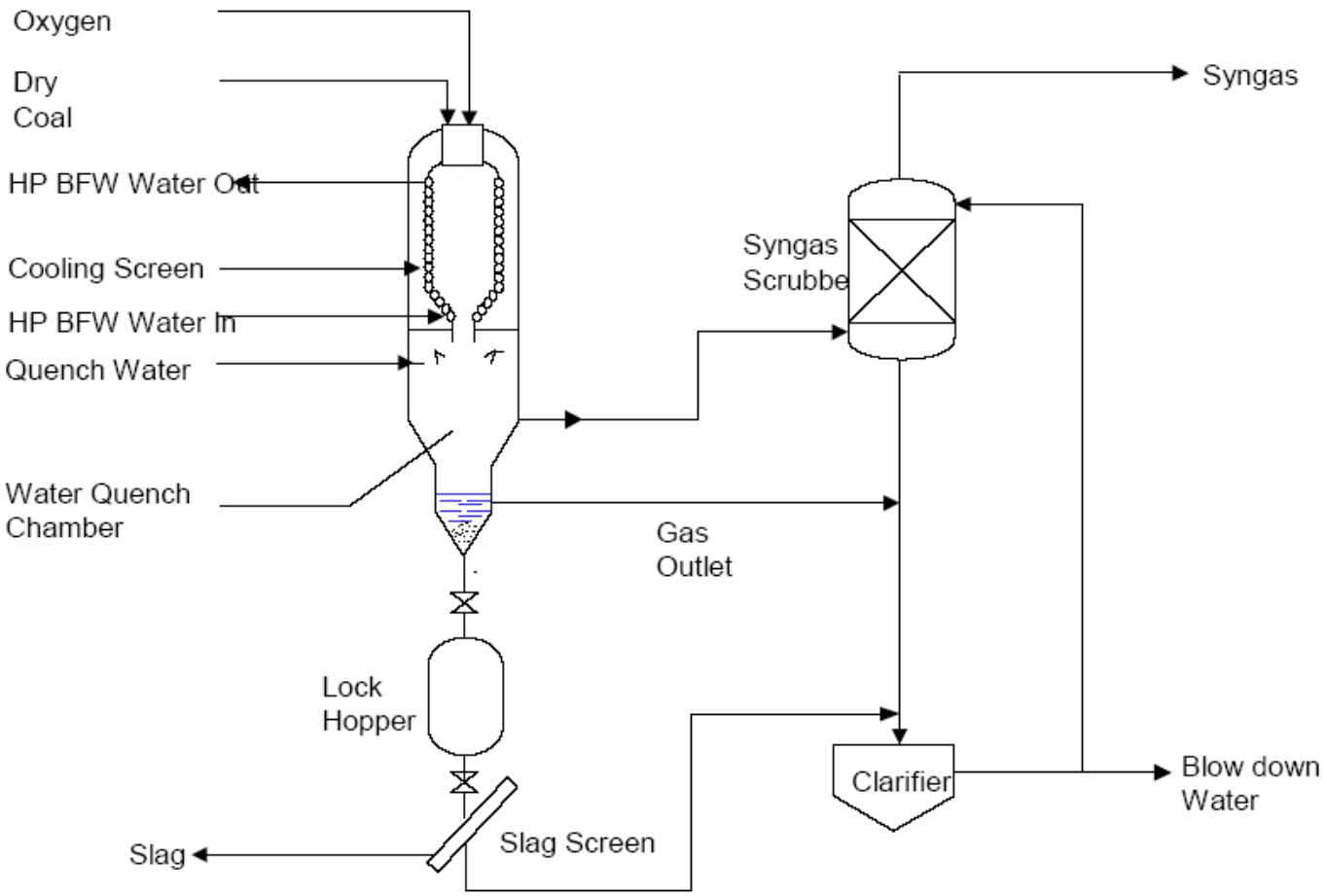
Advantages

- Dry feed to 1st Stage
- High efficiency
- Slagging gasifier
- High pressure operation

Disadvantages

- Refractory lined
- Higher methane content *(could limit CO_2 recovery)*
- No water quench

Future Energy



<u>Advantages</u>

- Dry feed
- Cooling screen
- Water quench
- Slagging gasifier

<u>Disadvantages</u>

- Lack of operating experience at high pressure

Phase II Status - Advanced Supercritical Steam

- Advanced supercritical steam optimization studies will be done by Mitsui Babcock and Alstom, with support from the UK Government (DTI).
- The MHI advanced amine scrubbing system will be used for amine optimization studies.
- CO_2/O_2 combustion optimization will be included, with support from Air Products.
- Studies on thermal integration to improve efficiency will be included in scope (Imperial College).
- Evaluating proposals for balance of plant sub-contractor.

Summary of Phase II ASC Case Studies

R0 Base Case Plant – an optimized air-fired ASC PC plant without CO_2 capture with appropriate emissions control, assume space is left to retrofit oxyfuel or post-combustion capture

A1 Oxy-Combustion Capture Plant – an optimized oxygen-fired ASC PC boiler with oxyfuel CO_2 capture

A2 Oxy-Combustion capture of base case plant – conversion of the base case R0 plant to CO_2 capture plus examination of pre-investment options

B1 Post-combustion Capture Plant – an optimized air-fired ASC PC boiler with amine-based post-combustion CO_2 capture

B2 Post-combustion capture of base case plant - conversion of the base case R0 plant to amine-based post-combustion CO_2 capture plus examination of pre-investment options

Expected Phase II Outcomes

- Optimization of the 3 technology options for clean coal with CO_2 capture.
- Refine the capital and operating cost estimates, price of power and cost of CO_2 removal.
- Completion by Q3 2006.

Conclusions

- Production of clean power with 90% CO_2 capture and removal of all emissions of concern is technically feasible and can become economically viable at certain locations
- Integrated gasification of low cost fuels (coal, coke) to co-produce power, hydrogen, heat and syngas (polygeneration) offers attractive commercial opportunities in Western Canada based on large markets for:
  - Hydrogen & heat for oil sands operations (replacing high cost natural gas)
  - Synthesis gas for chemical production
  - CO_2 for enhanced recovery of conventional oil (EOR) and for extraction of coal bed methane (ECBM). Excess CO_2 can be sequestered in deep aquifers
- Gasification costs and reliability depend on feed quality and there is little experience with low rank Western Canadian lignites, sub-bituminous coals and coal-coke mixtures

Next Steps

- Some CCPC members have already taken the next steps to demonstration projects:
  - SaskPower's Clean Coal Project (2011)
  - Coal Beneficiation – Gasification Pilot Facility (2008/2009)
  - An application is in progress for front end engineering for an IGCC coal plant in Alberta (2012)

Questions?